ABSTRACT

JENSEN, CHRISTINA LOUISE. Effect of atmospheric pressure plasma treatment on interfacial bonding strength of Ultrahigh Modulus Polyethylene fibers to epoxy resin (Under the direction of Yiping Qiu.)

The surface modification of UHMPE fibers by atmospheric pressure plasma treatments was examined. In one study the aging effects of atmospheric plasma treatments were studied. UHMPE fibers were treated for 0.5 and 1 min with He/O_2/air gas and for 2 and 4 min with He/air gas by atmospheric pressure plasma on a capacitively coupled device. The samples were tested for fiber/epoxy interfacial shear strength using the microbond technique at time intervals of 0, 3, 15 and 30 days after initial plasma treatment. Interfacial shear strengths (IFSS) for plasma treated fibers were 2 - 3 times as high as that of the control. The IFSS for the plasma treated fibers remained constant up to 15 days and then decreased afterwards. XPS Analysis and SEM photographs characterized the fiber surface modification. In a second study, delamination phenomena was studied by the transverse compression of seven-fiber bundle UHMPE microcomposites, a peeling test of laminated plain weave UHMPE fabric and tensile shear strength testing of a ten-layer plain weave UHMPE / Epoxy flat panel composite. Results showed a 49% increase in yield modulus of the plasma treated sample compared to the control in the transverse compression test. There was an 82.5% increase in bonding strength for the plasma treated sample during the peel test and a 25.7% increase in interlaminar shear strength of the ten-ply UHMPE composite proving that atmospheric plasma treatments are very effective in surface modification on a microscopic fiber level and a full-scale composite production level.

EFFECT OF ATMOSPHERIC PRESSURE PLASMA TREATMENT ON INTERFACIAL BONDING STRENGTH OF ULTRAHIGH MODULUS POLYETHYLENE FIBERS TO EPOXY RESIN

by

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A thesis submitted to the Graduate Faculty of
North Carolina State University
in partial fulfillment of the
requirements for the Degree of
Master of Science

TEXTILE ENGINEERING AND SCIENCE

Raleigh

2002

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DEDICATION

I would like to dedicate this thesis to my family. To my mother Diane, for her constant encouragement to “do anything you want to” and to my late father Lee, who was a strong role model, both academically and in life. To my sister Melinda, who keeps things in perspective and to my niece Miya whom, is just beginning down the long road of education. Without their support and encouragement and their willingness to allow me to move halfway across the world, I would not be where I am today.

BIOGRAPHY

Christina Jensen was born in Newcastle, Australia, on the 11th May 1979 to Lee and Diane Jensen. She has one sister, Melinda and a niece, Miya. She attended Newcastle Grammar School for much of her early education and then Abbotsleigh for High School in Sydney, NSW. She was involved in many school plays, the orchestra and woodwind quintet where she played the bassoon, and was on the social Cricket and Netball teams. It was also here that she was first exposed to Textile studies.

After winning the Year 12 prize for Textiles and Design, she decided to undertake a Bachelor of Science degree in Textile Engineering at Philadelphia University (formerly Philadelphia College of Textiles and Science) where she was awarded an academic scholarship. Her undergraduate studies at Philadelphia were coupled with numerous organization memberships, including Phi Psi professional textile fraternity, the Text newspaper, and Delta Phi Epsilon sorority, where she held multiple positions, including president. She was awarded the prize for Outstanding Undergraduate in Textile Engineering from 1997-99, was the recipient of the 1999-2000 DyStar scholarship and the 2000 SAMPE Undergraduate Engineering Scholarship and held the honor of Dean's List for all eight semesters. In 2001, Christina was the recipient of the AATCC Outstanding student in Textiles award, finished first in her major and was given the honor of being named in Who's Who in American Colleges and Universities. In 2001, she was invited to the SAMPE Student Symposium competition in Long Beach, CA; to present the paper her and another textile student had worked on for their senior research project. She was awarded first place for "Knitted Fiberglass, Kevlar and Spectra Composite Baseball Helmets". Christina also held numerous jobs along the way, including teaching freshman textile classes, tutoring textile core courses, assisting in the Grundy testing lab, a summer internship at DyStar in Charlotte, and a six-month stint at the United States Department of Agriculture in Wyndmoor, PA.

In August 2001, she moved to Raleigh, NC to pursue a Masters of Science degree in Textile Engineering. For three semesters, she worked on surface modification of Ultrahigh Modulus Polyethylene fibers using atmospheric plasma for use in composites. As she prepares to graduate in December 2002, she will also be beginning a new career in the Advanced Materials Research division at Nike World Headquarters in Beaverton, OR.

ACKNOWLEDGEMENTS

I would like to thank Dr Yiping Qiu, my advisor, for his encouragement, direction and weekly meetings that constantly held me accountable and allowed me to aim for an early graduation. Thank you also to each of my committee members, Dr. Marian McCord and Dr Mohamed Bourham for their plasma know-how and experimental suggestions. A thank you to the members of my research group, to Chuyang Zhang, for explaining the transverse compression machine, for SEM photographs and for answering the many questions I had about compliance calculations. To Brice Langston, for patiently showing me how to manufacture composites, use the vacuum system and for assistance in shear tensile sample preparation and testing. To Dr. Zasheng Cai, Brian Bures and Yoon Hwang, for assisting me in atmospheric plasma treatments. Thanks to Dr Jan Pegram, for setting up the Sintech machine many times and to Brian Nablo at UNC for XPS data and an explanation of the analysis. And lastly, a very special thank you to Bill Hayes of Industrial Machine Solutions in Raleigh, and Hai Bui of the COT machine shop, for last minute composite cutting and machining.

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CHAPTER ONE

INTRODUCTION

1.1 Fiber Reinforced Composites

Composites are a material structure made up of two or more materials combined together so that on a macroscopic scale, the components can be distinguished, yet are firmly bonded together [1]. Fiber Reinforced Composites (FRC) consist of highly aligned fibers in a matrix. These fibers are usually high performance fibers such as aramid, carbon, fiberglass, boron or ultrahigh modulus polyethylene (UHMPE). Matrices usually consist of thermoset resins such as epoxy, pholic and polyimide or thermoplastic resins such as nylon, polyethylene and polysolfone [1].

When well designed, composites exhibit the best qualities of their constituents such as:

- Light weight
- High strength to weight ratio
- High stiffness to weight ratio
- Corrosion resistance
- Wear resistance
- Attractiveness
- Long fatigue life
- Thermal insulation
- Thermal conductivity
- Acoustical insulation [2]

1.2 Composite Applications

The industrial application of composites is vast and varied, from sporting goods to Formula One racing cars. The advantages listed above have showcased composites as an excellent alternative to traditional structural materials such as metals and concrete. Fiber Reinforced Composites have found their application in aerospace technologies, such as helicopter rotor blades and aircraft brakes, and in leisure activities such as golf clubs and bicycle frames [1]. Composites are used in the construction of yachts and ship hulls and can also be found as casings for gas turbine combustors and microelectronic devices [1].

Composites have also allowed engineers to dramatically cut down on the time taken to construct or assemble structures. For example, traditional bridge building consists of layers of steel bars and concrete, often taking two to three weeks to complete. New technologies, some studied at NCSU, have cut this time down to three days using lighter weight composite materials that can be manufactured off-site and fitted together at the scene eliminating the need for heavy cranes and large concrete pourers.

As the use of composites increases in construction and in specialized product design, the ability to predict the failure strength of that composite becomes important. Fiber Reinforced Composites in particular, require an understanding of the constituent fiber properties, and it is here that the Textile Engineer can play an important role in the design process.

1.3 Ultra High Modulus Polyethylene Fibers

According to Honeywell, UHMPE fiber is one of the world's strongest and lightest fibers [3]. It is, pound-for-pound, ten times stronger than steel, more durable than polyester and has a specific strength that is forty percent greater than aramid fiber [3].

UHMPE has a specific gravity less than 1g/cc and has excellent toughness and visco-elastic properties [3]. It can absorb energy and dampen vibrations, can withstand flexural fatigue and has a low dielectric constant (which makes it undetectable by radar) [3]. UHMPE is also resistant to chemicals, water and UV light [3]. While for most applications this is advantageous, in composite applications, relatively inert chemical structure of the fiber that renders the resistance to chemicals proves problematic.

Honeywell states that UHMPE fiber is used in numerous high-performance applications, such as police and military ballistic-resistant vests, helmets and armored vehicles, as well as sailcloth, fishing lines, marine cordage, lifting slings, and cut-resistant gloves and apparel [3].

1.4 Adhesion problems between fiber and matrix

The major problem associated with the failure of all FRC is insufficient adhesion between layers, and subsequent delamination [5]. UHMPE fibers are particularly susceptible to this failure mechanism simply due to their molecular structure. While some textile companies, such as 3Tex have decided to combat this issue through a 3D woven structure with vertical Z-yarns that hold the multiple layers of the composite together [5], others have looked to more traditional methods such as surface modification. Another problem is that the wettability of the UHMPE fibers is also low, leading to poor resin infiltration into the preforms.

1.5 Modification of UHMPE fiber surface with plasma treatments

One solution to the interfacial bonding problem between UHMPE and matrix that has been studied extensively is surface modification by plasma treatments. While the traditional plasma process occurs under vacuum, this proves problematic for textile fabrics that are packaged on large beams, in hundreds of yards. The vacuum plasma process is a batch process, and has limitations on the size of the sample to be treated. By using an atmospheric plasma treatment device, the machine can operate in a pre-existing continuous processing line,. This can allow fabric to be thread through the device at a steady rate, treated and wound up again at the other end. An advantage of plasma treatments over other chemical finishing techniques for surface

Figure 1.1 Atmospheric Plasma Chamber at North Carolina State University

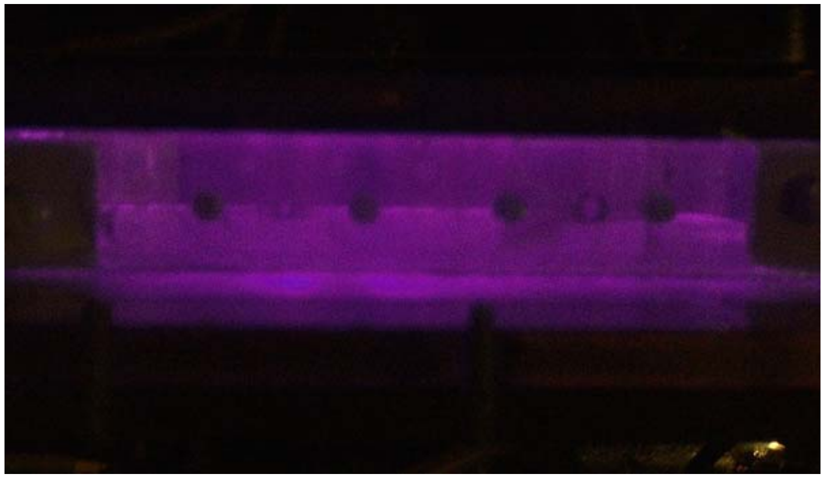

Figure 1.2 Plasma Glow – Helium / air.

modification is that there is virtually no waste generated. Plasma uses a series of inert gases that can be safely removed through an exhaust system.

1.6 Atmospheric pressure plasma treatment process

The atmospheric pressure plasma treatment system set up in the College of Textiles at North Carolina State University is a capacitively coupled chamber. It contains two horizontal parallel dielectric plates to which an electric charge is applied. A neutral gas such as Helium or Helium/Oxygen is pumped into the chamber where the electric field causes a breakdown of the gas into electrons and ions and the formation of charge carriers [6]. These charge carriers accelerated in the oscillating electric field couple their energy into the plasma via collisions with other particles [6].

There is very little research in how long atmospheric plasma treatment will last on a textile substrate. It has been suggested that traditional vacuum plasma treatments eventually “wear off” after a certain length of time, as chemical functional groups grafted to the surface of the polymer begin to rearrange. While the etching that occurs on some substrates does not revert, there is some suggestion that prolonged environmental exposure time after treatment will cause the surface to attract debris, filling in some of these micro-pits and therefore becoming less effective in resin bonding. The main focus of Chapter Two is to examine the aging of the atmospheric plasma treatment on UHMPE fibers. A one month study into levels of interfacial shear strength on the fiber level will reveal the length of time the plasma treatment stays effective for improved composite manufacturing.

1.7 Interfacial bonding tests

To quantify the effectiveness of the atmospheric plasma treatments on UHMPE fibers and fabrics, a series of interfacial bonding tests have been performed throughout this thesis. These include A) Microbond test that studies the interfacial shear strength (IFSS) of an epoxy bead on the individual fiber surface (predominantly Mode II failure). B) Transverse compression of seven-fiber microcomposites that will study the interfacial bonding strength in a predominantly Mode I failure. C) Peel test, that will study the bonding strength of two UHMPE fabric layers bonded together with epoxy (predominantly Mode I failure), and D) Tensile shear test, that studied the force required to delaminate composite layers in a pure shear loading mechanism (predominantly Mode II failure). By studying the interfacial bonding strength of UHMPE to epoxy before and after the plasma treatments through several micromechanical tests and macro-composite level tests, we are able to determine the effectiveness of the plasma treatment on UHMPE fiber surface modification.

1.8 References

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CHAPTER TWO

THE AGING OF ATMOSPHERIC PLASMA TREATED ULTRAHIGH-MODULUS POLYETHYLENE FIBERS

2.1 INTRODUCTION

Ultra high modulus polyethylene (UHMPE) fibers have found increasing use in fiber-reinforced composites and especially in ballistic applications where high-energy absorption is required due to their high tensile strength and modulus [1] and its low specific density. The molecular structure of the polymer, however, allows low or no chemical bonding to other substances [2]. This is particularly detrimental in fiber-reinforced composites where good adhesion between the fiber and the matrix is critical. In order to enhance the adhesion between UHMPE fibers and matrix, both low pressure (vacuum) and atmospheric pressure plasmas have been effectively used [3-6]. There are two major contributors to the improved adhesion between the fiber and the matrices. Through surface chemical analysis, radicals have been shown to graft to the surface of the polymer allowing chemical bonding to occur and through Scanning Electron Microscopy (SEM), mechanical etchings have been observed that increase surface roughness allowing greater adhesion to resins [3-11]

However, it is well known that the effect of the plasma treatments cannot be permanent. In other words, there is an aging process of the plasma treated surface. X-ray Photoelectron Spectroscopy (XPS) studies have found that over the time there is diffusion and reorientation of polar functional groups, adsorption of contaminants, and reaction of free radicals on the surface of plasma treated polymers [12-16]. Therefore there is a decrease in surface hydrophilicity that causes the polymer to lose some of its effective adhesion properties. In these studies, only low pressure plasma was used and little has been reported on aging of atmospheric pressure plasma treated fibers or polymers.

In our previous studies, UHMPE fibers treated by He/Air and He/O_2 atmospheric pressure plasmas showed a significant increase of interfacial shear strength (IFSS) with epoxy. It was found that the surface chemical composition of the Spectra® fibers was altered by the He/Air and He/O_2 plasma treatments significantly [7,8]. In addition, it was found that the 2 min He/air plasma treatment tended to increase the tensile strength of the fiber [7], while He-O_2/air tended to decrease its tensile strength due to a more aggressive surface etching effect of the treatment [8].

This paper presents a comprehensive aging study of atmospheric plasma treated UHMPE fibers over a period of thirty days using the treatment conditions proved to be effective in our previous studies. Interfacial shear strength will be measured using the microbond technique. XPS and SEM will analyze surface chemical and morphological changes.

2.2 EXPERIMENTAL PROCEDURE

2.2.1 Plasma Treatment

UHMPE fibers (Ningbo Dacheng Chemical Fibre Group Co.) were wound onto glass frames to allow effective overall treatment and then rinsed in acetone to remove any finishes. The frames were then placed sequentially in the atmospheric plasma chamber for treatment. The plasma chamber is a capacitively coupled device developed at the

College of Textiles, North Carolina State University. It had a frequency set to 5 kHz with a 100-150 watts maximum power input. A constant rate of flow for each gas was used in the treatment. A 5 mm thick Plexiglas dielectric material was used and the plate separation distance was 5.5 cm. It has been found from our previous studies [8,17] that a He/air only plasma treatment becomes effective for increasing UHMPE/epoxy IFSS at treatment times of 2 minutes and greater while He/O_2/air plasma treatments become effective at 30 seconds and longer. Therefore, two sets of fibers were treated with He/air at 2 minute and 4-minute treatment times respectively. Two sets of fibers were treated in a mixture of He/O_2/air at 30 second and 1-minute treatment times respectively. After the treatment, the fibers were taken off the glass frames and wound onto smaller bobbins, then placed in a desiccator.

2.2.2 Interfacial bonding sample preparation and test

The application of resin on the single fibers was time-critical, so the first set of samples was prepared exactly one hour after plasma treatment. The second set was prepared exactly three days from the initial plasma treatment and the third and fourth sets of samples were prepared 15 days and 30 days respectively after the initial plasma treatment. The process involved stringing individual fibers (8 denier) onto a frame then placing beads of epoxy resin along the length of each hung fiber, as described in the article by Qiu et. al. [18]. The sequence of applying resin beads to the fiber samples was determined using a randomization process to eliminate any systematic error due to the viscosity change in the resin over time. The total working time to distribute resin beads

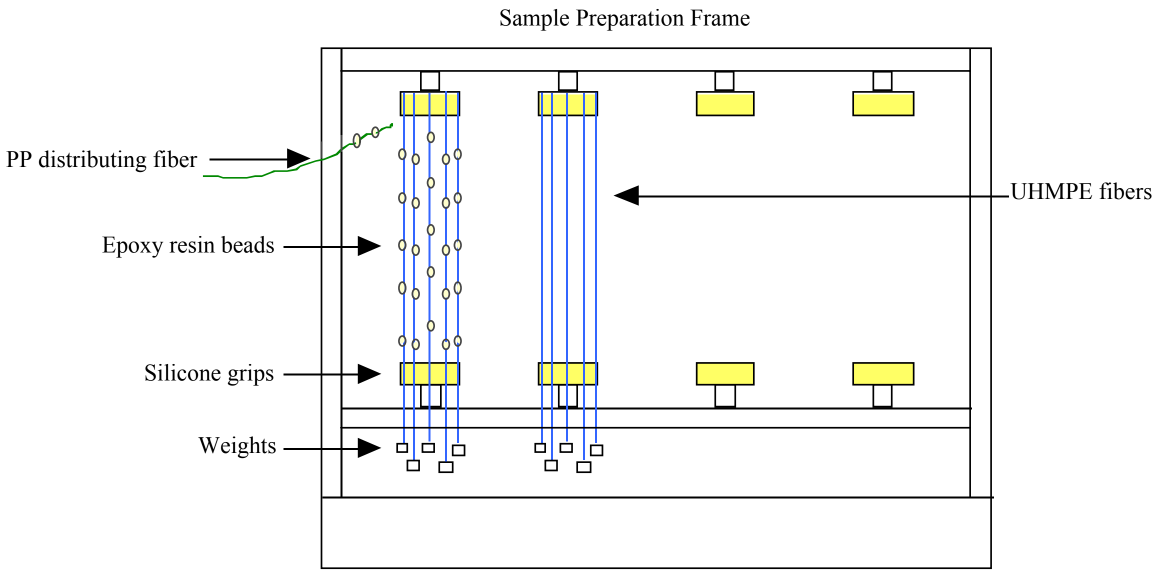

Figure 2.1 Microbond frame used to prepare epoxy resin beads on UHMPE fibers

was half an hour and exact placement and time was recorded. The epoxy resin used was 70% Dow Epoxy Resin (DER) 331 (polymer of epichlorohydrin and bisphenol-A), 30% DER 732 (polymer of epichlorohydrin and polyglycol) with 12 phr (parts per hundred) of Dow Epoxy Hardener (DEH) 26 (tetraethylenepentamine, triethylenetetramine and polyethylenepolyamine mix) from Dow Chemical. The fibers were then placed in the oven and cured for 3 hours at 80ºC. The microbond test [18] was carried out at an upper clamp displacement rate of 1mm/min on a Sintech universal testing machine with a load cell of 25 N.

2.2.3 Microscopy examination

An Anti-Mould Nikon Labophot2-POL polarized light microscope equipped with a Sony CCD camera was used to take images of the beads. The length and width of the beads was then determined using pixel measurements from Adobe Photoshop. A typical fiber/bead photograph is shown in Figure 2.2. Original data for the pixel measurements can be found in the Appendix.

2.2.4 Scanning electron microscopy

The Hitachi S-3200 Variable pressure SEM model was used to inspect the surface modification of the fibers directly after plasma treatment, then 3, 15 and 30 days after plasma treatment. The fibers were mounted on a sample platform and gold coated for three minutes in an Argon plasma sputtering device. SEM images were taken with a 5000x magnification.

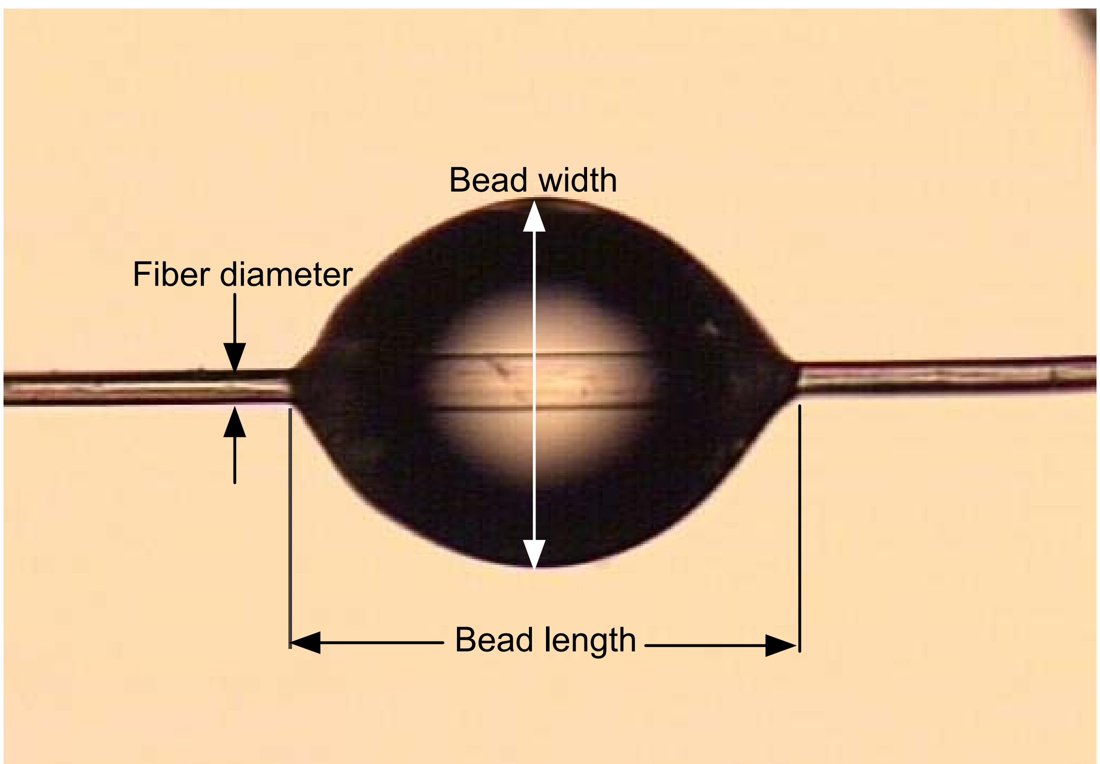

Figure 2.2 Typical fiber/bead photograph taken under the microscope for pixel measurements to calculate the fiber diameter and bead sizes. The values are used to plug into the Shear-lag model for calculation of Interfacial shear strength.

2.2.5 XPS Analysis

XPS analysis was performed on a Perkin Elmer PHI 5400 machine. The surface chemical composition of the UHMPE was obtained from measurement of the areas of the C 1s, N 1s and O 1s peaks, obtained at 35.75eV pass energy at a photoemission angle of 45°. Curve fitting was performed on the C 1s peaks, following subtraction of an "Integrated Shirley" baseline. A Gaussian band-type was used for the peak shape. Five component peaks were fitted to each sample at the following binding energies: C-C 285.0eV, C-OH 286.2eV, =C=O 288.1eV, -COOH 289.4eV and O=C-O 290.5eV [9,10,12]

2.2.6 Tensile Test

Single fiber tensile tests were performed at the beginning of aging study and after 30 days to determine any strength variability in the treated samples. Single fibers were prepared following ASTM standard D-3822 (Standard Test Method for Tensile Properties of Single Textile Fibers) at a gage length of 100 mm. The Sintech universal testing machine with a load cell of 25 N was again utilized for this test. The displacement rate was 50 mm/min. Data was collected from at least 20 fiber samples for each treatment.

2.2.7 Statistical Analysis

One way analysis of variance (ANOVA) and Fisher's pair-wise multiple comparisons were used to compare the tensile strengths of the fibers in different treatment groups. They were also used to evaluate the difference in IFSS among the treatment groups. A P-value less than 0.05 was considered significant.

2.3 RESULTS AND DISCUSSION

2.3.1 Microscopy examination

The surfaces of the UHMPE fibers with each plasma treatment are shown in Fig 1. The He/O_2/ air plasma treatment at 30 seconds and 1 minute appeared to etch the fiber surface where micro cracks were developed. Similar etching effect is evident again in the He/air plasma treatments at 2 minutes and 4 minutes respectively. The surface of the Control sample (no plasma treatment) remains free of etching or micro cracks at each time interval during the aging study (0, 3, 15, 30 days). The He/O_2/ air plasma treated fibers show similar levels of etching at each time interval with the 30 second treated samples slightly less etched than the 1-minute treatment. Similarly, the 2-minute He/air plasma treatment was etched and micro-cracked less severely than the 4-minute He/air plasma treated samples. The level of etching for each time interval during the aging process however remains fairly constant. Some surface debris appeared on SEM photographs taken at the 30-day interval. This may be due to a decrease in surface hydrophilicity, which leads to static charge build up and hence attracts more dust particles.

2.3.2 Micro-bond Test

The IFSS, τ_i, was calculated using the following equation [19], derived from the well-known shear-lag model:

$$\tau_i = \frac{nP_{\max}\coth(nL/r)}{2A} \quad (1)$$

where P_{max} is the peak load, A is the cross-sectional area of the fiber, L is the imbedded length, r is the equivalent fiber radius calculated from the fiber cross-sectional area and n is defined as:

$$n = \left[\frac{E_m}{E_f (1 + \nu_m) \ln(R / r)} \right]^{1/2} \qquad (2)$$

Where E_m (=1.4 GPa) is Young's modulus of the matrix reported in Ref. [18], ν_m (=0.4) is Poisson's ratio of the matrix measured in our laboratory, E_f (=90 GPa) is the tensile modulus of the fiber taken from the Ningbo Dacheng Chemical Fibre Group Co. product specification sheet, and R is the radius of the epoxy beads.

As shown in Fig 2, while the control samples remain constant over the 30-day time interval, the 2 and 4 min He/air plasma treated samples showed a steady but significantly higher value than that of the control group for the first fifteen days, then decreased significantly after 30 days though it is still significantly higher than control. Similar observations can be made in for the 30 second and 1 minute He/O_2/air plasma treated fibers as shown in Fig 3 where the IFSS remained constant up to the 15th day and significantly decreased after 30 days.

2.3.3 Single-fiber tensile strength

Table 2.1 shows the results of single fiber tensile testing of UHMPE fibers for different treatment groups. There appeared to be no statistically significant difference between tensile strengths of the control and the plasma treated fibers. There was however statistically significant difference between the tensile strength of the 1 min He/O_2/air plasma treatment and the 2 min He/air plasma treatment due to slightly improved fiber tensile strength after the 2 min He/air plasma treatment.

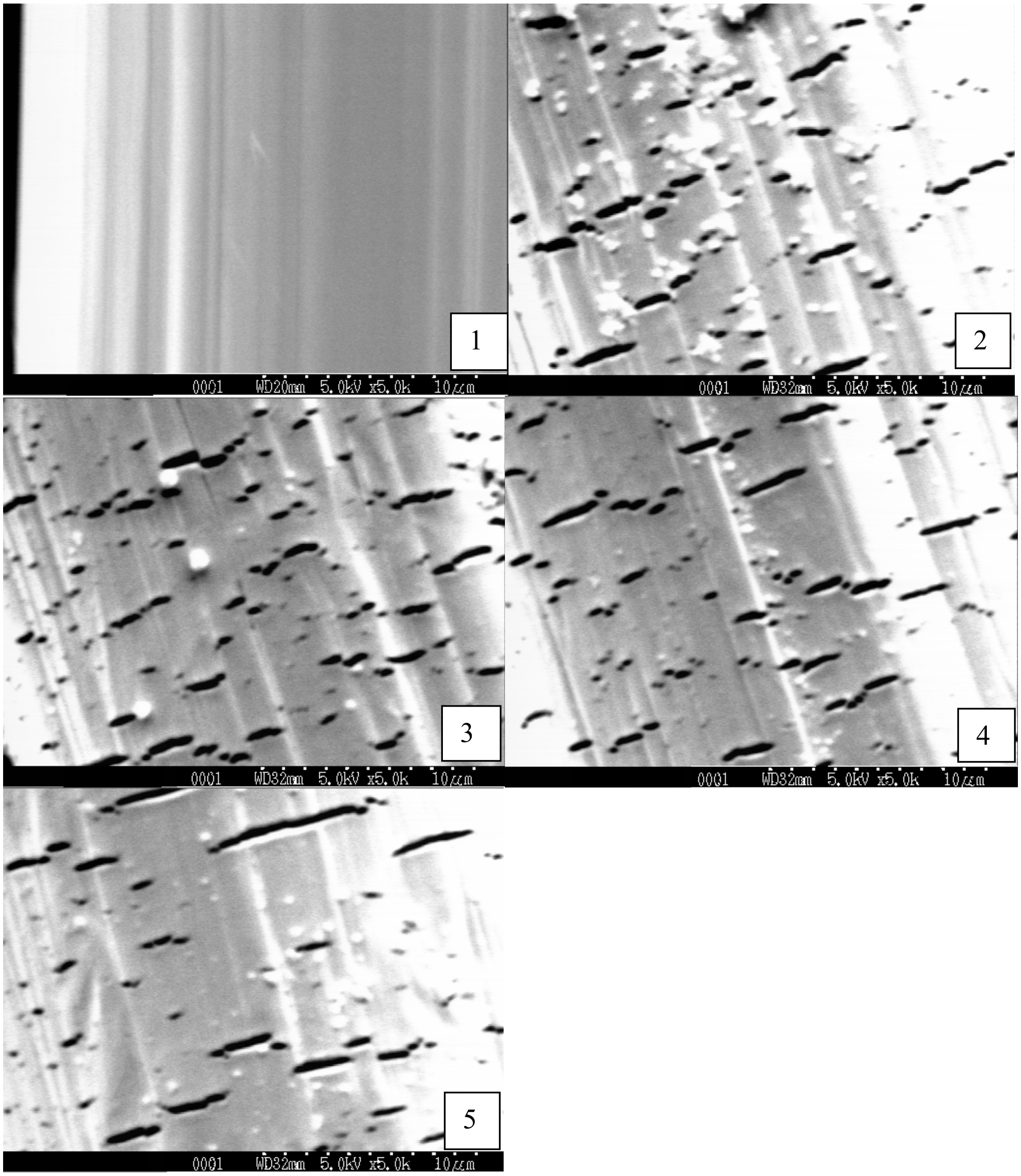

Figure 2.3 SEM Photographs of micro cracks on fiber surface, taken at 30-day time interval, 5000x Magnification: (1) control, (2) 0.5 min He/O_2/air plasma treatment, (3) 1 min He/O_2/air plasma treatment, (4) 2 min He/air plasma treatment, (5) 4 min He/air plasma treatment.

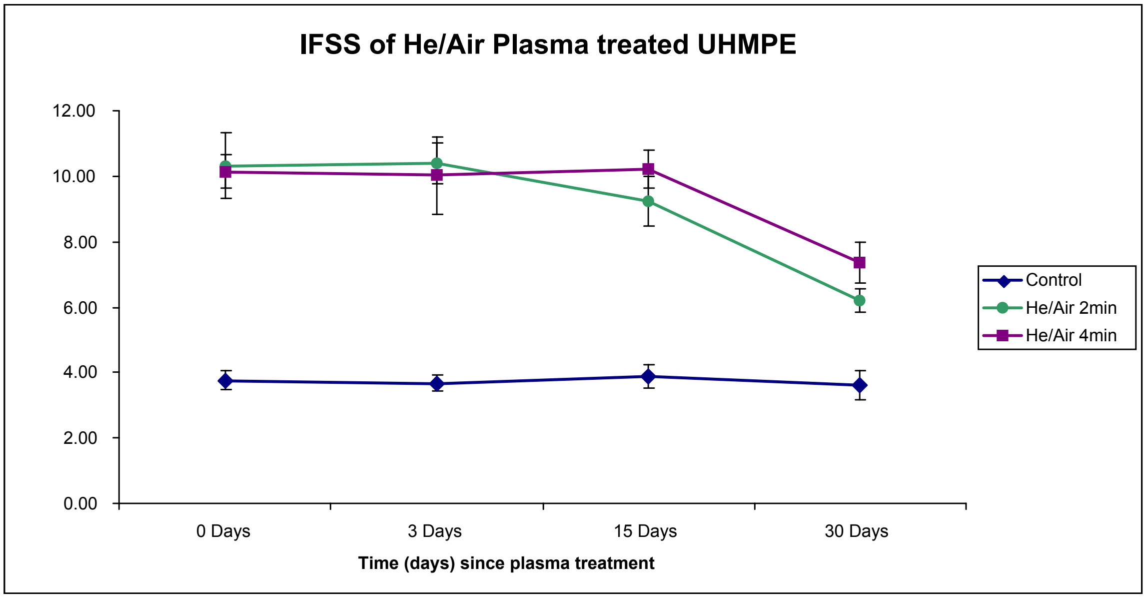

Figure 2.4 Change in interfacial shear strength for He/air plasma treated UHMPE fibers, over a time period of 30 days, using the Microbond technique.

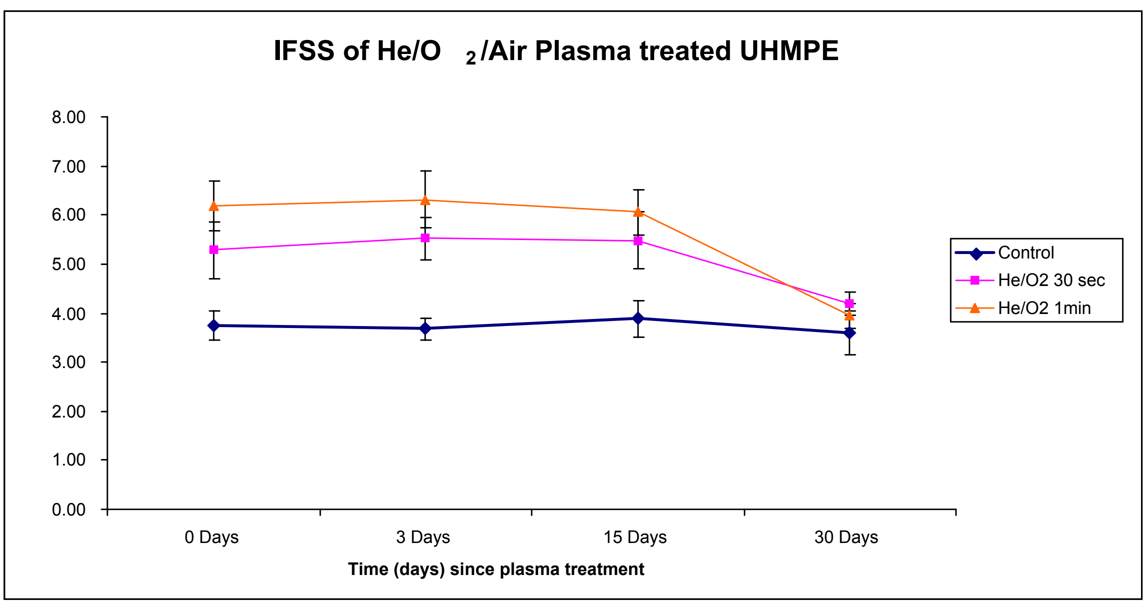

Figure 2.5 Change in interfacial shear strength for He/O_2/air plasma treated UHMPE fibers, over a time period of 30 days, using the microbond technique.

Table 2.1: Tensile Strength

Treatment	Number of Specimens	Tensile Strength (GPa)	Standard Deviation (GPa)
Control	22	2.80^{ab*}	0.29
0.5 min He/O_2/air	22	2.76^{ab}	0.21
1 min He/O_2/air	23	2.88^{a}	0.12
2 min He/air	20	2.64^{b}	0.37
4 min He/air	23	2.78^{ab}	0.18

*Means with different letters are statistically different at $P < 0.05$

2.3.4 XPS Analysis

From the XPS data analysis, it can be observed (Table 2.2) that immediately following plasma treatment there is a slight increase in both oxygen content and nitrogen content, except for the 4 minute He/air treatment. The control sample also showed significant oxygen and nitrogen contents, which may likely come from contamination. This can be confirmed by the fact that the 4-minute He/air treatment shows a slight decrease in both contents. For all plasma treated samples, there is also a slight increase in the percentage of C-OH bonds. For the He/O_2/air plasma treated samples, there is an increase in C=O bonds and COOH bonds while O=C-O bonds remain the same as the control. For the He/air plasma treated samples, there is a slight decrease in C=O bonds, COOH bonds and an increase in O=C-O bonds.

After 30 days from initial plasma treatment, it can be observed (Table 2.3) that there is a decrease in the atomic concentration of oxygen for all treated samples, and a decrease in nitrogen for the He/O_2/air plasma treated samples. The He/air treated samples show a slight increase in nitrogen content. The carbon bonds (C-C) observed after 30 days show a similar trend compared to the 0 day samples overall, with an increase seen only in the He/air plasma treated samples. Additionally, for the He/air treated samples, there is a decrease in C-OH, COOH and O=C-O percentages from the 0 day analysis, and for the He/O_2/air treated samples, there is a decrease in C-OH and C=O bonds. Therefore it can be concluded that the decrease of interfacial bonding strength is likely due to the change of the surface chemistry of the fibers. The decrease in surface oxygen content for each of the plasma treated samples, suggests that this may be the critical factor in fiber surface wet-ability. Therefore the decrease in Interfacial Shear Strength after 15 days is directly related to the rearrangement of polar functional groups on the surface and decrease in oxygen. The levels of oxygen present on the fiber surface may have been at a maximum immediately after treatment (contact angle = 0), and at the fifteen day interval, the critical level of oxygen may have dropped to below the optimum causing an increase in contact angle and decrease in surface wet-ability. This theory however, needs to be researched further using contact angle analysis on the individual fiber surface.

The increase in IFSS immediately after plasma treatment is a result of both the plasma gas induced surface chemical composition change and increased surface roughness may not be as effective in increasing the bonding strength because of poor wettability of the fiber to epoxy.

Table 2.2: XPS analysis of fiber immediately after plasma treatment

	Atomic Concentration							
Treatment	C	N	O	C-C	C-OH	C=O	COOH	O=C-O
Control	91.2	2.0	6.8	79.7	14.3	4.0	1.8	0.1
0.5 min He/O_2	88.0	2.4	9.7	77.2	16.2	4.7	1.8	0.1
1min He/O_2	87.5	2.9	9.6	77.7	15.1	4.1	2.9	0.1
2min He/air	88.8	2.1	9.1	76.5	18.1	3.2	1.8	0.4
4min He/air	93.2	1.5	5.3	81.0	15.4	2.7	0.5	0.4

Table 2.3: XPS analysis of fiber at 30 days after plasma treatment

	Atomic Concentration							
Treatment	C	N	O	C-C	C-OH	C=O	COOH	O=C-O
Control	92.8	2.0	5.2	79.2	15.8	2.9	1.9	0.2
0.5 min He/O_2	92.8	1.6	5.6	78.6	15.3	3.3	2.5	0.2
1min He/O_2	92.0	2.5	5.5	79.5	14.8	3.1	2.5	0.1
2min He/air	91.9	3.2	4.8	84.3	10.7	4.5	0.3	0.2
4min He/air	93.4	2.6	3.9	85.0	11.4	3.1	0.4	0.1

2.4 CONCLUSIONS

The aging effects of an atmospheric plasma treatment on UHMPE fibers were studied over a period of 30 days. The following conclusions can be made:

(1) The initial increase of IFSS between both sets of plasma treated UHMPE fibers to the control remains at a constant level until at least 15 days after the treatment. After 30 days a significant decrease in IFSS for all the plasma treated groups was observed. The He/air treated fibers still have significantly higher IFSS than that of the control.

(2) There is no observable difference in surface morphology of the fibers for each treatment group at different time intervals. Increased dust debris, however, was observed after 30 days of aging.

(3) Compared with the control, there was no statistical significance in the tensile strength of fibers after each corresponding plasma treatment.

(4) 30 days after the treatment, XPS analysis showed a decrease in oxygen content and in corresponding functional groups for all plasma treated samples. Therefore the decrease of interfacial bonding strength is likely due to the change of the surface chemistry of the fibers and in particular the decrease of oxygen content.

2.5 FUTURE WORK

Now that an understanding of the aging process of atmospheric plasma treatments has been reached, the next step in this research project is to effectively limit or inhibit the aging process. It has been proven that atmospheric plasma stays effective at room temperature for approximately 15 days. Prevention of the loss of surface chemical functional groups and in particular oxygen content is the next logical step. One suggestion is to study the effect of temperature on the aging process. By keeping the atmospheric plasma treated samples in a freezer (below 0˚C) or in liquid nitrogen, this could prevent the surface chemical groups from rearranging. It has been found in one study [20] that the aging process of vacuum plasma treatments on High Density Polyethylene (HDPE) can be reduced by an increase of Argon percentage (in an Argon/Oxygen gas mixture), or by increasing the crystallinity of the fiber itself. This is another interesting topic that may be studied with respect to atmospheric plasma.

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CHAPTER THREE

TRANSVERSE COMPRESSION AND DELAMINATION OF ATMOSPHERIC PLASMA TREATED UHMPE COMPOSITES

3.1 INTRODUCTION

Ultra high modulus polyethylene (UHMPE) fibers have found increasing use in fiber-reinforced composites, especially in load-bearing situations. Newer applications, such as under-water cables and ballistic panels, require a high level of transverse compressive stiffness in order to resist failure [1-3]. Therefore it is essential for composite design purposes to fully understand the load-response and delamination process in the transverse direction, in order to determine lifetimes for those load-bearing structures [4].

The transverse response of unidirectional composites has been studied [5-10] and three main failure characteristics have emerged [4,6,9-12]. In composites with strong fibers and strong bonding between fiber and matrix, failure occurs within the bulk matrix close to the fiber, this is shown in Figure 3.1(a). Figure 3.1(b) shows the failure effect with a weak interface where debonding occurs under transverse compression. The third failure mechanism observed is when the transverse fiber strength is low. shows that in this case, the fiber splits near the aligned surface or across the core as shown in Figure 3.1(c). An assumption here is that currently, polyethylene / epoxy composites fail at the interface region. Atmospheric plasma treatments improve interfacial bonding and

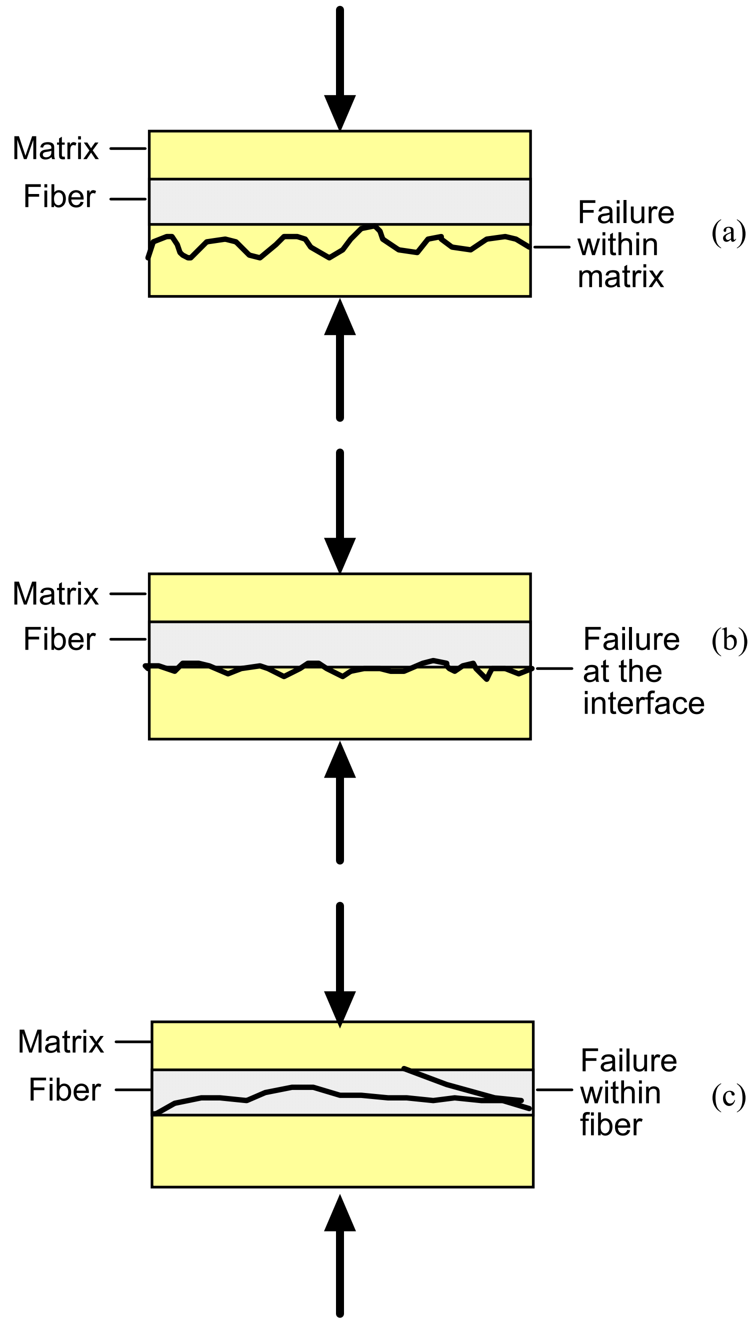

Figure 3.1 (a) Failure within the matrix, **(b)** Failure at the Interface, (c) Failure within the fiber

therefore it should be proven (using Scanning Electron Microscopy) that the plasma treated UHMPE fibers should bond more readily with the epoxy, causing failure to occur instead within the bulk matrix.

Debonding of fiber/matrix interface is most likely to be a Mode I and Mode II mixed type of failure [13]. However, in a fiber pull out test, Mode II type of failure is considered dominant while a composite tensile tested along perpendicular to the fiber oriented direction gives Mode I types of failure. At micromechanical level, however, there has been little report on testing Mode I type of failure on fiber-matrix interface. Our research group has made an effort on a new transverse compression test of seven fiber microcomposite in order to characterize the Mode I type of failure that occurs often in compression loading of composites [14].

The purpose of this experiment is to study the debonding between a UHMPE fiber and epoxy resin in a composite, illustrating the weak interface mode of failure. It is well known that UHMPE fibers do not bond easily to resins, due to their inert molecular structure. By modifying the surface of the fiber and therefore strengthening the interface, it has been shown that compressive strength will increase significantly [15]. From our previous research, treatment with atmospheric plasma has proven to be effective in improving interfacial shear strength between UHMPE fibers and epoxy resin [16-18] [Chapter 2]. As a result of the plasma treatment, chemical functional groups were grafted to the fiber surface, and micro-etchings occur, allowing epoxy resins to bond more readily to the fiber [16-18] [Chapter 2]. To effectively study the delaminating effect, three test methods have been implemented. These include transverse compression of seven-fiber microcomposites, a peeling test of laminated fabric layers, and pure shear test of ten-layer UHMPE fabric composites.

3.2 EXPERIMENTAL PROCEDURE

3.2.1 Plasma Treatment

For the seven-fiber bundle experiment, UHMPE fibers (Ningbo Dacheng Chemical Fibre Group Co.) were wound onto two glass frames to allow effective overall treatment and then rinsed in acetone to remove any finishes. One frame was then placed in the atmospheric plasma chamber for treatment. The second frame was left as the control. The plasma chamber is a capacitively-coupled device developed at the College of Textiles, North Carolina State University. It had a frequency set to 5 kHz with 100-150 watt maximum power input. A constant rate of flow for the gas was used in the treatment. A 5mm thick Plexiglas dielectric material was used and the plate separation distance was 5.5 cm. It has been found from our previous studies [16,18] that a He/air plasma treatment becomes effective for increasing UHMPE/epoxy IFSS at a treatment time of 2 min. Therefore, the fibers were treated with He/air for 2 min duration. After the treatment, the fibers were immediately made into the seven fiber microcomposites.

For the ten-layer composite experiment and the peeling test, 304.8 mm × 304.8 mm plain weave UHMPE fabric samples (Honeywell / Warwick Mills) were cut and placed individually into the atmospheric plasma chamber and treated with He/air for 2 minutes each with the same specifications described above.

3.2.2 Seven-fiber bundle composite sample preparation

Seven-fiber bundle microcomposites have been researched and proven to be an effective scaled study of the composite's response to tensile load and interface delamination [4,14,19-21]. Figure 3.2 shows the apparatus used to manufacture the microcomposites. First, lengths of single fibers were draped over the upper silicon grip and weighted with springs of equal mass. Six fibers hung around the perimeter of the grip at equal distances and one hung in the center. Next, a polypropylene fiber was used to place large droplets of resin on exactly three of the hung fibers, beginning from the top.

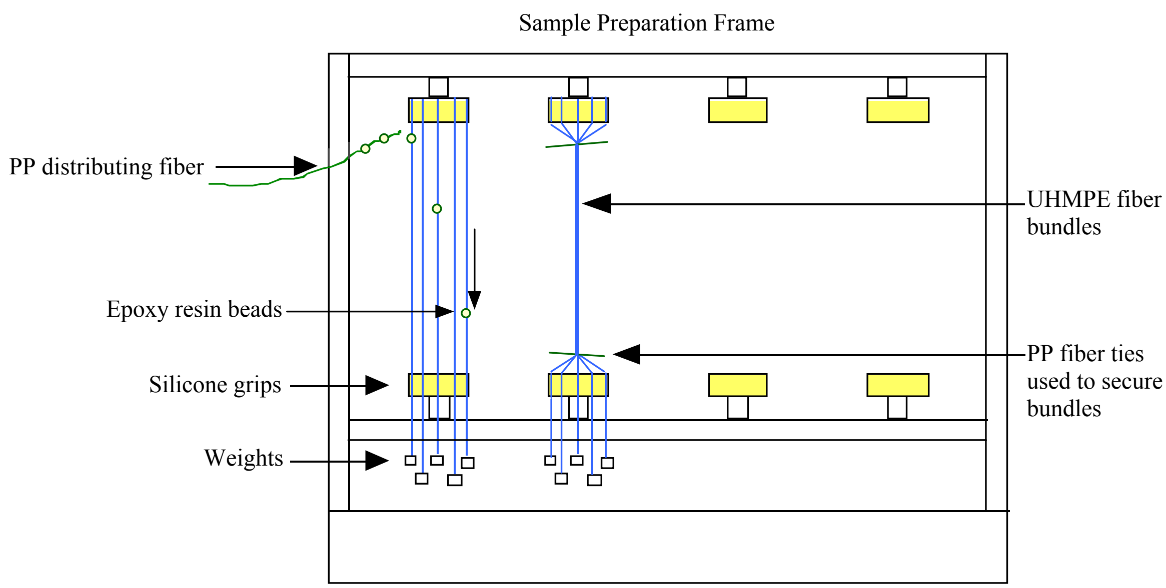

Figure 3.2 Seven-fiber bundle composite manufacturing. The fibers are shown hung from silicone grips with epoxy resin beads coating the fiber length. Polypropylene monofilaments are used to tie off the seven-fiber bundles at the top and bottom.

The beads were then allowed to run down the length of the fibers to coat the surface. The epoxy resin used was 70% DER 331, 30% DER 732 with 12 phr (parts per hundred) of DEH 26 hardener (Dow Chemical). A piece of polypropylene monofilament was then used to tie together the seven fibers at the top. A second monofilament was then tied around the fibers, just below the knot of the first monofilament. This second monofilament was then slowly dragged down the length of the fiber bundle to allow the resin to fully coat each fiber and to remove excess resin. A knot was tied at the bottom to secure the bundle. The microcomposites were then placed in the oven and cured for 3 hours at 80ºC.

3.2.3 Microscopy examination

An Anti-Mould Nikon Labophot2-POL polarized light microscope equipped with a Kodak DC290 camera was used to take cross-sectional images of the microcomposites. The seven-fiber bundle composites were first placed cross-wise in a mold of DER 331 resin, cured and then the surfaces polished. This allowed effective cross-sectional images to be captured.

3.2.4 Transverse compression testing of seven-fiber bundle microcomposites

A compression testing device developed in our laboratory was used to measure the load-displacement of the microcomposites. It consisted of a thermal-coupled set of vices that move at a constant rate (1.67 microns per second) to transversely compress a vertically mounted 10mm section of the fiber bundles. A fifty-pound load cell was used. The time, load and displacement were recorded using a data acquisition system, which was then transferred to an excel spreadsheet for analysis. The data was normalized using a program that took the compliance of the machine into account. The output was then used to plot the load-displacement curves of each specimen. Approximately thirty samples were tested for each treatment group. Chuyang Zhang contributed Finite Element Analysis modeling of the failure schemes in both the X-direction and the XY-direction (shear).

3.2.5 Finite Element Analysis of seven fiber microcomposites – The Model

The Finite Element Analysis (FEA) modeling using ANSYS was adapted to simulate transverse compression of seven fiber microcomposites. The internal stress state of the microcomposite was recorded. In this model, a two-dimensional four-node viscoelastic element PLANE82 was employed for both the UHMPE fiber and the resin matrix, while a two-dimensional target element TARGE169 was used to simulate compression heads of the lateral compression device. In order to complete the contact pair with the target element, a two-dimensional contact element CONTA172 was modeled on the outer surface of the microcomposite where it touches the compression heads.

Figure 3.3 on the following page shows the two loading conditions modeled. The microcomposite was loaded as either Condition A or Condition B. Three assumptions were made to simplify the model:

1. Plain stress loading, three-dimensional model was simplified to two-dimensional model
2. Perfect bonding between the matrix and fiber
3. Elastic deformation

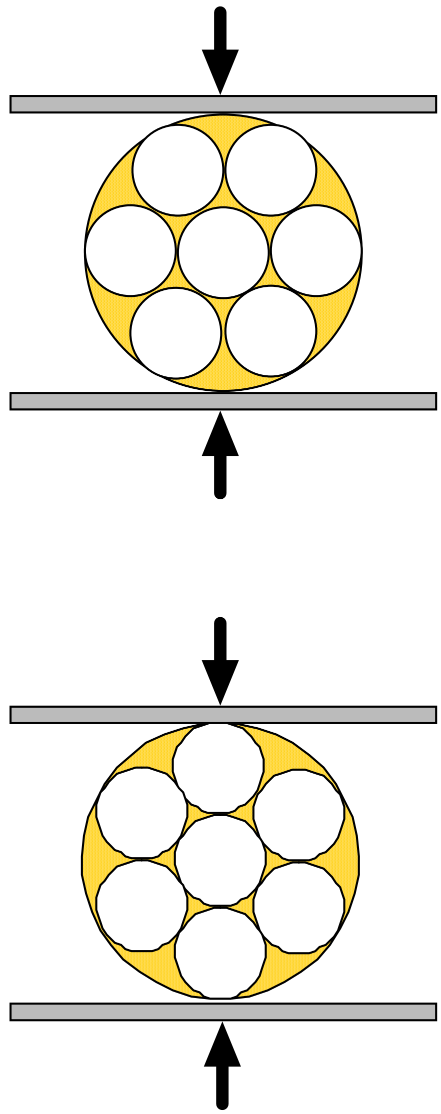

Figure 3.3 Schematic diagram of optimal seven-fiber composite transverse compression. Condition A (top) and Condition B (bottom) fiber arrangements are shown.

Table 3.1 Constants used in the FEA model

Modulus(GPa)		Fiber Diameter (microns)	Distance between fibers (microns)
Fiber	Matrix		
1.2	1.4	35	2

Geometrical and mechanical constants used in the FEA model are listed in table 3.1. Both loading conditions are symmetrical about the X and Y axis, therefore, only a quarter of the composite was modeled as shown in figure 3.10. A symmetrical boundary condition about the Y axis was applied at location x=0, while all the nodes of x direction deformations (UY) at location y=0 were coupled.

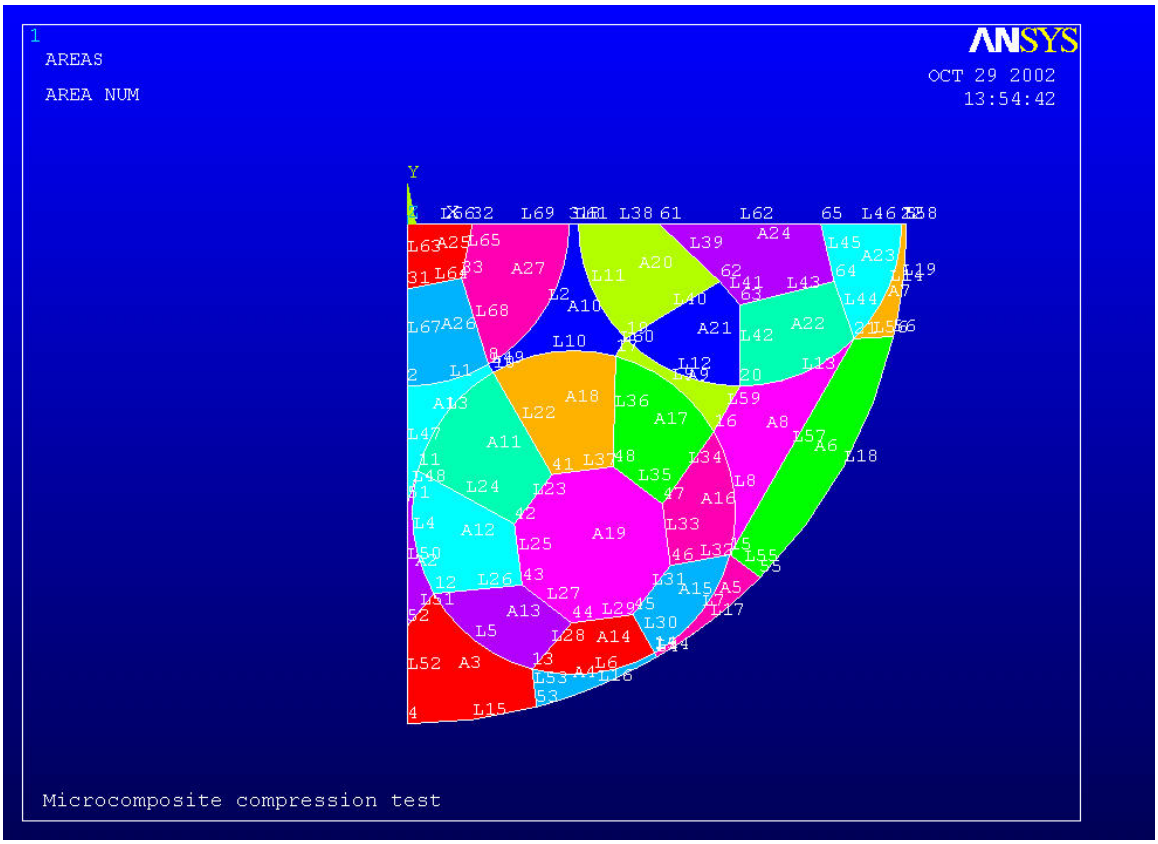

Figure 3.4 Geometric model of seven fiber microcomposite

From experimental data, the linear portion of the load-displacement curve of control sample ends at a displacement around 8 microns. Therefore, UY= 4 microns was applied to nodes at y=0. Plasma treated sample had a better bonding between fiber and matrix, The linear portion of plasma treated sample ends at a displacement around 12 microns. As a result, UY=6 microns was applied to nodes at y=0 for plasma treated samples.

3.2.6 Scanning electron microscopy

The Hitachi S-3200 Variable pressure SEM model was used to inspect the delamination of the seven-fiber bundle microcomposites. In particular, the epoxy adhesion to the individual fibers was observed. The microcomposites were mounted on a sample platform and gold coated for three minutes in an Argon plasma sputtering device. SEM images were taken with a 5000x magnification.

3.2.7 Peeling test of laminated textiles.

ASTM standard D-2724 (Standard Test Methods for Bonded, Fused, and Laminated Apparel Fabrics) was used to determine the bonding strength between a plain weave UHMPE fabric and the epoxy resin. One set of samples was treated with a two min He/ air plasma and the second set were left untreated. Fabric was cut in the warp direction into rectangles measuring 76.2 mm x 152.4 mm. A line was drawn across the width, 25.4 mm from the end to record where resin should be placed. Resin was applied using a wooden spatula across the 76.2 mm x 127 mm area until the fabric was wet and excess resin was then scraped off. A second sample was wetted with resin using the same procedure then placed on top of the first fabric leaving the one-inch dry ends free from resin. A piece of release film was placed in between these one-inch dry regions to ensure no transfer of resin to the region. Nine other sets of samples were prepared in the same manner, and then each was placed between layers of release film with a heavy caul plate placed on top. This equal amount of load applied to the samples ensured an even amount of resin to remain on the specimens for later comparison. The samples were cured in an

80ºC oven for three hours and then post-cured for 2 hours at 100°C. The samples were then tested on the Sintech tensile tester with one of the resin-free ends in the upper grip and the second in the lower grip. Displacement occurred at a cross-head speed of 5mm/min. A 250lb load cell was used. As the peeling test was performed, the load required to delaminate the two layers was recorded. The five highest and five lowest peaks of the load-displacement graph were averaged to give the final result. A comparison was then made between the untreated and treated samples and a typical load-displacement curve was generated.

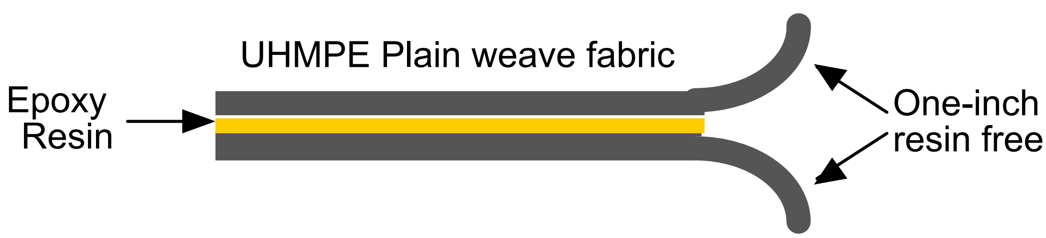

Figure 3.5 Schematic diagram of the peel test sample preparation.

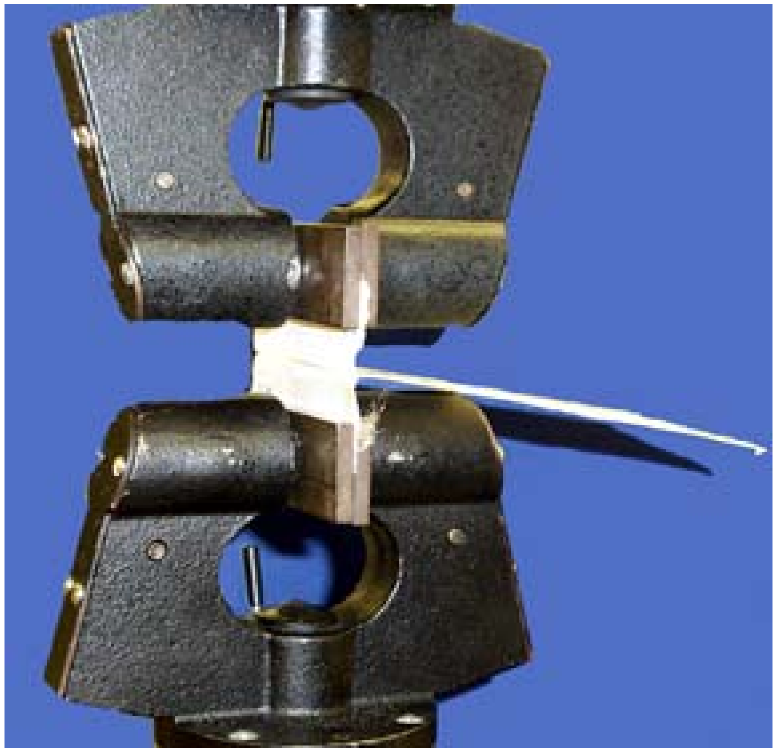

Figure 3.6 Photograph of the Sintech tensile testing machine gripping the resin free ends of the laminated fabric sample for peel strength analysis.

3.2.8 Shear strength of ten-ply UHMPE laminates.

Ten-ply UHMPE composites were manufactured using a hand-lay up process coupled with a vacuum pressured mold to create perfectly flat, void-free samples. The apparatus is shown in Figure 3.7. One composite was manufactured using 2 min He/air plasma treated fabric and the second composite was a control. Initially, to ensure complete wetting out of the fabric, each layer was placed individually into a shallow dish with the epoxy resin. Layer upon layer of wetted fabric was placed on top and excess air pockets were squeezed out. The ten-layer laminate was then placed onto an aluminum plate in between layers of release film and Mylar to allow release after curing. A double layer vacuum bag seal was placed on top of the composite with a heavy caul plate and breather fabric to ensure even pressure was placed on the laminate. The sample was then vacuumed to remove air and to create a pressurized mold. The composite was cured under vacuum for three hours at 80ºC and post-cured at 100ºC for two hours. Complying with ASTM method D-3846 (Standard Test Method for In-Plane Shear Strength of Reinforced Plastics), each composite was then removed from the mold and cut into 12.7 mm × 101.4 mm coupons using a water-jet cutter. The thickness of the composites was recorded as 2 mm each. Two 1.2 mm deep cuts were machined using a Diamond Head blade in the center region of the composite strips one on each side, ~10mm separating the cuts. The actual notch separation distance was measured to the nearest 0.1 mm for later calculation. Figure 3.8 is a schematic of the machining required for this test procedure. The coupons were then mounted in an I-shaped support jig described in ASTM D-695 (Standard Test Method for Compressive Properties of Rigid Plastics) and placed in the Instron for shear tensile test. Figure 3.9 shows the support jig used. A torque wrench was used to tighten the four screws on the jig to a standard 1lb.ft.

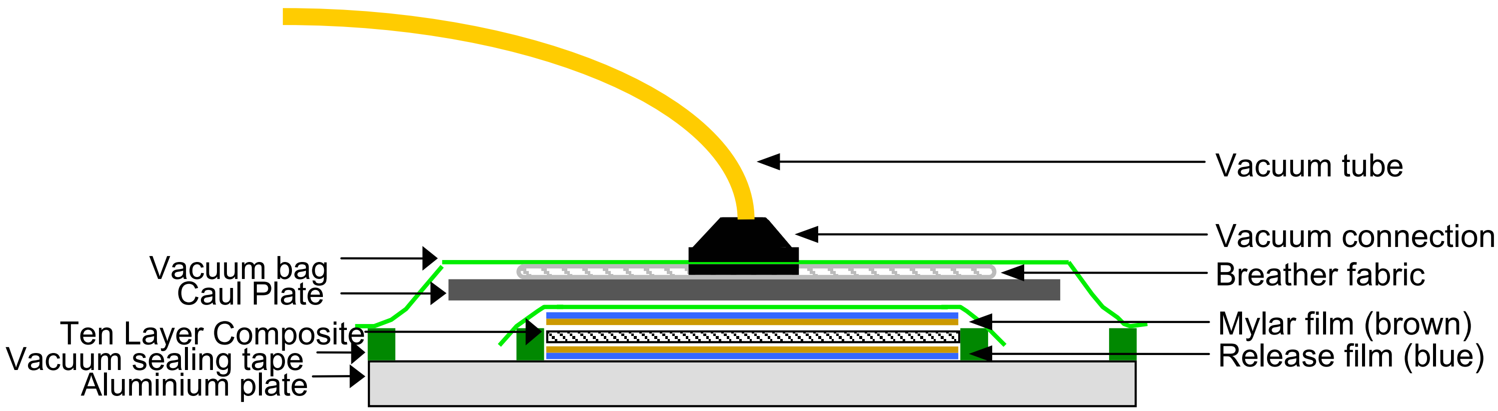

Figure 3.7 Schematic diagram of the composite manufacturing

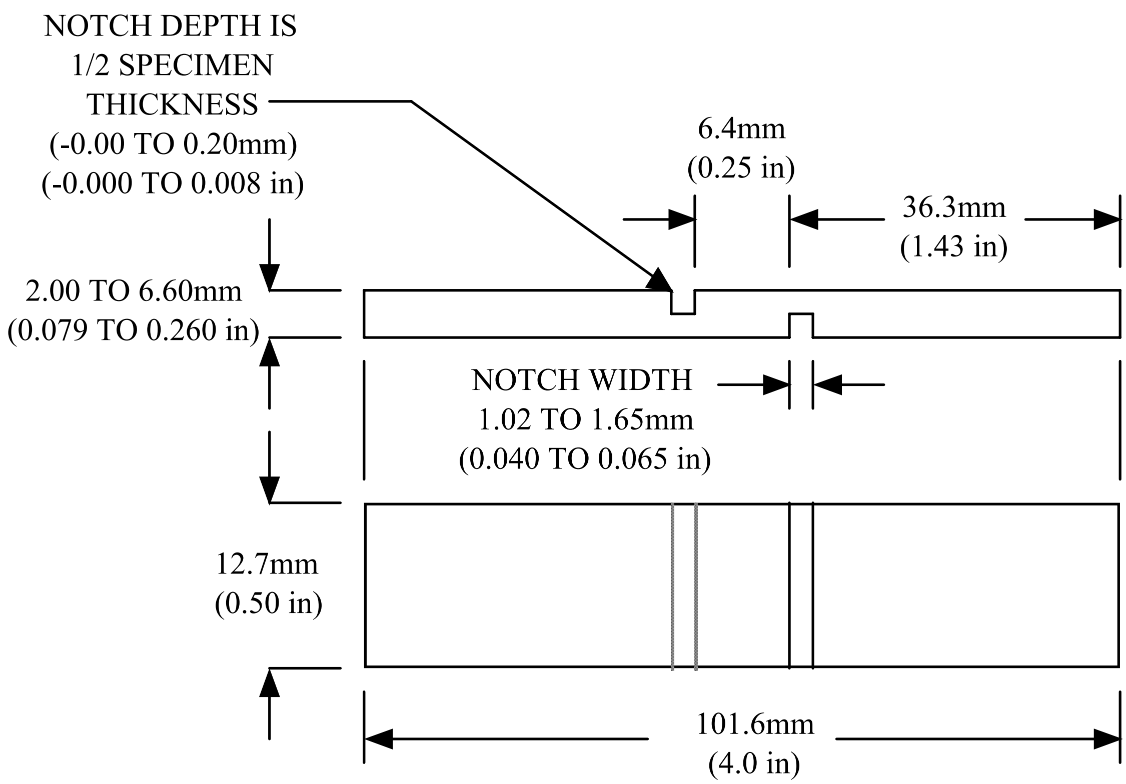

Figure 3.8 Schematic of machined samples for shear strength test (ASTM D-3846).

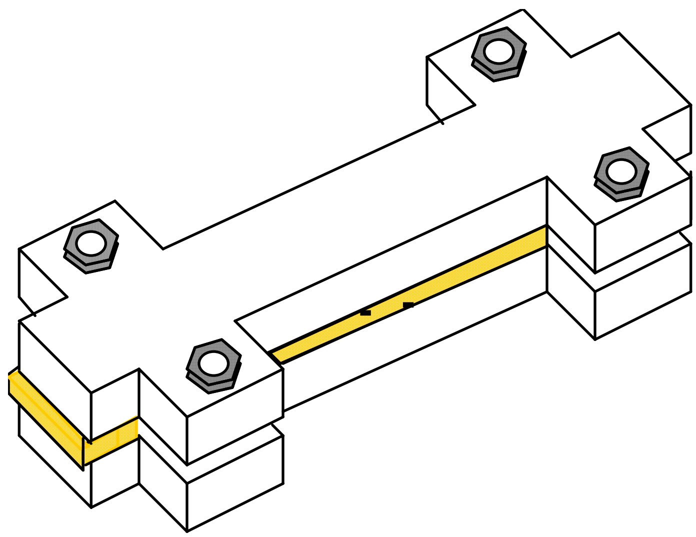

Figure 3.9 Supporting jig for shear strength composite samples. (ASTM D-695)

3.3 RESULTS AND DISCUSSION

3.3.1 Microscopy examination

Figure 3.10 shows typical images of the seven-fiber bundle composites with and without atmospheric plasma treatment. The control sample often shows an irregular array of fibers, due to the poor interfacial bonding and wetting out of the UHMPE fibers. This certainly reduces the transverse stiffness of the overall microcomposite while increasing the variation of the test results. In fact, in another study researching the interfacial bonding of boron/epoxy composites, it was found that the presence of just 10% of unbonded fiber reduced the modulus by 17% [10]. The atmospheric plasma treated samples however, consistently showed perfectly packed seven-fiber bundles that can be attributed to the improved chemical bonding between fiber and matrix. This regular array also contributed to the uniform load-displacement results collected from transverse compression testing and described in detail in the next section.

3.3.2 Transverse compression testing of seven-fiber bundle microcomposites

The transverse compression test generated a very interesting load-displacement trend for the atmospheric plasma treated samples. While the results for the control samples generated much less consistent load-displacement curves, due mostly to the fact that the bundles delaminated very early on, the plasma treated samples generated a very uniform and consistent set of load-displacement curves. Two such curves are demonstrated in Figure 3.11. The control and plasma treated sample both show an initial modulus of

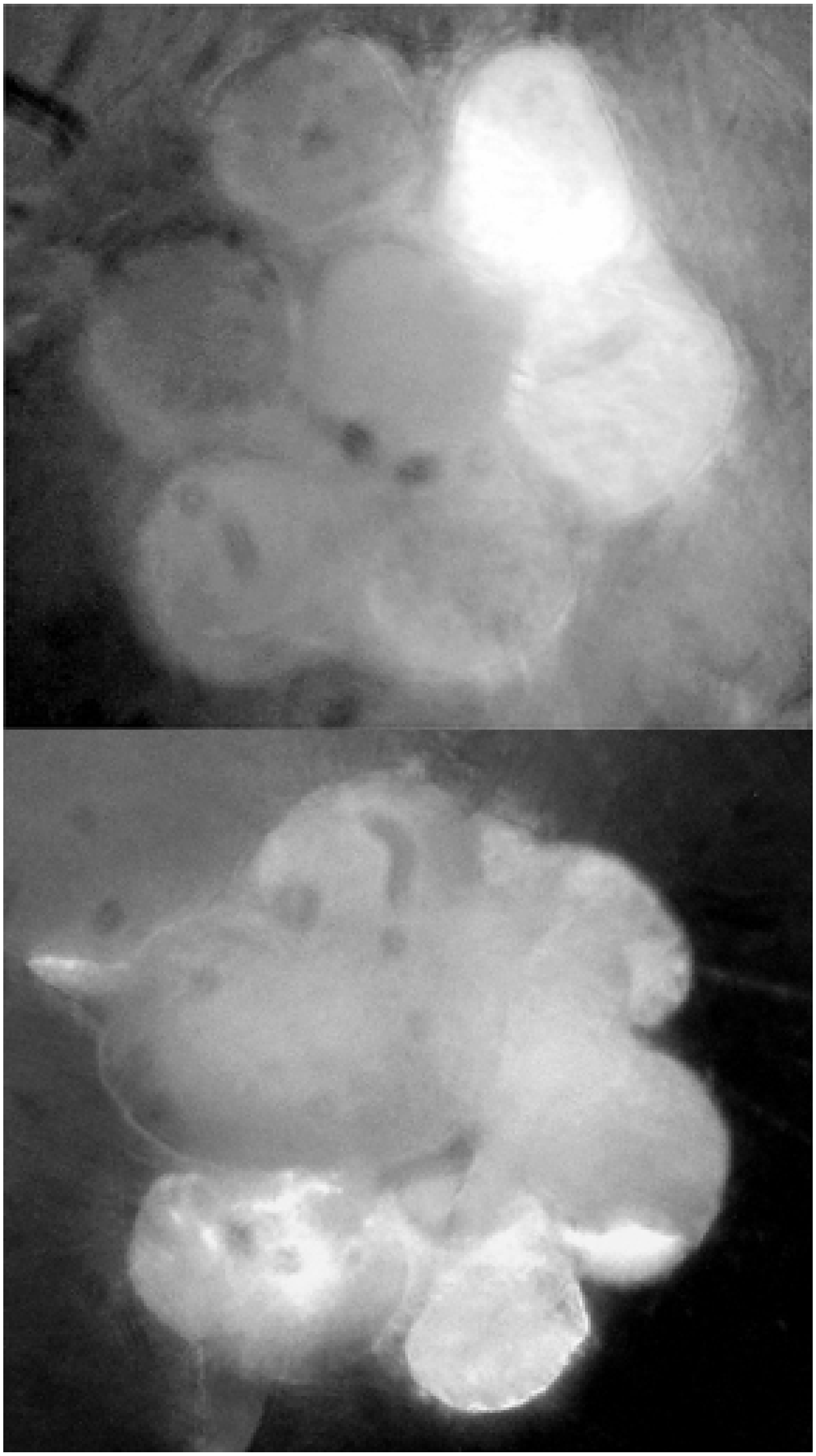

Figure 3.10 Microscopic photograph of seven-fiber microcomposite treated with (top) 2min He/air plasma. (bottom) Control

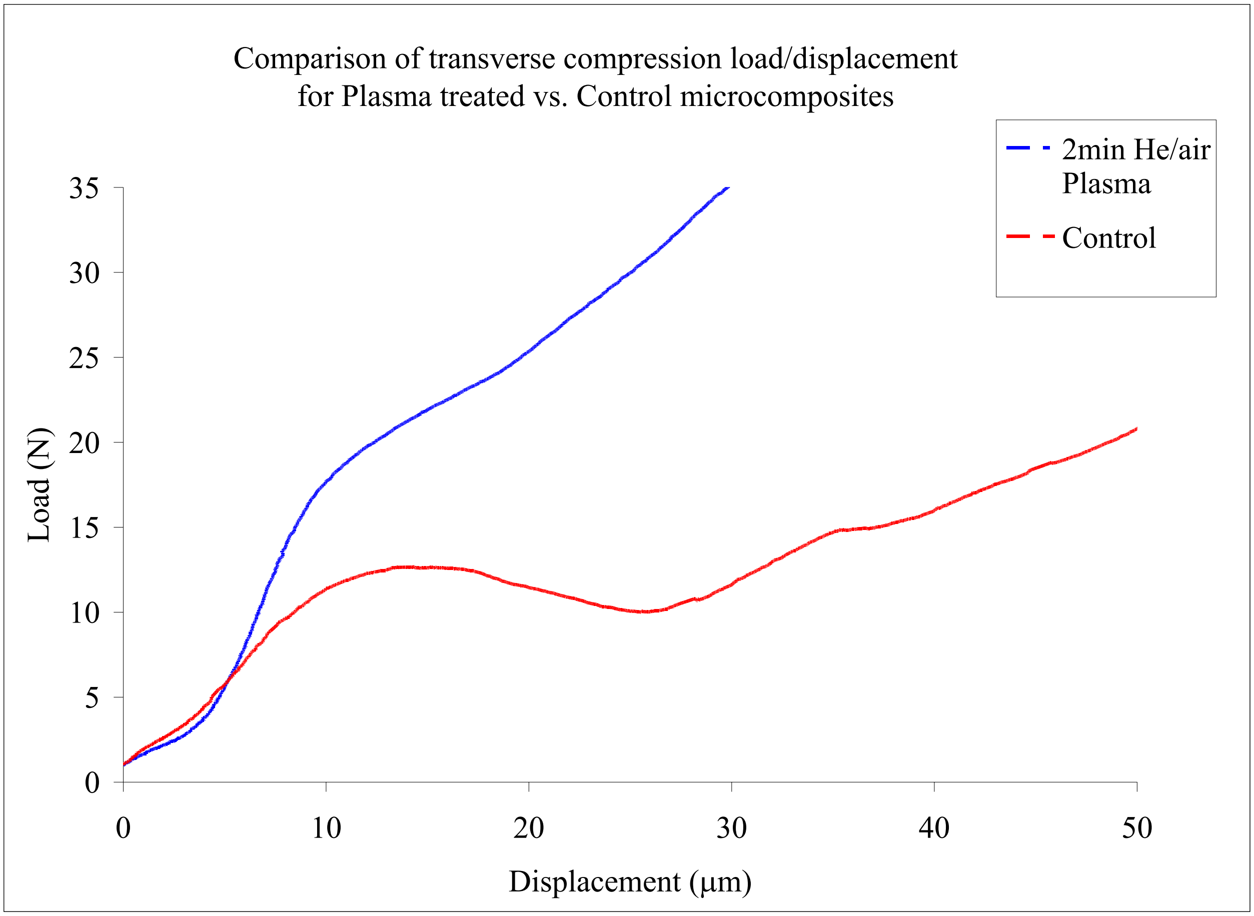

Figure 3.11 Typical Load-Displacement curves of transverse compression testing.

approximately the same value, but as transverse compression continues, the untreated sample yields at a much lower value than the treated sample. In fact, using the Meredith method, the yield modulus of the treated sample is almost 17.7N while the control yields around 11.9N. Considering the yield point corresponds to the onset of interfacial debonding, there is an increase of 49% in debonding load for the treated sample.

The irregular array of fibers observed in some of the control samples under the microscope proves to reinstate the fact that there is poor interfacial bonding between the fiber and resin. The atmospheric plasma treated samples however, have a more consistent fiber packing arrangement with increased interfacial bonding and therefore yield at a much higher and more consistent load value. The full array of load-displacement curves generated by the transverse compression test can be located in the appendix.

3.3.3 Finite Element Analysis of seven fiber microcomposites

The stress distribution in the composite was obtained as well as deformed shape and reaction force. The load displacement curve was then plotted and used as a judgment of the accuracy of the FEA model. Good agreement was found between experimental data and FEA model as shown in figure 3.12. Therefore, the stress calculated in the FEA model can be used to characterize the interfacial bonding strength and failure strength. Taking real values from the experimental data of the compression test, it was found that in the X-direction for a Type-A fiber arrangement, the Control had a yield stress of 35.8GPa (Fig. 3.13) while the Plasma treated sample yielded at 56.2GPa (Fig. 3.14). This is a 57% increase. For the same Type-A fiber arrangement in the XY-direction (shear), the Control yielded at 160GPa (Fig. 3.15), while the Plasma treated yielded at 251GPa (Fig. 3.16). This is also a 57% increase in yield stress. The high values noted here compared to the experimental values, are a result of the localized study. One would expect a much higher yielding value to occur at the microscopic level than in an actual full-scale experiment.

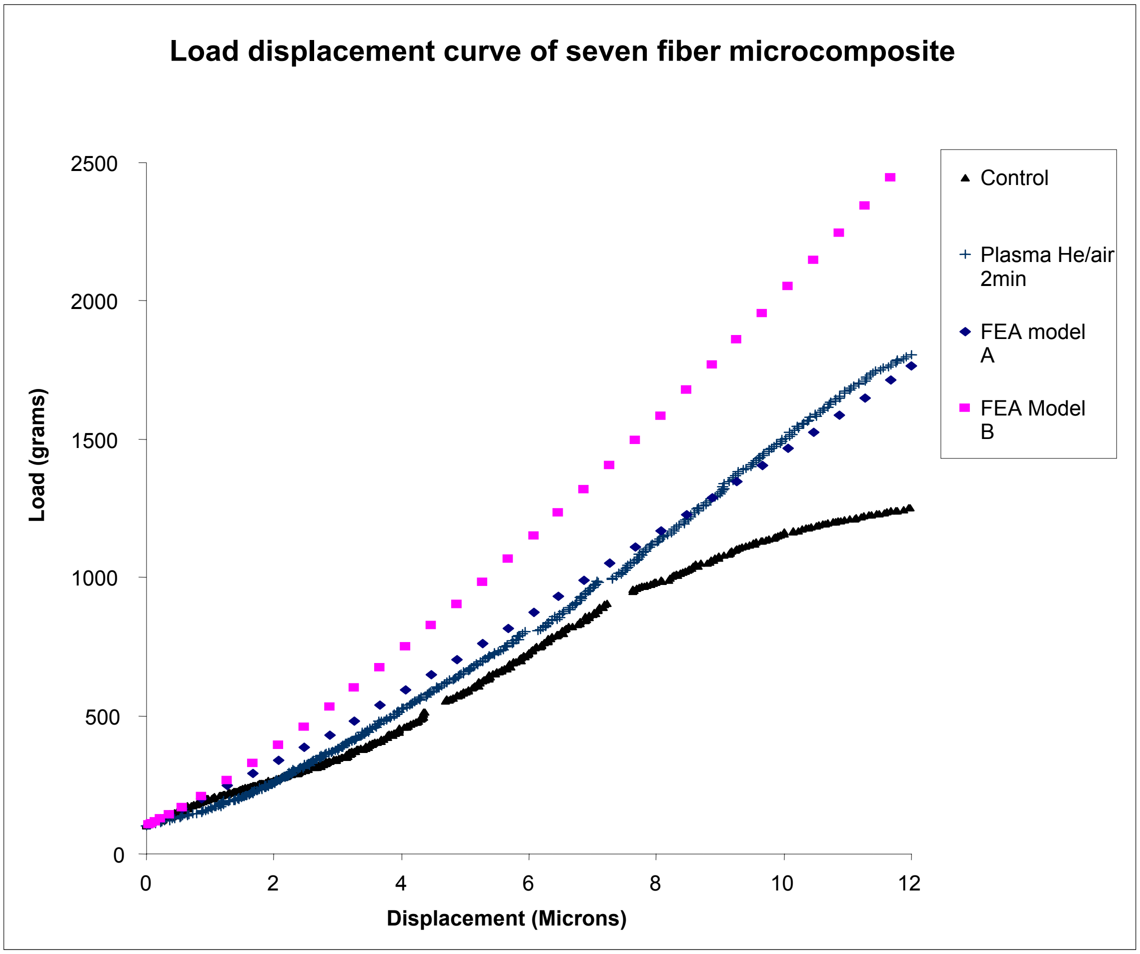

Figure 3.12 Load-displacement curve of seven fiber microcomposite with FEA modeling

The Type-B fiber arrangement was also analyzed using Finite Element Modeling. In the X-direction, the Control yielded at 4.41GPa (Fig. 3.17) while the Plasma treated sample yielded at 7.3GPa (Fig. 3.18). This is a 66% increase. In the XY-direction (shear), the Control yielded at 27.3GPa (Fig. 3.19), while the Plasma treated sample yielded at 31.2GPa (Fig. 3.20). This is a 14.4% increase.

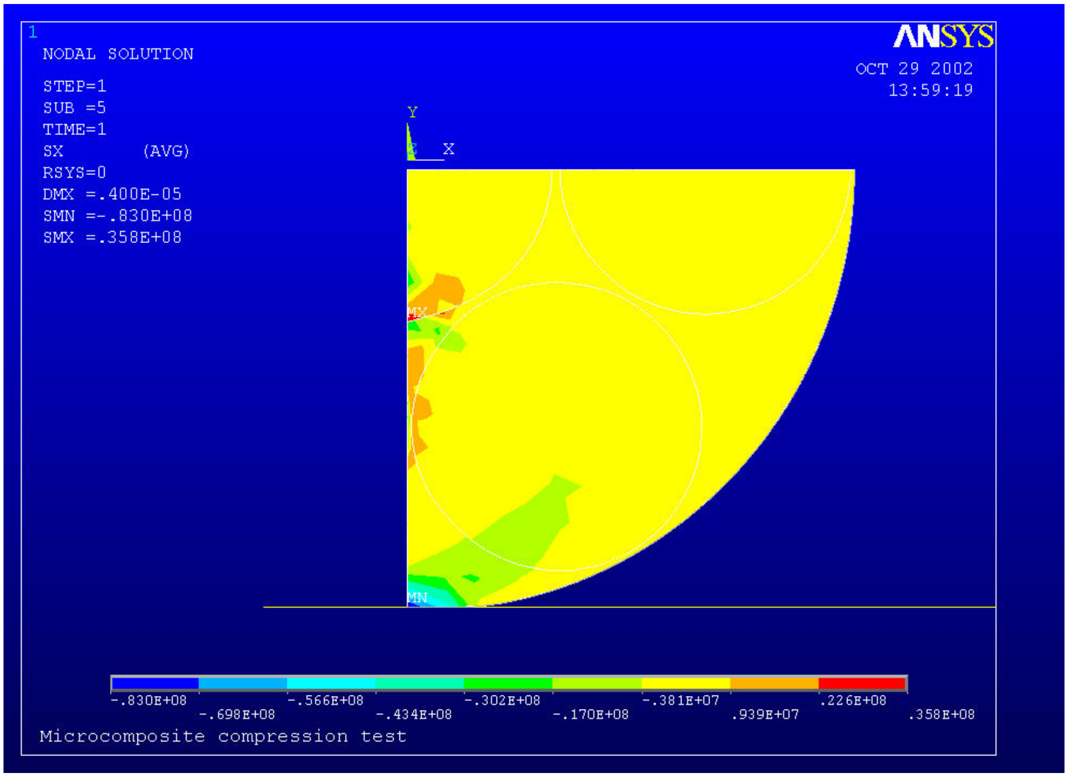

Figure 3.13 Finite Element Analysis (FEA) for failure of Type-A fiber arrangement Control sample in the X-direction.

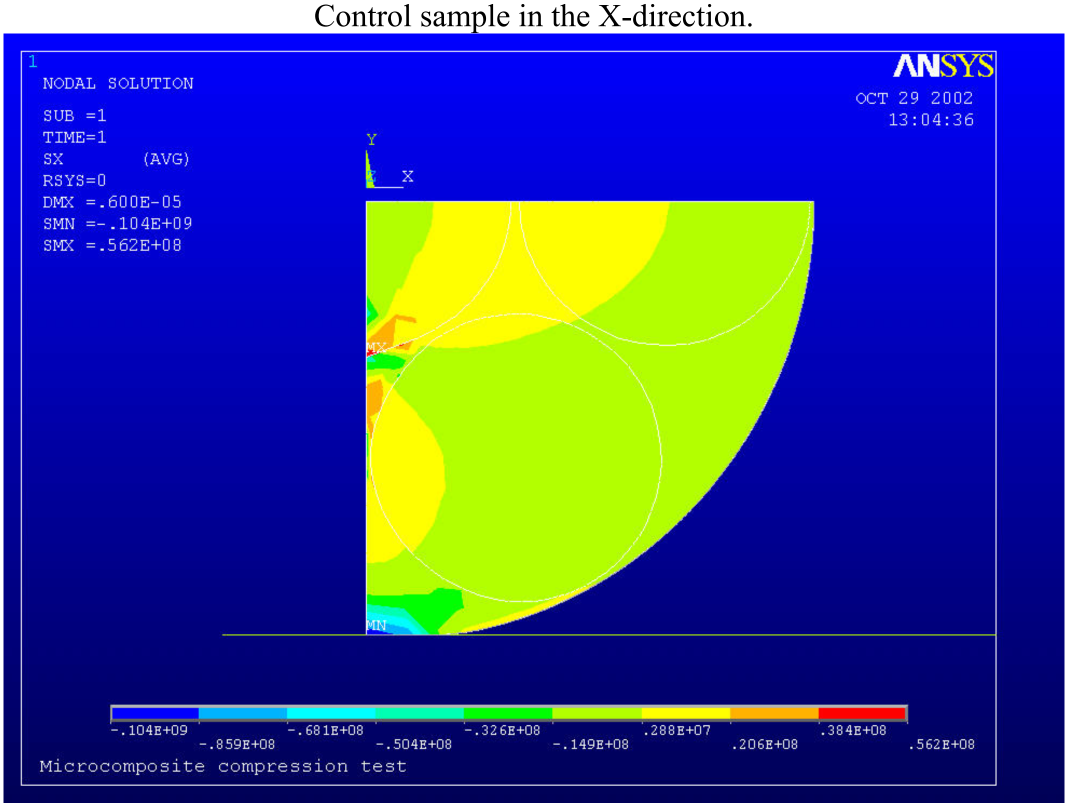

Figure 3.14 FEA for failure of Type-A fiber arrangement Plasma-treated sample in the X-direction.

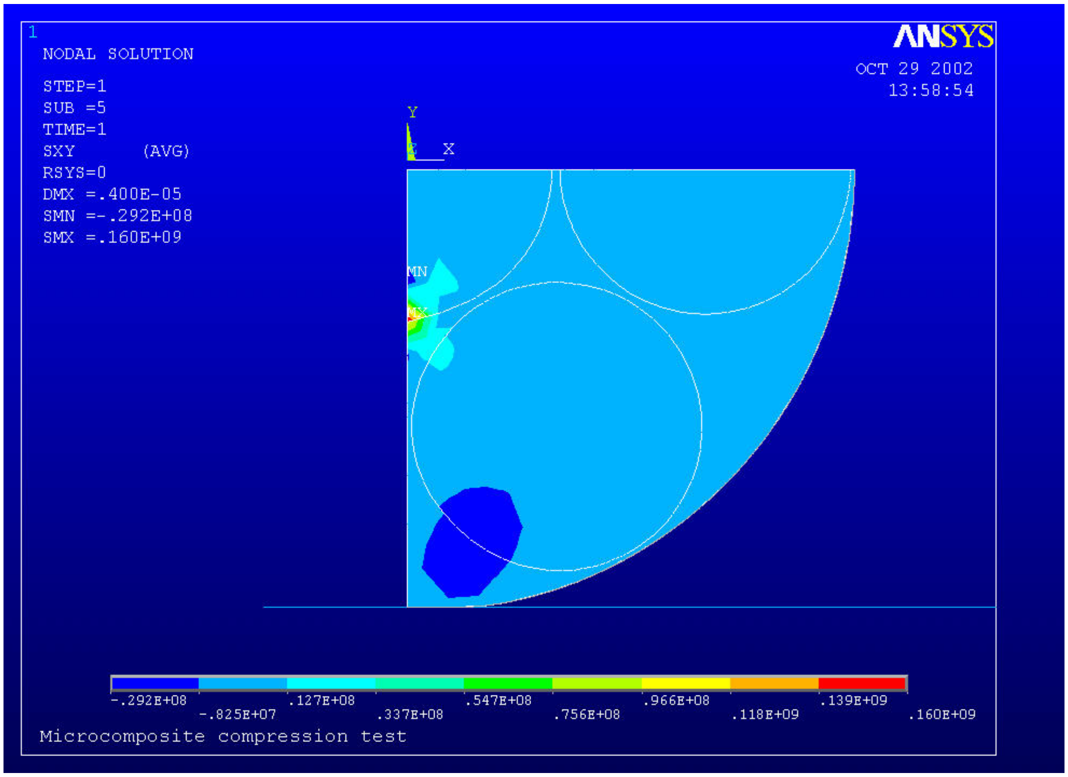

Figure 3.15 FEA for failure of Type-A fiber arrangement
Control sample in the XY-direction.

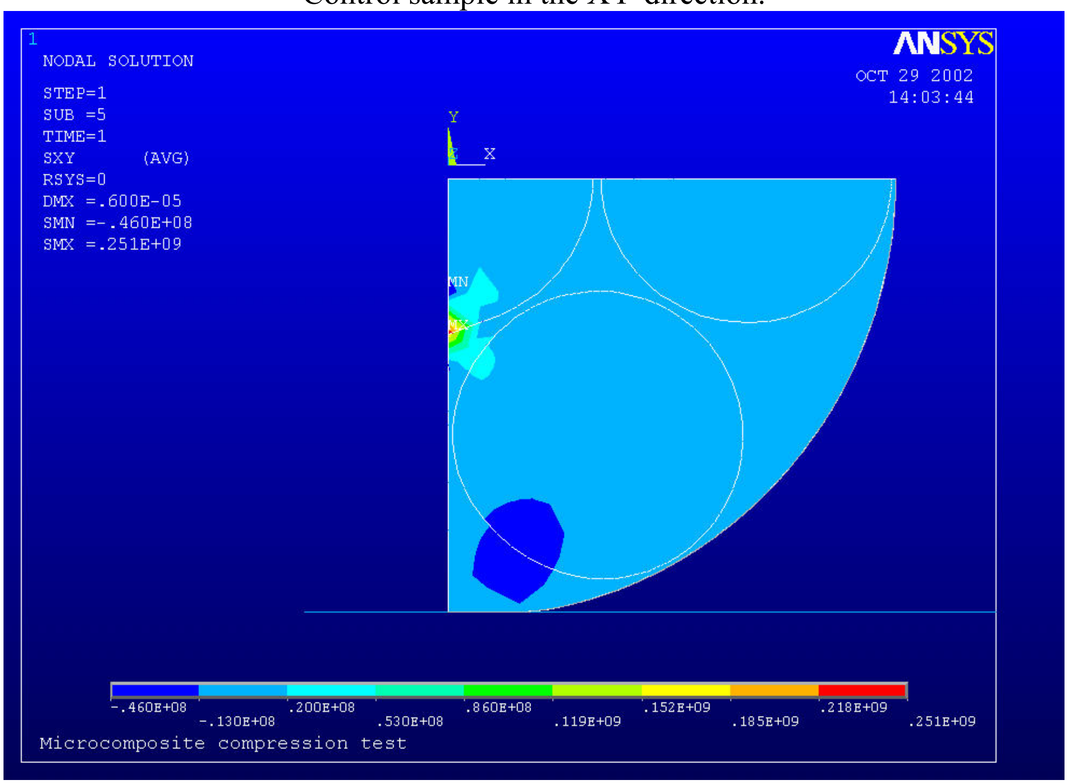

Figure 3.16 FEA for failure of Type-A fiber arrangement
Plasma-treated sample in the XY-direction.

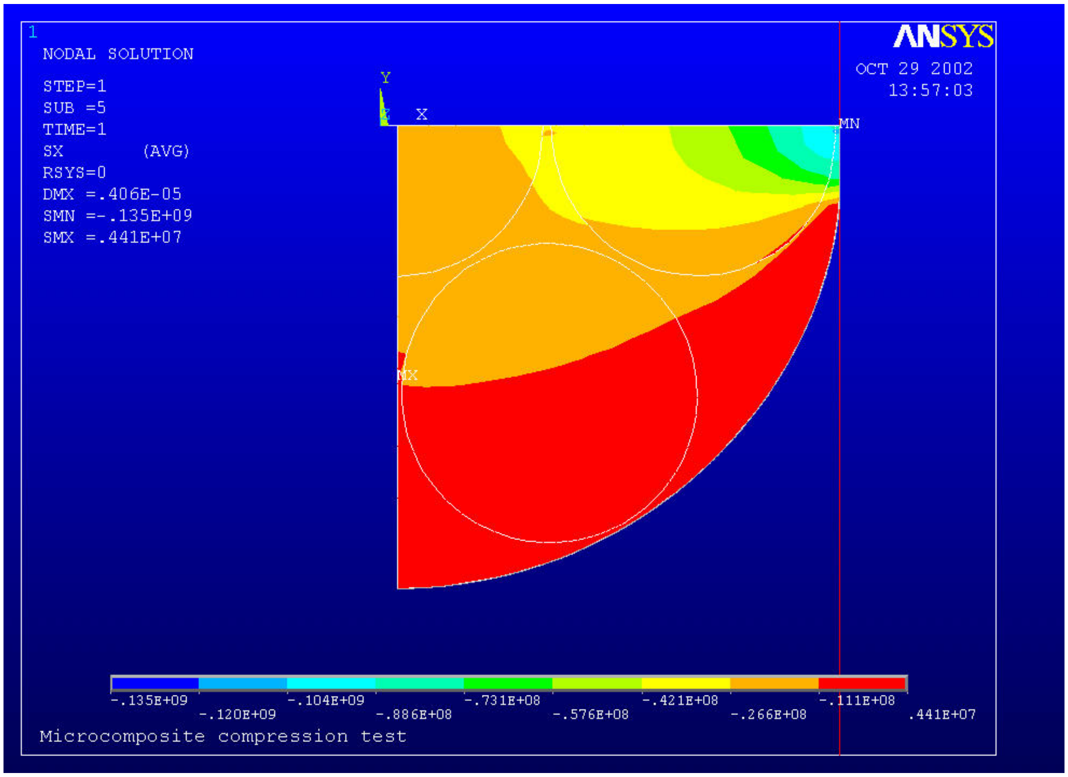

Figure 3.17 FEA for failure of Type-B fiber arrangement
Control sample in the X-direction.

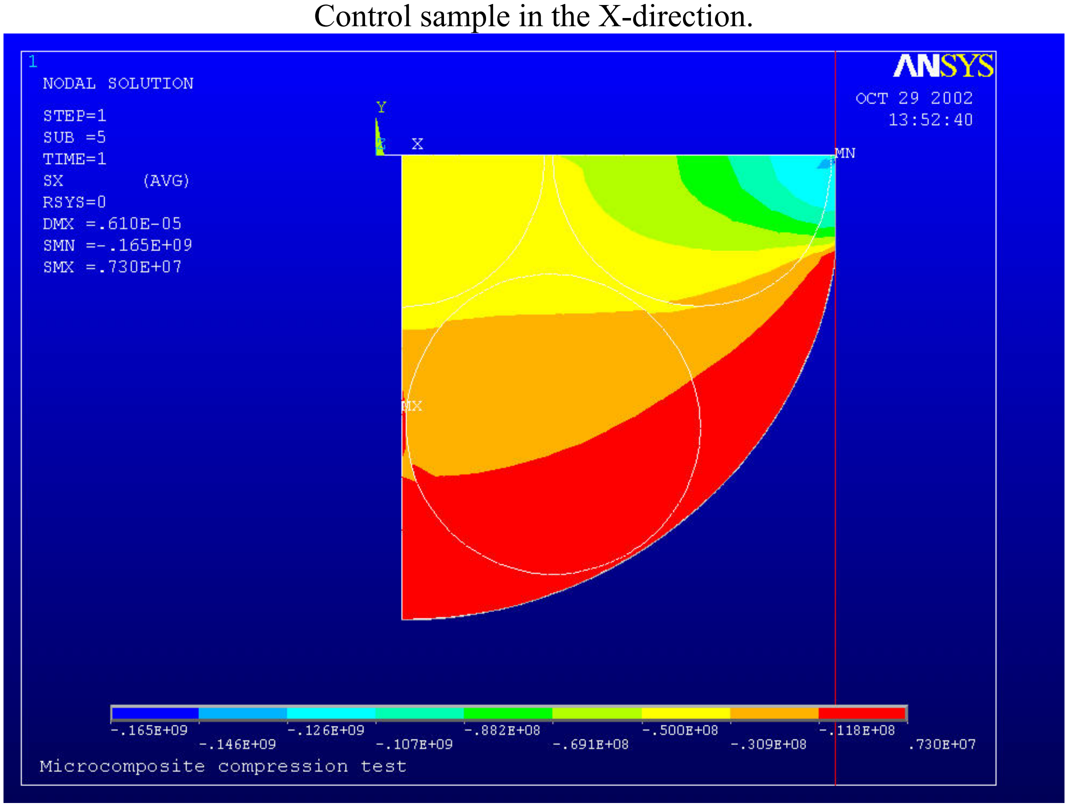

Figure 3.18 FEA for failure of Type-B fiber arrangement
Plasma-treated sample in the X-direction.

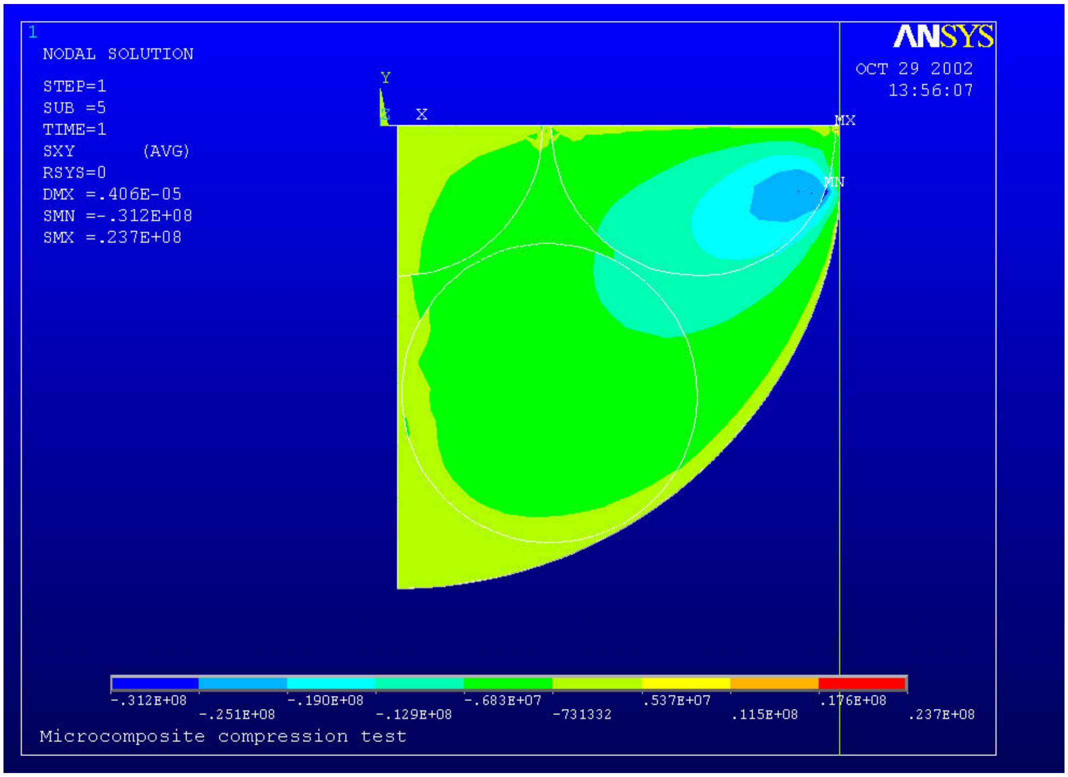

Figure 3.19 FEA for failure of Type-B fiber arrangement
Control sample in the XY-direction.

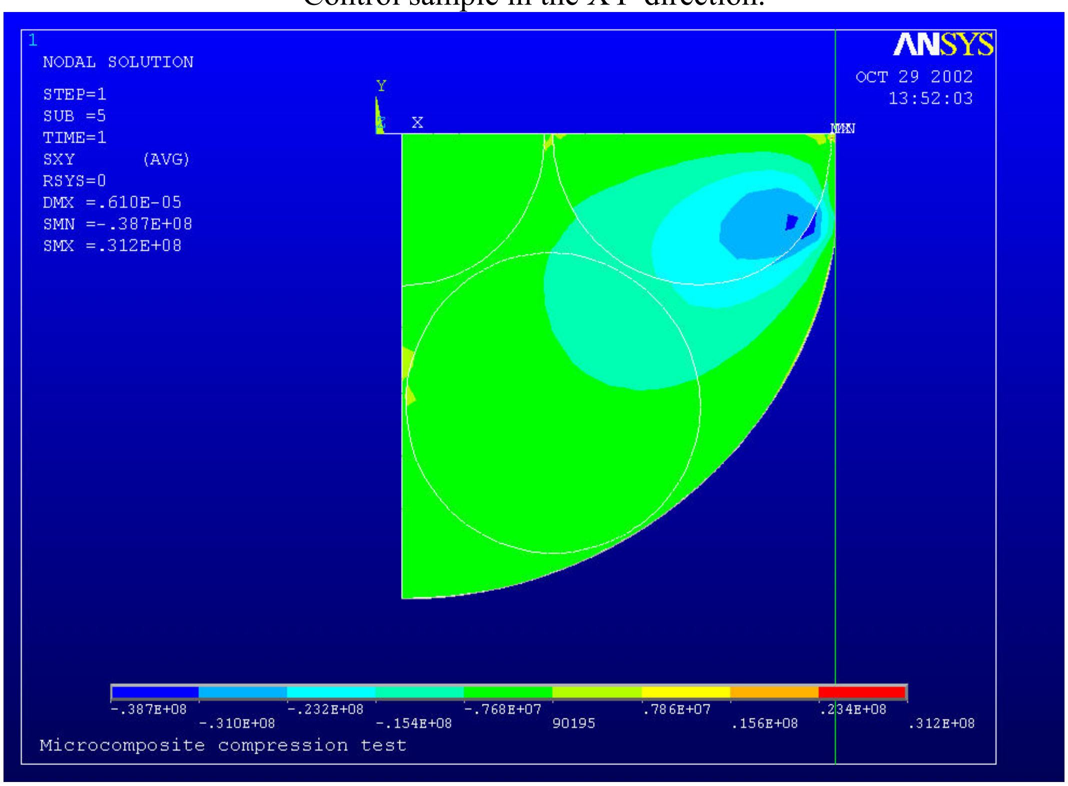

Figure 3.20 FEA for failure of Type-B fiber arrangement
Plasma-treated sample in the XY-direction.

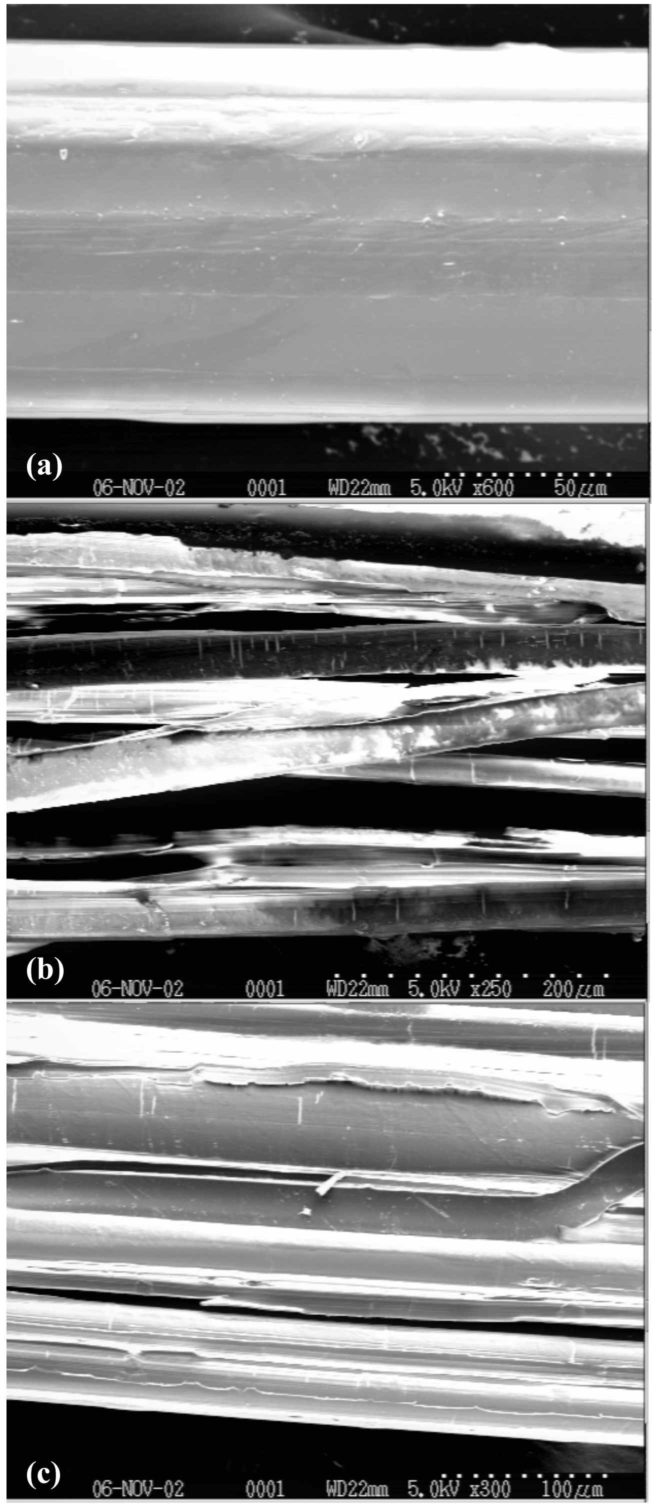

Figure 3.21 (a) SEM of Seven fiber microcomposite before compression, at 600x **(b)** SEM of Control sample after compression with total delamination at interface, at 250x **(c)** SEM of Plasma treated sample after compression with bulk matrix failure, interface remains intact, at 300x.

3.3.4 Scanning Electron Microscopy

Figure 3.21 (a) shows the seven-fiber bundle microcomposite as a complete unit, before transverse compression testing. The individual fibers can be distinguished from the epoxy matrix. Figure 3.21 (b) shows the failure mechanism of the control composite. The individual fibers have completely separated from the epoxy resin, leaving a clean fiber surface. The atmospheric plasma treated microcomposite in figure 3.21 (c) shows compression failure in the bulk matrix. The fibers are observed with large pieces of epoxy still attached to the surface. This suggests that the atmospheric plasma treatment has microscopically improved the interfacial bonding strength to an extent that failure occurs in the bulk matrix instead of at the interface region.

3.3.5 Peeling test of laminated textiles

The average load values of the five maximum and five minimum peaks collected from the Peeling test revealed significant differences between the treated and untreated samples. In fact, the average bonding strength recorded for the 2min He/air plasma treated sample tested was 3.94KPa while the control sample bonding strength was recorded at 2.16KPa. That is an 82.5% increase in bonding strength after atmospheric plasma treatment. Table 3.2 shows the values calculated for each sample tested as well as the average totals. The standard deviation and variance was also included. A comparison between typical load-displacement curves for both the treated and control samples is displayed in Figure 3.22. Here the discrepancy between bonding strength of each set of samples is clearly demonstrated. The plasma treated fabric shows a peel strength curve almost double the response of the control sample.

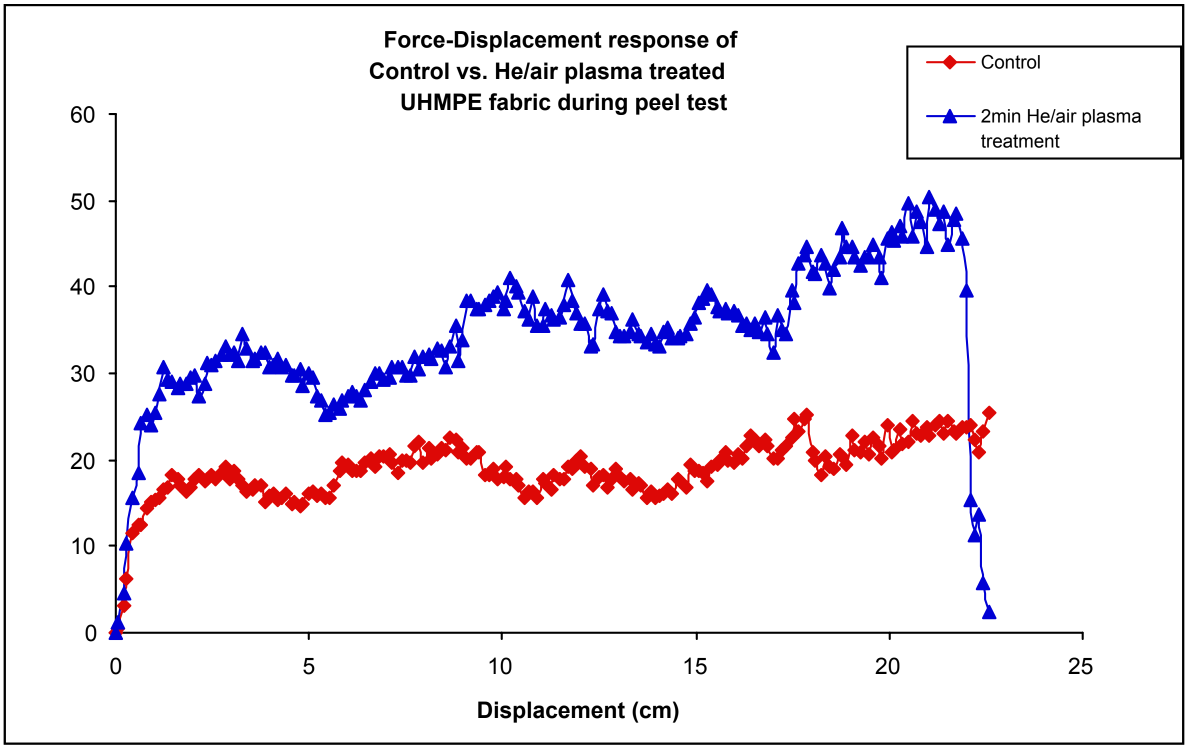

Figure 3.22 Typical load-displacement response of control vs. plasma treated UHMPE fabric during peel test.

Table 3.2 Average values for the five maximum and five minimum peaks of each sample tested during the peel test. An 82.5% increase in strength was calculated by the plasma treatment.

Control

Average Max Peaks (KPa)	Average Min Peaks (KPa)	Average Totals	St Dev	St dev/(n)^-2
2.37	1.99	2.18		
2.61	2.15	2.38		
1.99	1.61	1.80		
2.85	2.58	2.72		
2.81	2.56	2.69		
2.45	1.90	2.18		
1.61	1.41	1.51		
2.22	1.97	2.10		
2.03	1.72	1.88		
2.33	1.99	2.16	0.40	0.13

2min He/Air Plasma treated

Average Max Peaks (KPa)	Average Min Peaks (KPa)	Average Totals	St Dev	St dev/(n)^-2
4.96	4.14	4.55		
4.11	3.55	3.83		
3.47	3.02	3.24		
4.90	4.09	4.50		
4.23	4.23	4.23		
4.94	4.39	4.66		
3.44	2.53	2.99		
3.77	3.27	3.52		
4.23	3.65	3.94	0.64	0.23

3.3.6 Visual inspection of the laminated composites

The first observation noted between the treated and untreated composites was the color of the cured resin. The control sample appeared a lighter shade than the more yellow color of the plasma treated sample. This is an indication of the level of wetting each sample incurred during manufacturing. The control fabrics took much longer to soak up the resin than did the atmospheric plasma treated fabrics. Another observation noted was during the coupon cutting of the samples. The plasma treated composites cut more easily with initial edge trimming using a diamond edge blade compared to the control which showed signs of slight delamination. A water-jet cutter was commissioned to prepare the coupons to ensure straight even edges with little delamination.

3.3.7 Shear strength of ten-ply UHMPE laminates.

Twenty-three control samples and twenty plasma treated samples were tested on the Instron 5500R with a 1000-lb load cell at 1.3mm/min extension rate. The maximum load each specimen withstood before delamination occurred was recorded. Table 3.3 gives the actual data recorded and the conversions used to calculate the final average interlaminar shear strength of each set of samples. The control showed average shear strength of 5.77 MPa while the 2-min He/air plasma treated samples demonstrated average shear strength of 7.25 MPa. That is a statistically significant 25.7% increase in interlaminar shear strength of the plasma treated versus the untreated fiber reinforced composite. Figure 3.23 shows graphically the difference in interlaminar shear strength of the control versus the 2-min He/air atmospheric plasma treated sample. Here it is clearly shown that the plasma treated samples give a greater response to shear load than do the untreated samples.

Table 3.3 Data collected from Interlaminar Shear Strength test.

CONTROL	LENGTH (cm)	AREA (cm2)	MAX LOAD (N)	In-Plane Shear Strength (MPa)
A	1.76	2.23	932.74	4.18
B	2.13	2.71	1121.63	4.15
C	1.76	2.23	1314.42	5.89
D	1.70	2.16	1232.06	5.70
E	1.81	2.29	1012.45	4.41
F	1.64	2.09	1328.30	6.37
G	2.14	2.71	1403.76	5.17
H	2.17	2.75	1288.73	4.68
I	2.15	2.73	1078.14	3.95
J	2.15	2.73	1619.00	5.94
K	2.13	2.70	1585.95	5.87
L	1.58	2.00	1404.78	7.01
M	2.14	2.71	1515.48	5.59
N	1.66	2.11	1358.01	6.44
O	2.13	2.70	1596.05	5.91
P	1.79	2.28	1566.59	6.87
Q	2.13	2.70	1725.77	6.38
R	1.77	2.25	1391.19	6.17
S	1.68	2.13	1300.94	6.10
T	1.73	2.20	1560.61	7.08
U	2.14	2.71	1538.76	5.67
V	2.13	2.71	1645.15	6.07
W	1.60	2.03	1440.55	7.08
AVERAGE				5.77
StDev				0.95
Variance				0.20

PLASMA	LENGTH (cm)	AREA (cm2)	MAX LOAD (N)	In-Plane Shear Strength (MPa)
1	1.73	2.19	1607.04	7.33
2	1.73	2.19	1581.97	7.21
3	0.45	0.57	669.04	11.73
4	1.72	2.18	1335.37	6.12
5	0.28	0.35	322.71	9.20
6	0.34	0.43	496.09	11.55
7	1.72	2.19	1065.92	4.88
8	0.86	1.10	824.44	7.51
9	0.52	0.66	749.54	11.39
10	1.71	2.18	1169.99	5.37
11	1.73	2.19	1029.52	4.69
12	1.40	1.77	1037.61	5.85
13	1.76	2.23	1014.34	4.55
14	1.72	2.19	1155.14	5.28
15	1.11	1.40	991.77	7.06
16	1.31	1.66	1206.80	7.27
17	1.35	1.71	1291.85	7.53
18	1.73	2.19	1124.81	5.13
19	1.19	1.51	1226.84	8.10
20	1.46	1.85	1339.75	7.23
AVERAGE				7.25
StDev				2.24
Variance				0.50

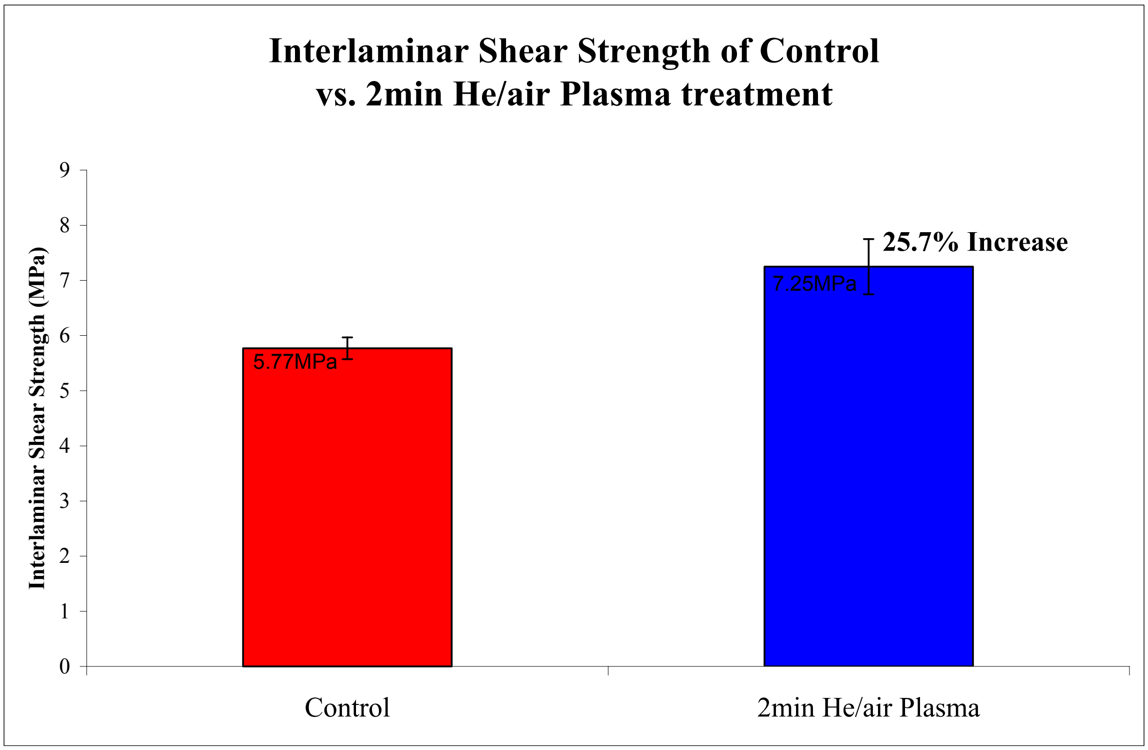

Figure 3.23 Interlaminar Shear Strength graph of Control vs. He/air plasma treatment

3.4 CONCLUSION

The delamination responses of 2-min He/air atmospheric plasma treated UHMPE composites were studied. The following conclusions can be made:

(1) Transverse compression of the seven-fiber microcomposites demonstrated a 49% increase in yield load for the plasma treated sample compared to the untreated. This can be attributed to greater adhesion between fibers of the plasma treated set and also greater uniformity of the seven-fiber bundle arrangement.

(2) Compared to the experimental results, the FEA model is most like the Type-A fiber arrangement with a combination of X and XY-direction failure. The 57% increase is close to the 49% increase found in the experiment.

(3) The peel test demonstrated an 82.5% increase in bonding strength after atmospheric plasma treatment.

(4) The shear strength test showed that compared with the control; there was a 25.7% increase in interlaminar shear strength of the atmospheric plasma treated samples.

Each set of delamination tests performed in this chapter showed a significant increase in strength between the UHMPE fiber and the epoxy resin after 2-min He/air atmospheric plasma treatments. Since the plasma treatment can increase bonding strength in peel test more than interlaminar shear strength in shear strength test, we conclude that the plasma treatment is more effective in increasing Mode I type of debonding stress than Mode II type debonding stress in a real composite.

Beginning with micromechanical experiments, namely the microbond test and a microcomposite transverse compression test through to a peeling test of laminated plain weave fabric and concluding with a ten-layer plain weave UHMPE flat panel composite, this experiment has demonstrated clearly that an atmospheric plasma treatment can increase fiber-matrix bonding at the microscopic level as well as the full-scale composite production level.

3.5 REFERENCES

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Appendix A. 0-Days Microbond Data

Report Date: Feb 15, 2002

North Carolina State Univ.
College of Textiles
2401 Research Dr
Raleigh NC 27695-8301

Sample ID: CHRIS1A – CONTROL 0 DAYS
Method: Tensile microbond – 5lb
Data Path: C:\GRAD-12

Test Date: Jan 30, 2002
Operator ID: GRAD

Sample Inputs:

Name	
Class/Project	
Type of Test	Straight
Grip Pressure	
Lab Conditions	70F, 65% R

	Denier	Adj gage len1	Peak Load	Elong @ Pk Ld	%Strn @ Pk Ld	Energy to Pk Ld	Fiber Modulus	Fiber Tenacity
	Denier	mm	Gm	mm	%	Gm-cm	Gm/Denier	Gm/Denier
1	7.00	50.000	3.67	0.2	0.45085	0.01	183.39	0.52
2	7.00	50.000	9.54	0.2	0.36672	0.07	371.18	1.36
3	7.00	50.000	7.09	0.4	0.88900	0.04	352.67	1.01
4	7.00	50.000	3.18	0.2	0.40005	0.01	147.61	0.45
5	7.00	50.000	3.18	0.4	0.77470	0.03	157.19	0.45
6	7.00	50.000	9.29	0.7	1.35890	0.07	460.61	1.33
7	7.00	50.000	5.62	0.5	1.01600	0.04	304.04	0.80
8	7.00	50.000	8.56	0.3	0.50800	0.05	465.53	1.22
9	7.00	50.000	8.31	0.4	0.70485	0.06	463.30	1.19
10	7.00	50.000	9.05	0.4	0.80645	0.09	375.11	1.29
11*	7.00	50.000	4.89	0.7	1.38430	0.15	67.37	0.70
12	7.00	50.000	6.11	0.2	0.36195	0.04	318.52	0.87
13	7.00	50.000	5.38	0.4	0.70485	0.04	303.54	0.77
14	7.00	50.000	5.14	0.3	0.69215	0.04	258.90	0.73
15	7.00	50.000	5.14	0.2	0.40005	0.04	190.44	0.73
16	7.00	50.000	2.69	1.3	2.67970	0.24	44.37	0.38
17	7.00	50.000	5.87	0.5	0.90170	0.07	261.98	0.84
18	7.00	50.000	10.03	0.5	0.97155	0.10	522.66	1.43
19	7.00	50.000	12.96	0.4	0.83820	0.24	302.59	1.85
20	7.00	50.000	11.98	0.3	0.64770	0.14	384.08	1.71
21	7.00	50.000	12.47	0.4	0.86360	0.18	342.33	1.78
22	7.00	50.000	10.27	0.4	0.76835	0.14	326.03	1.47
Mean	7.00	50.000	7.64	0.4	0.72128	0.08	324.58	1.09
Stdv	0.00	0.000	3.04	0.1	0.25646	0.06	105.91	0.43

*Exclude

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2401 Research Dr
Raleigh NC 27695-8301

Sample ID: CHRIS2A – HE/O2/AIR 30SEC 0 DAYS
Method: Tensile microbond – 5lb		Test Date: Jan 30, 2002
Data Path: C:\GRAD-12		Operator ID: GRAD

Sample Inputs:

Name	
Class/Project	
Type of Test	Straight
Grip Pressure	
Lab Conditions	70F, 65% R

	Denier	Adj gage len1	Peak Load	Elong @ Pk Ld	%Strn @ Pk Ld	Energy to Pk Ld	Fiber Modulus	Fiber Tenacity
	Denier	mm	Gm	mm	%	Gm-cm	Gm/Denier	Gm/Denier
1	7.00	50.260	6.50	0	-0.01521	0.40	331.82	0.94
2	7.00	50.381	3.91	-0.2	-0.33756	0.01	189.65	0.56
3	7.00	50.108	5.87	0	0.01227	0.02	428.83	0.84
4	7.00	50.216	4.16	0	0.03161	0.01	293.54	0.59
5	7.00	50.127	7.58	0.2	0.36593	0.07	269.06	1.08
6	7.00	50.044	6.85	0	0.08834	0.02	******	0.98
7	7.00	50.454	8.31	0.1	0.14474	0.03	******	1.19
8	7.00	50.038	8.31	0.1	0.16417	0.04	629.24	1.19
9*	7.00	50.190	2.20	0.2	0.31629	0.01	92.04	0.31
10	7.00	50.295	7.34	0.1	0.27002	0.07	356.65	1.05
11	7.00	50.000	10.03	0.3	0.67801	0.04	692.15	1.43
12	7.00	50.003	13.94	0.4	0.79226	0.10	747.71	1.99
13	7.00	50.000	4.89	0.2	0.48895	0.02	435.55	0.70
14	7.00	50.000	7.34	0.5	0.97155	0.05	336.84	1.05
15	7.00	50.000	11.49	0.4	0.83041	0.14	355.99	1.64
16	7.00	50.003	19.07	0.5	1.02863	0.35	570.97	2.72
17	7.00	50.003	11.00	0.4	0.78346	0.08	577.04	1.57
18	7.00	50.000	11.98	5	1.01600	0.12	476.11	1.71
19	7.00	50.000	10.03	0.3	0.55245	0.09	415.43	1.43
20	7.00	50.000	9.54	0.5	0.95106	0.13	301.70	1.36
Mean	7.00	50.102	8.86	0.2	0.46406	0.07	435.78	1.27
Stdv	0.00	0.147	3.67	0.2	0.41899	0.08	158.23	0.52

*Exclude

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2401 Research Dr
Raleigh NC 27695-8301

Sample ID: CHRIS3A – HE/O2/AIR 1MIN 0 DAYS
Method: Tensile microbond – 5lb   Test Date: Jan 30, 2002
Data Path: C:\GRAD-12   Operator ID: GRAD

Sample Inputs:

Name	
Class/Project	
Type of Test	Straight
Grip Pressure	
Lab Conditions	70F, 65% R

	Denier	Adj gage len1	Peak Load	Elong @ Pk Ld	%Strn @ Pk Ld	Energy to Pk Ld	Fiber Modulus	Fiber Tenacity
	Denier	mm	Gm	mm	%	Gm-cm	Gm/Denier	Gm/Denier
1	7.00	50.000	8.80	0.7	1.43510	0.12	346.84	1.26
2	7.00	50.000	4.16	0.2	0.45085	0.02	******	0.59
3	7.00	50.000	11.98	0.3	0.61595	0.09	618.94	1.71
4	7.00	50.000	8.07	0.3	0.55880	0.05	437.31	1.15
5	7.00	50.000	19.32	0.6	1.23190	0.23	652.74	2.76
6	7.00	50.000	25.19	0.5	1.06680	0.40	617.54	3.60
7	7.00	50.000	13.94	0.4	0.88900	0.15	537.07	1.99
8	7.00	50.000	12.96	0.3	0.59055	0.15	447.01	1.85
9*	7.00	50.000	14.18	0.6	1.28905	0.24	363.11	2.03
10	7.00	50.000	12.72	0.5	0.95885	0.19	322.05	1.82
11	7.00	50.000	12.23	0.2	0.49530	0.09	683.54	1.75
12	7.00	50.000	9.29	0.3	0.66040	0.10	613.65	1.33
13	7.00	50.000	16.38	0.3	0.53340	0.22	513.49	2.34
14	7.00	50.000	12.23	0.4	0.77470	0.20	330.10	1.75
15	7.00	50.000	10.52	0.3	0.58420	0.12	366.78	1.50
16	7.00	50.000	33.01	1	2.02565	1.84	231.65	4.72
17	7.00	50.000	20.79	0.8	1.64465	1.04	378.24	2.97
18	7.00	50.000	14.18	0.7	1.41605	0.38	324.80	2.03
19	7.00	50.000	5.87	0.6	1.24460	0.21	125.04	0.84
20	7.00	50.000	4.65	0.7	1.42240	0.23	90.44	0.66
21*	7.00	50.000	6.11	0.6	1.16205	0.10	188.22	0.87
Mean	7.00	50.000	13.52	0.5	0.99441	0.30	421.07	1.93
Stdv	0.00	0.000	6.97	0.2	0.44992	0.42	172.27	1.00

*Exclude

North Carolina State Univ.
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Raleigh NC 27695-8301

Sample ID: CHRIS3A – HE/AIR 2MIN 0 DAYS
Method: Tensile microbond – 5lb — Test Date: Jan 30, 2002
Data Path: C:\GRAD-12 — Operator ID: GRAD

Sample Inputs:

Name	
Class/Project	
Type of Test	Straight
Grip Pressure	
Lab Conditions	70F, 65% R

	Denier	Adj gage len1	Peak Load	Elong @ Pk Ld	%Strn @ Pk Ld	Energy to Pk Ld	Fiber Modulus	Fiber Tenacity
	Denier	mm	Gm	mm	%	Gm-cm	Gm/Denier	Gm/Denier
1	7.00	50.000	15.16	0.8	1.61290	0.59	415.43	2.17
2	7.00	50.000	19.07	0.5	1.00330	0.52	442.82	2.72
3	7.00	50.000	9.78	0.6	1.11125	0.13	415.68	1.40
4	7.00	50.000	11.25	0.4	0.86995	0.18	324.46	1.61
5	7.00	50.000	61.38	0.6	1.29540	2.44	1213.61	8.77
6	7.00	50.000	25.19	0.7	1.38430	0.34	819.64	3.60
7	7.00	50.000	23.97	0.4	0.84455	0.41	485.44	3.42
8	7.00	50.000	15.16	0.4	0.78105	0.32	503.34	2.17
9	7.00	50.000	22.99	0.7	1.45415	0.58	384.08	3.28
10	7.00	50.000	19.56	0.3	0.60325	0.24	640.20	2.79
11	7.00	50.000	39.62	1	1.93675	1.98	664.35	5.66
12	7.00	50.000	26.66	0.9	1.80975	0.59	517.16	3.81
13	7.00	50.000	25.92	0.6	1.27635	0.61	462.14	3.70
14	7.00	50.000	24.94	0.6	1.18745	0.70	392.98	3.56
15	7.00	50.000	18.59	0.3	0.59055	0.17	794.69	2.66
16	7.00	50.000	22.25	0.3	0.54610	0.27	756.48	3.18
17	7.00	50.000	25.92	0.5	1.00965	0.50	515.78	3.70
18	7.00	50.000	24.21	0.5	1.00330	0.41	550.17	3.46
19	7.00	50.000	21.28	0.5	1.06680	0.38	479.18	3.04
20	7.00	50.000	6.11	0.6	1.16205	0.10	188.22	0.87
Mean	7.00	50.000	22.95	0.6	1.12744	0.57	548.29	3.28
Stdv	0.00	0.000	11.61	0.2	0.38389	0.59	222.38	1.66

North Carolina State Univ.
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2401 Research Dr
Raleigh NC 27695-8301

Sample ID: CHRIS3A – HE/AIR 4MIN 0 DAYS
Method: Tensile microbond – 5lb　　Test Date: Jan 30, 2002
Data Path: C:\GRAD-12　　Operator ID: GRAD

Sample Inputs:

Name	
Class/Project	
Type of Test	Straight
Grip Pressure	
Lab Conditions	70F, 65% R

	Denier	Adj gage len1	Peak Load	Elong @ Pk Ld	%Strn @ Pk Ld	Energy to Pk Ld	Fiber Modulus	Fiber Tenacity
	Denier	mm	Gm	mm	%	Gm-cm	Gm/Denier	Gm/Denier
1	7.00	50.000	12.72	0.5	0.94615	0.30	465.53	1.82
2	7.00	50.000	33.75	0.6	1.17966	1.17	627.38	4.82
3	7.00	50.000	31.55	0.9	1.70815	1.02	498.05	4.51
4	7.00	50.000	10.27	0.6	1.18601	0.11	406.08	1.47
5	7.00	50.000	17.61	0.3	0.66675	0.28	402.56	2.52
6	7.00	50.000	10.27	0.3	0.65405	0.07	719.45	1.47
7	7.00	50.000	14.67	0.8	1.68910	0.17	560.55	2.10
8	7.00	50.000	19.32	0.8	1.54305	0.41	487.65	2.76
9	7.00	50.000	22.74	0.7	1.39065	0.75	453.08	3.25
10	7.00	50.000	19.81	0.8	1.67005	0.64	333.00	2.83
11	7.00	50.000	19.81	0.6	1.21531	0.17	858.26	2.83
12	7.00	50.000	26.66	0.6	1.11125	0.33	799.46	3.81
13	7.00	50.000	19.07	0.4	0.74295	0.32	460.61	2.72
14	7.00	50.000	29.10	0.8	1.57336	1.00	357.13	4.16
15	7.00	50.000	25.43	0.6	1.21632	0.72	327.98	3.63
16	7.00	50.000	30.81	1.3	2.61476	2.33	346.68	4.40
17	7.00	50.000	32.77	1.1	2.13606	1.59	324.46	4.68
18	7.00	50.060	23.97	0.2	0.36786	0.21	933.04	3.42
19	7.00	50.057	19.81	0.4	0.79919	0.21	963.89	2.83
20	7.00	50.038	19.32	0.4	0.75364	0.19	724.94	2.76
21	7.00	50.063	19.81	0.2	0.34881	0.23	595.84	2.83
22	7.00	50.197	25.43	0.4	0.74636	0.50	510.91	3.63
Mean	7.00	50.019	22.03	0.6	1.19361	0.58	552.57	3.15
Stdv	0.00	0.045	6.90	0.3	0.56636	0.56	200.42	0.99

$$n=\left[\frac{E_m}{E_f(1+\nu_m)\ln(R/r)}\right]^{1/2}$$

Em = 1.4 Gpa, young's modulus of matrix
Vm= 0.4, possion's ratio
Ef= 90 Gpa, tensile modulus of Spectra
R=bead's radius
r=fiber radius

$$\tau_i=\frac{nP_{\max}\coth(nL/r)}{2A}$$

Pmax=peak load
A=cross-section area of fiber
L=bead length

$$\bar{\tau}_i=\frac{P_{\max}}{S_f L}$$

Sf=circumference of fiber

		Fiber Diameter	Fiber Radius, r	Bead Diameter D	Bead Radius, R	Bead Length L	Peak Load, g	*n*	ncoth(nL/r)	A, mm^2	Pmax/2A, kgf/mm^2	Pmax/2A, Mpa	IFSS(Shear Lag), Mpa		IFSS(imbedded length), Mpa	
1	1AA	0.03057918	0.015	0.220	0.110	0.344	3.67	0.075	0.080	0.000734	2.499854249	24.52357019	1.971672532		1.09106043	
2	1AB	0.03604698	0.018	0.205	0.103	0.342	9.54	0.080	0.088	0.00102	4.676391784	45.87540341	4.038487032		2.42021986	
3	1AC	0.03807209	0.019	0.242	0.121	0.368	7.09	0.078	0.086	0.0011378	3.11553802	30.56342797	2.618526921		1.580287255	
4	1AD	0.03260429	0.016	0.205	0.102	0.330	3.18	0.078	0.085	0.0008345	1.905363699	18.69161788	1.583824914		0.923113644	
5	1AE	0.03483192	0.017	0.227	0.113	0.347	3.18	0.077	0.085	0.0009524	1.669447419	16.37727918				
6	1AF	0.03361685	0.017	0.199	0.100	0.307	9.29	0.079	0.088	0.0008871	5.236029162	51.36544608	4.539117993		2.814080544	
7	1AG	0.03159174	0.016	0.181	0.091	0.283	5.62	0.080	0.089	0.0007835	3.586655278	35.18508828	3.14822519		1.965929001	
8	1AH	0.03057918	0.015	0.190	0.095	0.282	8.56	0.078	0.087	0.000734	5.830722718	57.19938986	4.996368514		3.10463978	
9	1AI	0.03260429	0.016	0.292	0.146	0.408	8.31	0.071	0.075	0.0008345	4.979110797	48.84507692	3.679672248		1.950411058	
10	1AJ	0.03381936	0.017	0.233	0.117	0.352	9.05	0.076	0.083	0.0008978	5.039856323	49.44099053	4.08331179		2.373963605	
11	1AK	0.03280680	0.016	0.198	0.099	0.307	6.11	0.079	0.087	0.0008449	3.615877426	35.47175755	3.097753463		1.895258813	
12	1AL	0.03159174	0.016	0.252	0.126	0.373	5.38	0.073	0.078	0.0007835	3.433488505	33.68252223	2.623726533		1.424748771	
13	1AM	0.03260429	0.016	0.252	0.126	0.367	5.14	0.074	0.079	0.0008345	3.079738809	30.21223771	2.39378511		1.341470014	
14	1AN	0.03057918	0.015	0.190	0.095	0.303	5.14	0.078	0.085	0.000734	3.501158267	34.3463626	2.935213608		1.734548747	
15	1AO	0.03260429	0.016	0.273	0.137	0.379	2.69	0.072	0.078	0.0008345	1.611769921	15.81146293				
16	1AP	0.03179425	0.016	0.199	0.100	0.302	5.87	0.078	0.086	0.0007935	3.698633639	36.283596	3.133734672		1.911585427	
17	1AQ	0.03584447	0.018	0.203	0.101	0.288	10.03	0.080	0.093	0.0010086	4.972295369	48.77821757	4.552068555		3.035775144	
18	1AR	0.03381936	0.017	0.196	0.098	0.308	12.96	0.079	0.089	0.0008978	7.217297011	70.80168367	6.28385738		3.881773202	
19	1AS	0.03483192	0.017	0.200	0.100	0.307	11.98	0.080	0.090	0.0009524	6.28930191	61.69805174	5.547629176		3.50233165	
20	1AT	0.03361685	0.017	0.307	0.154	0.428	12.47	0.071	0.075	0.0008871	7.028340544	68.94802073	5.157936113		2.70576157	
21	1AU	0.03381936	0.017	0.189	0.094	0.304	10.27	0.080	0.090	0.0008978	5.719262369	56.10596384	5.041078405	StDev	3.123231987	StDev
	AVE	0.0333	0.017	0.222	0.111	0.335	7.406	0.077	0.085	0.001	4.224	41.438	3.759	1.299406	2.252	0.838214

		Fiber Diameter	Fiber Radius, r	Bead Diameter D	Bead Radius, R	Bead Length L	Peak Load, g	*n*	ncoth(nL/r)	A, mm^2	Pmax/2A, kgf/mm^2	Pmax/2A, Mpa	IFSS(Shear Lag), Mpa		IFSS(imbedded length), Mpa	
1	2AA	0.0305792	0.015	0.220	0.110	0.330	6.60	0.075	0.081	0.000734	4.495650694	44.1023333	3.580588908		2.042776788	
2	2AB	0.0305792	0.015	0.178	0.089	0.258	3.91	0.079	0.091	0.000734	2.663332456	26.1272914				
3	2AC	0.0295666	0.015	0.172	0.086	0.048	5.87	0.079	0.317	0.0006862	4.276957242	41.95695054	13.31636292		13.0334357	
4	2AD	0.0295666	0.015	0.196	0.098	0.276	4.16	0.077	0.086	0.0006862	3.031029323	29.73439766	2.55408754		1.591357059	
5	2AE	0.0283516	0.014	0.258	0.129	0.351	7.58	0.071	0.075	0.000631	6.006419392	58.92297423	4.434866088		2.37866678	
6	2AF	0.0328068	0.016	0.208	0.104	0.299	6.85	0.078	0.087	0.0008449	4.053806934	39.76784602	3.475005983		2.185342963	
7	2AG	0.0317942	0.016	0.237	0.119	0.356	8.31	0.074	0.080	0.0007935	5.236055458	51.36570404	4.103486129		2.296245881	
8	2AH	0.0326043	0.016	0.197	0.099	0.307	8.31	0.079	0.087	0.0008345	4.979110797	48.84507692	4.257435354		2.593686472	
9	2AI	0.0305792	0.015	0.155	0.077	0.257	2.20	0.083	0.094	0.000734	1.498550231	14.70077777				
10	2AJ	0.0305792	0.015	0.203	0.101	0.285	7.34	0.077	0.086	0.000734	4.999708499	49.04714037	4.218271873		2.631882799	
11	2AK	0.0388821	0.019	0.216	0.108	0.340	10.03	0.080	0.091	0.0011868	4.2257227	41.45433968	3.762469967		2.373057012	
12	2AL	0.0328068	0.016	0.317	0.158	0.422	13.94	0.070	0.074	0.0008449	8.24964506	80.92901803	5.984082554		3.147023745	
13	2AM	0.0338194	0.017	0.149	0.074	0.233	4.89	0.087	0.104	0.0008978	2.723193085	26.71452416	2.782067819		1.938021518	
14	2AN	0.0295666	0.015	0.169	0.084	0.244	7.34	0.080	0.092	0.0006862	5.348018084	52.4640574	4.839879628		3.183604481	
15	2AO	0.0305792	0.015	0.416	0.208	0.490	11.49	0.065	0.067	0.000734	7.826519162	76.77815298	5.164820489		2.393373472	
16	2AP	0.0326043	0.016	0.279	0.140	0.406	19.07	0.072	0.076	0.0008345	11.42619048	112.0909286	8.522175004		4.500408855	
17	2AQ	0.0315917	0.016	0.209	0.104	0.315	11.00	0.077	0.084	0.0007835	7.020143783	68.86761051	5.801020197		3.45001517	
18	2AR	0.0293641	0.015	0.235	0.118	0.352	11.98	0.073	0.078	0.0006769	8.849593708	86.81451428	6.736245824		3.619351515	
19	2AS	0.0305792	0.015	0.231	0.116	0.348	10.03	0.074	0.079	0.000734	6.832026736	67.02218228	5.320469127		2.94538694	
20	2AT	0.0295666	0.015	0.171	0.085	0.248	9.54	0.080	0.091	0.0006862	6.950966284	68.18897924	6.235091982	StDev	4.066826376	StDev
	AVE	0.0313	0.016	0.221	0.110	0.308	8.522	0.076	0.096	0.001	5.535	54.295	5.283	2.491088	3.354	2.533122

Fiber	Fiber R	Bead Diameter I	Bead Radius, R	Bead Length L	Peak Load, g	*n*	ncoth(nL/r)	A, mm^2	x/2A, kgf/mm	max/2A, Mp	IFSS(Shear Lag), Mpa		IFSS(imbedded length), Mpa			
1	3AA	0.0380721	0.019	0.233	0.117	0.368	8.8	0.078	0.086	0.0011378	3.87	37.93486124				
2	3AB	0.0400972	0.020	0.176	0.088	0.290	4.16	0.087	0.102	0.0012621	1.65	16.16718754				
3	3AC	0.0400972	0.020	0.271	0.136	0.396	11.98	0.076	0.084	0.0012621	4.75	46.55839105	3.918575963		2.360102772	
4	3AD	0.0378696	0.019	0.226	0.113	0.338	8.07	0.079	0.089	0.001258	3.58	35.16105098	3.127993314		1.972140532	
5	3AE	0.0338194	0.017	0.292	0.146	0.401	19.32	0.072	0.077	0.0008978	10.76	105.5469544	8.098002072		4.453345472	
6	3AF	0.0348319	0.017	0.275	0.138	0.384	25.19	0.073	0.079	0.0009524	13.22	129.7307115	10.29277869		5.887515138	
7	3AG	0.0328068	0.016	0.196	0.098	0.297	13.94	0.079	0.088	0.0008449	8.25	80.92901803	7.156059036		4.465429469	
8	3AH	0.0348319	0.017	0.225	0.112	0.331	12.96	0.077	0.086	0.0009524	6.80	66.74513778	5.730435802		3.510753424	
9	3AI	0.0336168	0.017	0.174	0.087	0.278	14.18	0.082	0.094	0.0008871	7.99	78.40280145	7.349537267		4.732678196	
10	3AJ	0.0348319	0.017	0.149	0.074	0.251	12.72	0.088	0.103	0.0009524	6.68	65.50911671	6.731928716		4.543374223	
11	3AK	0.0390846	0.020	0.195	0.098	0.288	12.23	0.083	0.099	0.0011992	5.10	50.02457011	4.944483868		3.394775679	
12	3AL	0.0305792	0.015	0.153	0.077	0.247	9.29	0.083	0.095	0.000734	6.33	62.07737521	5.913260093		3.844825126	
13	3AM	0.0548805	0.027	0.224	0.112	0.333	16.38	0.069	0.112	0.0023643	3.46	33.98183617	3.809635647		2.79741118	
14	3AN	0.0326043	0.016	0.231	0.115	0.279	12.23	0.075	0.088	0.0008345	7.33	71.88631658	6.302015114		4.193368467	
15	3AO	0.0358445	0.018	0.290	0.145	0.417	10.52	0.073	0.078	0.0010086	5.22	51.16120128	3.989794798		2.200080813	
16	3AP	0.0400972	0.020	0.344	0.172	0.559	33.01	0.072	0.075	0.0012621	13.08	128.2881877	9.56518528		4.599974858	
17	3AQ	0.0400972	0.020	0.269	0.134	0.396	20.79	0.076	0.084	0.0012621	8.24	80.79707428	6.810609898		4.095704226	
18	3AR	0.0394897	0.020	0.203	0.101	0.325	14.18	0.082	0.094	0.0012242	5.79	56.81703081	5.350077856		3.453653681	
19	3AS	0.0360470	0.018	0.263	0.131	0.385	5.87	0.075	0.081	0.00102	2.88	28.22731845				
20	3AT	0.0370595	0.019	0.232	0.116	0.330	4.65	0.078	0.088	0.0010781	2.16	21.15545155		StDev		StDev
	AVE	0.0373	0.019	0.231	0.116	0.345	13.524	0.079	0.089	0.001	6.356	62.355	6.193	2.039951	3.782	1.060683

Fiber	Fiber R	Bead Diameter I	Bead Radius, R	Bead Length L	Peak Load, g	*n*	ncoth(nL/r)	A, mm^2	x/2A, kgf/mm	max/2A, Mp	IFSS(Shear Lag), Mpa		IFSS(imbedded length), Mpa			
1	4AA	0.0326043	0.016	0.222	0.111	0.321	6.11	0.076	0.084	0.0008345	3.660934654	35.91376895				
2	4AB	0.0317942	0.016	0.206	0.103	0.297	15.16	0.077	0.086	0.0007935	9.552178188	93.70686802	8.083473777		5.010891785	
3	4AC	0.0315917	0.016	0.404	0.202	0.526	19.07	0.066	0.068	0.0007835	12.17037654	119.3913939	8.079191595		3.583119939	
4	4AD	0.0368570	0.018	0.223	0.111	0.332	9.78	0.079	0.088	0.0010664	4.585625646	44.98498759	3.97813605		2.496118214	
5	4AE	0.0317942	0.016	0.171	0.085	0.247	11.25	0.081	0.095	0.0007935	7.088522732	69.538408	6.636484689		4.478068111	
6	4AF	0.0368570	0.018	0.231	0.115	0.343	61.38	0.078	0.087	0.0010664	28.77972415	282.3290939	24.54126346		15.17539725	
7	4AG	0.0370595	0.019	0.304	0.152	0.431	25.19	0.073	0.078	0.0010781	11.68230409	114.6034031	8.913756406		4.923103938	
8	4AH	0.0338194	0.017	0.205	0.102	0.320	23.97	0.079	0.087	0.0008978	13.34865813	130.9503362	11.40232164		6.92924783	
9	4AI	0.0348319	0.017	0.180	0.090	0.290	15.16	0.082	0.094	0.0009524	7.958749329	78.07533092	7.307215834		4.688881605	
10	4AJ	0.0358445	0.018	0.216	0.108	0.322	22.99	0.079	0.089	0.0010086	11.39711571	111.8057051	9.904852331		6.230985453	
11	4AK	0.0423248	0.021	0.315	0.158	0.445	19.56	0.074	0.081	0.0014062	6.954706344	68.22566923	5.539320877		3.243668078	
12	4AL	0.0378696	0.019	0.224	0.112	0.339	39.62	0.079	0.089	0.0011258	17.5968032	172.6246394	15.36985251		9.653351543	
13	4AM	0.0368570	0.018	0.231	0.116	0.348	26.66	0.078	0.086	0.0010664	12.50028423	122.6277882	10.60631991		6.49163975	
14	4AN	0.0380721	0.019	0.213	0.107	0.311	25.92	0.080	0.093	0.0011378	11.38995	111.7354095	10.3744542		6.833525367	
15	4AO	0.0360470	0.018	0.271	0.136	0.379	24.94	0.074	0.081	0.00102	12.22528418	119.9300378	9.72308566		5.707900196	
16	4AP	0.0338194	0.017	0.192	0.096	0.286	18.59	0.080	0.091	0.0008978	10.35258884	101.5588966	9.287975209		6.005784606	
17	4AQ	0.0360470	0.018	0.165	0.083	0.264	22.25	0.085	0.101	0.00102	10.90667895	106.9945205	10.77318091		7.313757547	
18	4AR	0.0315917	0.016	0.204	0.102	0.305	25.92	0.077	0.085	0.0007835	16.54201153	162.2771331	13.87093474		8.410376335	
19	4AS	0.0336168	0.017	0.215	0.108	0.323	24.21	0.077	0.086	0.0008871	13.64523854	133.8597901	11.47546207		6.974490003	
20	4AT	0.0338194	0.017	0.201	0.101	0.319	21.28	0.079	0.087	0.0008978	11.85062349	116.2546164	10.16195123	StDev	6.171176395	StDev
	AVE	0.0352	0.018	0.230	0.115	0.337	22.951	0.078	0.087	0.001	11.709	114.869	10.317	4.36202	6.333	2.76661

		Fiber Diameter	Fiber Radius, r	Bead Diameter D	Bead Radius, R	Bead Length L	Peak Load, g	*n*	ncoth(nL/r)	A, mm^2	Pmax/2A, kgf/mm^2	Pmax/2A, Mpa	IFSS(Shear Lag), Mpa		IFSS(imbedded length), Mpa	
1	5AA	0.0358445	0.018	0.201	0.101	0.320	12.72	0.080	0.090	0.0010086	6.305842182	61.86031181				
2	5AB	0.0358445	0.018	0.251	0.126	0.368	33.75	0.076	0.083	0.0010086	16.73130296	164.134082	13.56737768		7.994422818	
3	5AC	0.0358445	0.018	0.349	0.175	0.489	31.55	0.070	0.073	0.0010086	15.64066988	153.4349715	11.20327018		5.620444941	
4	5AD	0.0370595	0.019	0.240	0.120	0.369	10.27	0.077	0.085	0.0010781	4.762892538	46.7239758				
5	5AE	0.0390846	0.020	0.244	0.122	0.353	17.61	0.078	0.088	0.0011992	7.342555818	72.03047258	6.326999408		3.98563108	
6	5AF	0.0317942	0.016	0.214	0.107	0.325	10.27	0.076	0.083	0.0007935	6.47103364	63.48084001				
7	5AG	0.0305792	0.015	0.205	0.102	0.301	14.67	0.076	0.084	0.000734	9.992605405	98.02745903	8.274473572		4.983887647	
8	5AH	0.0336168	0.017	0.271	0.136	0.377	19.32	0.073	0.079	0.0008871	10.88913707	106.8224347	8.409018203		4.76680757	
9	5AI	0.0338194	0.017	0.283	0.141	0.400	22.74	0.072	0.077	0.0008978	12.66368318	124.230732	9.594265495		5.254947377	
10	5AJ	0.0338194	0.017	0.207	0.103	0.306	19.81	0.077	0.088	0.0008978	11.03199489	108.2238699	9.535611182		5.980604325	
11	5AK	0.0368570	0.018	0.184	0.092	0.278	19.81	0.083	0.098	0.0010664	9.288470761	91.11989817	8.907316633		6.030480533	
12	5AL	0.0358445	0.018	0.352	0.176	0.474	26.66	0.070	0.073	0.0010086	13.21648998	129.6537667	9.50326399		4.897293366	
13	5AM	0.0380721	0.019	0.234	0.117	0.338	19.07	0.078	0.089	0.0011378	8.379874476	82.20656861	7.279595621		4.62442696	
14	5AN	0.0378696	0.019	0.294	0.147	0.429	29.1	0.074	0.079	0.0011258	12.92445666	126.7889199	10.02072012		5.591869815	
15	5AO	0.0378696	0.019	0.242	0.121	0.375	25.43	0.077	0.085	0.0011258	11.29446505	110.7987021	9.414091284		5.587744688	
16	5AP	0.0358445	0.018	0.169	0.084	0.272	30.81	0.085	0.099	0.0010086	15.27382057	149.8361798	14.78514458		9.866444874	
17	5AQ	0.0370595	0.019	0.179	0.090	0.285	32.77	0.084	0.098	0.0010781	15.19766197	149.089064	14.56655622		9.702453309	
18	5AR	0.0328068	0.016	0.225	0.112	0.331	23.97	0.076	0.083	0.0008449	14.18536529	139.1584334	11.60785702		6.894087529	
19	5AS	0.0338194	0.017	0.248	0.124	0.434	19.81	0.075	0.078	0.0008978	11.03199489	108.2238699	8.44166231		4.220781473	
20	5AT	0.0305792	0.015	0.235	0.118	0.348	19.32	0.074	0.079	0.000734	13.15999567	129.0995575	10.2134289		5.670166719	
21	5AU	0.0338194	0.017	0.193	0.096	0.297	19.81	0.080	0.090	0.0008978	11.03199489	108.2238699	9.751265901		6.151595054	
22	5AV	0.0346294	0.017	0.221	0.110	0.342	25.43	0.077	0.085	0.0009414	13.50693028	132.5029861	11.27611162	StDev	6.711496036	StDev
	AVE	0.0351	0.018	0.238	0.119	0.355	22.032	0.077	0.085	0.001	11.378	111.621	10.141	2.271343	6.028	1.632641

Appendix B. 3-Days Microbond Data

Report Date: Feb 15, 2002

North Carolina State Univ.
College of Textiles
2401 Research Dr
Raleigh NC 27695-8301

Sample ID: CHRIS1A – CONTROL 3 DAYS
Method: Tensile microbond – 5lb
Data Path: C:\GRAD-12

Test Date: Feb 4, 2002
Operator ID: GRAD

Sample Inputs:

Name	
Class/Project	
Type of Test	Straight
Grip Pressure	
Lab Conditions	70F, 65% R

	Denier	Adj gage len1	Peak Load	Elong @ Pk Ld	%Strn @ Pk Ld	Energy to Pk Ld	Fiber Modulus	Fiber Tenacity
	Denier	mm	Gm	mm	%	Gm-cm	Gm/Denier	Gm/Denier
1	7.00	50.044	9.05	0.5	1.03413	0.25	225.22	1.29
2	7.00	50.013	9.78	0.5	1.07778	0.07	487.67	1.40
3	7.00	50.165	4.65	0.2	0.40363	0.03	408.79	0.66
4	7.00	50.038	7.33	0.3	0.50127	0.07	346.01	1.05
5	7.00	50.079	5.38	0.3	0.67837	0.07	205.25	0.77
6	7.00	50.092	4.16	0.3	0.52966	0.01	220.43	0.59
7	7.00	50.492	8.07	0.4	-0.79230	0.01	******	1.15
8	7.00	50.159	3.67	0.1	-0.17358	0.00	******	0.52
9	7.00	50.111	7.82	0.4	0.77753	0.22	290.14	1.12
10	7.00	50.495	9.78	0	0.03831	0.10	329.18	1.40
11	7.00	50.337	9.78	0.2	-0.37032	0.03	******	1.40
12	7.00	50.505	13.45	0.2	-0.48004	0.08	654.38	1.92
13	7.00	50.362	9.78	0.2	-0.41088	0.04	607.65	1.40
14	7.00	50.127	10.02	0.3	0.69382	0.07	485.80	1.43
15	7.00	50.352	7.09	0.1	0.25222	0.04	379.00	1.01
16	7.00	50.038	2.93	0.5	1.02792	0.07	35.51	0.42
17	7.00	50.124	8.56	0.3	0.50041	0.07	534.70	1.22
18	7.00	50.083	8.56	0.3	0.54520	0.13	295.64	1.22
19	7.00	50.194	10.51	0.2	0.37809	0.10	404.03	1.50
20	7.00	50.095	15.40	0.4	0.71475	0.29	296.75	2.20
Mean	7.00	50.195	8.29	0.2	0.34630	0.09	365.07	1.18
Stdv	0.00	0.165	3.13	0.3	0.54245	0.08	157.31	0.45

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Raleigh NC 27695-8301

Sample ID: CHRIS2A – HE/O2/AIR 30SEC 3 DAYS
Method: Tensile microbond – 5lb — Test Date: Feb 4, 2002
Data Path: C:\GRAD-12 — Operator ID: GRAD

Sample Inputs:

Name	
Class/Project	
Type of Test	Straight
Grip Pressure	
Lab Conditions	70F, 65% R

	Denier	Adj gage len1	Peak Load	Elong @ Pk Ld	%Strn @ Pk Ld	Energy to Pk Ld	Fiber Modulus	Fiber Tenacity
	Denier	mm	Gm	mm	%	Gm-cm	Gm/Denier	Gm/Denier
1	7.00	50.394	10.76	0	0.04361	0.20	621.58	1.54
2	7.00	50.498	9.54	-0.3	-0.58099	0.06	517.22	1.36
3	7.00	50.137	8.31	0	0.02533	0.06	409.72	1.19
4	7.00	50.184	7.58	0.4	0.86043	0.13	243.94	1.08
5	7.00	50.117	14.18	0.5	1.03190	0.43	289.45	2.03
6	7.00	50.562	13.20	0.3	0.57285	0.21	386.27	1.89
7	7.00	50.267	6.36	-0.1	-0.23184	0.02	467.91	0.91
8	7.00	50.264	7.09	0.1	0.25123	0.05	456.78	1.01
9	7.00	50.530	11.25	0.3	0.50753	0.16	400.24	1.61
10	7.00	50.321	9.54	0	0.06264	0.14	289.37	1.36
11	7.00	50.098	12.96	0.3	0.51968	0.18	371.17	1.85
12	7.00	50.156	24.69	0.3	0.66468	0.64	509.32	3.53
13	7.00	50.197	16.14	0.4	0.74636	0.34	431.42	2.31
14	7.00	50.051	12.22	0.6	1.10234	0.41	403.78	1.75
15	7.00	50.079	17.60	0.8	1.52158	0.81	311.39	2.51
16	7.00	50.102	15.89	0.2	0.38656	0.17	697.07	2.27
17	7.00	50.133	14.91	0.4	0.85058	0.25	528.54	2.13
18	7.00	50.121	10.27	0.3	0.58769	0.08	565.89	1.47
19	7.00	50.048	28.85	0.7	1.37520	1.28	489.40	4.12
20	7.00	50.057	19.80	0.5	1.02609	0.62	376.07	2.83
21	7.00	50.048	21.76	0.5	0.98966	0.66	605.63	3.11
Mean	7.00	50.208	13.948	0.295	0.586	0.329	446.293	1.993
Stdv	0.00	0.164	5.945	0.273	0.528	0.317	118.225	0.850

*Exclude

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2401 Research Dr
Raleigh NC 27695-8301

Sample ID: CHRIS3A – HE/O2/AIR 1MIN 3 DAYS
Method: Tensile microbond – 5lb Test Date: Feb 4, 2002
Data Path: C:\GRAD-12 Operator ID: GRAD

Sample Inputs:

Name	
Class/Project	
Type of Test	Straight
Grip Pressure	
Lab Conditions	70F, 65% R

	Denier	Adj gage len1	Peak Load	Elong @ Pk Ld	%Strn @ Pk Ld	Energy to Pk Ld	Fiber Modulus	Fiber Tenacity
	Denier	mm	Gm	mm	%	Gm-cm	Gm/Denier	Gm/Denier
1	7.00	50.048	21.76	0.5	0.98966	0.66	605.63	3.11
2	7.00	50.073	13.20	0.6	1.26527	0.44	526.37	1.89
3	7.00	50.149	16.38	0.5	1.04953	0.47	551.69	2.34
4	7.00	50.054	17.11	0.5	1.01346	0.53	487.11	2.44
5	7.00	50.063	22.25	0.9	1.70163	0.57	394.70	3.18
6	7.00	50.022	10.02	0.3	0.57759	0.16	264.96	1.43
7	7.00	50.102	5.38	0.4	0.77313	0.11	254.39	0.77
8	7.00	50.203	5.62	0	0.01599	0.04	241.63	0.80
9	7.00	50.079	7.09	0.2	0.41844	0.08	255.79	1.01
10	7.00	50.044	15.65	0.2	0.40604	0.12	770.75	2.24
11	7.00	50.051	14.18	0.1	0.22693	0.08	******	2.03
12	7.00	50.003	25.43	0.5	1.03210	0.41	613.21	3.63
13	7.00	50.003	28.36	0.8	1.52246	0.61	540.26	4.05
14	7.00	50.070	18.09	0.3	0.53900	0.31	663.81	2.58
15	7.00	50.063	22.98	0.3	0.65178	0.41	596.64	3.28
16	7.00	50.051	12.22	0.5	1.03890	0.14	456.60	1.75
17	7.00	50.048	19.80	0.6	1.19379	0.69	457.08	2.83
18	7.00	50.060	26.41	0.8	1.51438	1.05	568.48	3.77
Mean	7.00	50.066	16.774	0.444	0.885	0.382	485.241	2.396
Stdv	0.00	0.048	7.036	0.245	0.468	0.276	157.395	1.005

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Sample ID: CHRIS3A – HE/AIR 2MIN 3 DAYS
Method: Tensile microbond – 5lb
Test Date: Feb 4, 2002
Data Path: C:\GRAD-12
Operator ID: GRAD

Sample Inputs:

Name	
Class/Project	
Type of Test	Straight
Grip Pressure	
Lab Conditions	70F, 65% R

	Denier	Adj gage len1	Peak Load	Elong @ Pk Ld	%Strn @ Pk Ld	Energy to Pk Ld	Fiber Modulus	Fiber Tenacity
	Denier	mm	Gm	mm	%	Gm-cm	Gm/Denier	Gm/Denier
1	7.00	50.000	14.18	0.5	0.98425	0.34	567.79	2.03
2	7.00	50.000	16.38	0.2	0.31115	0.17	835.26	2.34
3	7.00	50.000	21.27	0.4	0.86360	0.62	532.31	3.04
4	7.00	50.000	25.92	0.3	0.53340	0.41	609.52	3.70
5	7.00	50.057	27.87	0.6	1.27980	0.75	446.78	3.98
6	7.00	50.013	27.14	0.2	0.35493	0.24	1053.56	3.88
7	7.00	50.019	16.63	0.4	0.70314	0.35	779.53	2.38
8	7.00	50.025	13.69	0.2	0.41254	0.13	524.12	1.96
9	7.00	50.016	14.48	0.2	0.38723	0.14	491.27	2.03
10	7.00	50.003	14.91	0.3	0.53337	0.20	372.12	2.13
11	7.00	50.019	22.74	0.7	1.38911	0.47	634.92	3.25
12	7.00	50.029	31.05	0.7	1.33157	0.72	666.23	4.44
13	7.00	50.038	34.23	0.5	1.07202	0.90	536.71	4.89
14	7.00	50.000	42.05	0.7	1.36381	1.52	473.04	6.01
15	7.00	50.003	24.94	0.5	1.02719	0.56	433.72	3.56
16	7.00	50.270	21.03	0.1	0.15158	0.39	1017.56	3.00
17	7.00	50.006	22.98	0.7	1.35035	0.63	412.59	3.28
18	7.00	50.022	34.47	0.9	1.79625	1.71	355.03	4.92
19	7.00	50.000	30.32	1	2.08136	1.79	248.65	4.33
20	7.00	50.000	20.78	1.1	2.12437	1.25	196.86	2.97
Mean	7.00	50.026	23.853	0.510	1.003	0.665	559.379	3.406
Stdv	0.00	0.059	7.868	0.286	0.587	0.518	225.695	1.126

North Carolina State Univ.
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Sample ID: CHRIS3A – HE/AIR 4MIN 3 DAYS
Method: Tensile microbond – 5lb — Test Date: Feb 4, 2002
Data Path: C:\GRAD-12 — Operator ID: GRAD

Sample Inputs:

Type of Test	Straight
Grip Pressure	
Lab Conditions	70F, 65% R

	Denier	Adj gage len1	Peak Load	Elong @ Pk Ld	%Strn @ Pk Ld	Energy to Pk Ld	Fiber Modulus	Fiber Tenacity
	Denier	mm	Gm	mm	%	Gm-cm	Gm/Denier	Gm/Denier
1	7.00	50.057	21.26	0.8	1.62230	0.39	419.56	3.11
2	7.00	50.010	18.09	0.7	1.32546	0.41	283.41	2.58
3	7.00	50.029	19.07	0.7	1.39620	0.65	220.15	2.72
4	7.00	50.006	13.94	0.8	1.53261	0.56	157.18	1.99
5	7.00	50.016	9.29	1	2.00596	0.55	99.44	1.33
6	7.00	50.003	6.36	0.5	1.09848	0.23	125.02	0.91
7	7.00	50.000	27.63	0.4	0.71611	0.44	858.62	3.95
8	7.00	50.003	15.16	0.5	1.04768	0.38	465.46	2.17
9	7.00	50.013	58.68	1	2.00609	3.84	719.93	8.38
10	7.00	50.000	21.52	0.7	1.47955	1.19	409.48	3.07
11	7.00	50.000	15.65	0.9	1.75607	0.51	300.03	2.24
12	7.00	50.016	13.94	0.3	0.69193	0.22	579.18	1.99
13	7.00	50.003	14.67	0.4	0.83180	0.18	570.46	2.10
14	7.00	50.000	18.09	0.7	1.40970	0.50	456.14	2.58
15	7.00	50.000	15.89	0.5	1.02870	0.38	436.80	2.27
16	7.00	50.000	16.87	0.5	1.06680	0.47	376.35	2.41
17	7.00	50.000	22.98	1	1.99390	1.42	275.03	3.28
18	7.00	50.016	11.00	0.3	0.52918	0.09	550.23	1.57
19	7.00	50.013	34.47	0.4	0.78085	0.72	775.91	4.92
20*	7.00	50.035	15.16	0.4	0.87569	0.22	435.76	2.17
21	7.00	50.003	17.85	0.5	0.95244	0.22	514.21	2.55
22	7.00	50.013	13.94	0.3	0.51422	0.14	481.42	1.99
23	7.00	50.003	18.83	0.5	1.06529	0.50	359.24	2.69
Mean	7.00	50.009	19.326	0.609	1.221	0.636	428.784	2.764
Stdv	0.00	0.013	10.624	0.233	0.467	0.782	200.846	1.517

*Exclude

$$n = \left[\frac{E_m}{E_f (1+\nu_m)\ln(R/r)} \right]^{1/2}$$

Em = 1.4 Gpa, young's modulus of matrix
Vm= 0.4, possion's ratio
Ef= 90 Gpa, tensile modulus of Spectra
R=bead's radius
r=fiber radius

$$\tau_i = \frac{nP_{max}\coth(nL/r)}{2A}$$

Pmax=peak load
A=cross-section area of fiber
L=bead length

$$\bar{\tau}_i = \frac{P_{max}}{S_f L}$$

Sf=circumference of fiber

		Fiber Diameter	Fiber Radius, r	Bead Diameter D	Bead Radius, R	Bead Length L	Peak Load, g	*n*	ncoth(nL/r)	A, mm^2	Pmax/2A, kgf/mm^2	Pmax/2A, Mpa	IFSS(Shear Lag), Mpa		IFSS(imbedded length), Mpa	
1	1BA	0.032604293	0.016	0.187727825	0.094	0.278452815	9.05	0.080	0.091	0.0008345	5.422497319	53.19469869	4.834679128		3.114307814	
2	1BB	0.037059538	0.019	0.287970838	0.144	0.389226407	9.78	0.074	0.081	0.0010781	4.535646448	44.49469166	3.586908109		2.118243645	
3	1BC	0.034831916	0.017	0.225799919	0.113	0.310247064	4.65	0.077	0.088	0.0009524	2.441173112	23.94790823	2.099429901		1.344334274	
4	1BD	0.031794249	0.016	0.183475091	0.092	0.268934791	7.33	0.080	0.091	0.0007935	4.618566367	45.30813606	4.130608163		2.678229428	
5	1BE	0.035844471	0.018	0.23835561	0.119	0.329080599	5.38	0.077	0.086	0.0010086	2.667093627	26.16418849	2.25977845		1.424941958	
6	1BF	0.038072094	0.019	0.258404212	0.129	0.343863913	4.16	0.076	0.087	0.0011378	1.828016666	17.93284349				
7	1BG	0.034831916	0.017	0.333130822	0.167	0.444106926	8.07	0.070	0.074	0.0009524	4.236616562	41.56120848	3.083066143		1.629851313	
8	1BH	0.034831916	0.017	0.208788983	0.104	0.306196841	3.67	0.079	0.089	0.0009524	1.926689316	18.90082219				
9	1BI	0.036857027	0.018	0.196233293	0.098	0.273187525	7.82	0.082	0.097	0.0010664	3.666625005	35.9695913	3.506377707		2.426414239	
10	1BJ	0.036046983	0.018	0.236330498	0.118	0.328068044	9.78	0.077	0.087	0.00102	4.794036861	47.0295016	4.084067178		2.583719533	
11	1BK	0.034831916	0.017	0.259416768	0.130	0.368165249	9.78	0.074	0.081	0.0009524	5.134338288	50.3678586	4.084023855		2.382637976	
12	1BL	0.03908465	0.020	0.263669502	0.132	0.383961118	13.45	0.076	0.084	0.0011992	5.608028152	55.01475617	4.637982994		2.800065385	
13	1BM	0.036857027	0.018	0.287970838	0.144	0.407047388	9.78	0.074	0.079	0.0010664	4.585625646	44.98498759	3.574613161		2.036633766	
14	1BN	0.037869583	0.019	0.263669502	0.132	0.350141758	10.02	0.076	0.085	0.0011258	4.450276831	43.65721571	3.73194103		2.360873146	
15	1BO	0.03908465	0.020	0.189955448	0.095	0.275415148	7.09	0.084	0.101	0.0011992	2.956202201	29.00034359	2.936467081		2.057744968	
16	1BP	0.032604293	0.016	0.216079384	0.108	0.431348724	2.93	0.077	0.079	0.0008345	1.755570955	17.22215107				
17	1BQ	0.034831916	0.017	0.301741596	0.151	0.421830701	8.56	0.072	0.076	0.0009524	4.49385846	44.0847515	3.364617068		1.820109759	
18	1BR	0.035844471	0.018	0.257391657	0.129	0.345889024	8.56	0.075	0.084	0.0010086	4.243554173	41.62926644	3.490090261		2.157019953	
19	1BS	0.042324828	0.021	0.322802754	0.161	0.438841636	10.51	0.074	0.081	0.0014062	3.736910208	36.65908914	2.975789279		1.767824096	
20	1BT	0.035844471	0.018	0.277440259	0.139	0.360672337	15.4	0.074	0.082	0.0010086	7.634431573	74.89377373	6.118135102	StDev	3.721560345	StDev
	AVE	0.036	0.018	0.250	0.125	0.353	8.289	0.076	0.085	0.001	4.037	39.601	3.676	0.962851	2.260	0.61137

		Fiber Diameter	Fiber Radius, r	Bead Diameter D	Bead Radius, R	Bead Length L	Peak Load, g	*n*	ncoth(nL/r)	A, mm^2	Pmax/2A, kgf/mm^2	Pmax/2A, Mpa	IFSS(Shear Lag), Mpa		IFSS(imbedded length), Mpa	
1	2BA	0.030579182	0.015	0.21182665	0.106	0.322600243	10.76	0.077	0.083	0.000734	7.329272949	71.90016763	5.970046611		3.407697838	
2	2BB	0.035844471	0.018	0.236127987	0.118	0.355407047	9.54	0.101	0.105	0.0010086	4.729381637	46.39523386	4.855865547		2.339588716	
3	2BC	0.036857027	0.018	0.109761037	0.055	0.212029162	8.31	0.078	0.109	0.0010664	3.896375165	38.22344037	4.179454781		3.322190138	
4	2BD	0.037869583	0.019	0.230052653	0.115	0.328068044	7.58	0.073	0.086	0.0011258	3.366576684	33.02611727	2.833559327		1.906137015	
5	2BE	0.035844471	0.018	0.28473066	0.142	0.396516808	14.18	0.078	0.083	0.0010086	7.029625955	68.96063062	5.713880712		3.116964152	
6	2BF	0.035844471	0.018	0.225799919	0.113	0.342851357	13.2	0.077	0.085	0.0010086	6.543798491	64.1946632	5.470058628		3.355716298	
7	2BG	0.032806804	0.016	0.218307007	0.109	0.310044552	6.36	0.075	0.084	0.0008449	3.763826584	36.92313879	3.110430463		1.953477624	
8	2BH	0.034831916	0.017	0.253138923	0.127	0.348116646	7.09	0.075	0.083	0.0009524	3.722132767	36.51412244	3.013866801		1.826768197	
9	2BI	0.036046983	0.018	0.265897124	0.133	0.360874848	11.25	0.085	0.091	0.00102	5.514612953	54.09835307	4.912997634		2.701881831	
10	2BJ	0.034629405	0.017	0.161401377	0.081	0.262656946	9.54	0.082	0.097	0.0009414	5.067090636	49.70815914	4.811984952		3.276829304	
11	2BK	0.035844471	0.018	0.187727825	0.094	0.287970838	12.96	0.066	0.084	0.0010086	6.424820337	63.0274875	5.283831143		3.922596796	
12	2BL	0.03381936	0.017	0.441879303	0.221	0.560145808	24.69	0.075	0.076	0.0008978	13.74961907	134.8837631	10.27884049		4.071870651	
13	2BM	0.035844471	0.018	0.25617659	0.128	0.355609559	16.14	0.078	0.086	0.0010086	8.001280882	78.49256546	6.729682487		3.95591802	
14	2BN	0.034831916	0.017	0.212029162	0.106	0.304981774	12.22	0.074	0.086	0.0009524	6.415297942	62.93407281	5.433099557		3.593844795	
15	2BO	0.036857027	0.018	0.272985014	0.136	0.37019036	17.6	0.079	0.086	0.0010664	8.252250651	80.95457889	6.922358302		4.030014595	
16	2BP	0.037059538	0.019	0.224787363	0.112	0.300526529	15.89	0.075	0.089	0.0010781	7.369266059	72.29250004	6.461899115		4.457387974	
17	2BQ	0.035844471	0.018	0.259416768	0.130	0.371202916	14.91	0.076	0.082	0.0010086	7.391517841	72.51079002	5.979234557		3.500930124	
18	2BR	0.035844471	0.018	0.251113811	0.126	0.383758607	10.27	0.074	0.080	0.0010086	5.091273523	49.94539326	4.011423237		2.332542113	
19	2BS	0.032604293	0.016	0.251113811	0.126	0.363710004	28.85	0.073	0.079	0.0008345	17.28608261	169.5764704				
20	2BT	0.033616849	0.017	0.265897124	0.133	0.37545565	19.8	0.076	0.081	0.0008871	11.15967464	109.4764082	8.895608822	StDev	4.901047402	StDev
	AVE	0.035	0.018	0.241	0.121	0.346	13.557	0.077	0.087	0.001	7.105	69.702	5.519	1.879164	3.262	0.88632

		Fiber Diameter	Fiber Radius, r	Bead Diameter D	Bead Radius, R	Bead Length L	Peak Load, g	*n*	ncoth(nL/r)	A, mm^2	Pmax/2A, kgf/mm^2	Pmax/2A, Mpa	IFSS(Shear Lag), Mpa		IFSS(imbedded length), Mpa	
1	3BA	0.034831916	0.017	0.389226407	0.195	0.527339004	21.76	0.068	0.070	0.0009524	11.42	112.0659103	7.857547758		3.701101494	
2	3BB	0.034831916	0.017	0.190968003	0.095	0.294451195	13.2	0.081	0.092	0.0009524	6.93	67.98115885	6.257965883		4.020893852	
3	3BC	0.035844471	0.018	0.297488862	0.149	0.416565411	16.38	0.072	0.078	0.0010086	8.12	79.65974115	6.184020553		3.427266452	
4	3BD	0.034629405	0.017	0.244633455	0.122	0.379708384	17.11	0.075	0.081	0.0009414	9.09	89.15163553	7.232231877		4.06531458	
5	3BE	0.035844471	0.018	0.265694613	0.133	0.383961118	22.25	0.074	0.081	0.0010086	11.03	108.2069133	8.750178009		5.050797379	
6	3BF	0.032604293	0.016	0.262656946	0.131	0.376468206	10.02	0.073	0.078	0.0008345	6.00	58.89622994	4.60399204		2.550374669	
7	3BG	0.036857027	0.018	0.177197246	0.089	0.275415148	5.38	0.084	0.099	0.0010664	2.52	24.74634286	2.448194566		1.655821471	
8	3BH	0.034831916	0.017	0.223572296	0.112	0.30599433	5.62	0.077	0.088	0.0009524	2.95	28.94349339	2.554279526		1.647346414	
9	3BI	0.036857027	0.018	0.21000405	0.105	0.30599433	7.09	0.080	0.092	0.0010664	3.32	32.61181615	3.000629144		1.964047167	
10	3BJ	0.038072094	0.019	0.229850142	0.115	0.332320778	15.65	0.079	0.089	0.0011378	6.88	67.46370209	6.031947196		3.864465567	
11	3BK	0.036857027	0.018	0.2509113	0.125	0.371202916	14.18	0.076	0.084	0.0010664	6.65	65.22363231	5.449509735		3.238052668	
12	3BL	0.035844471	0.018	0.365127582	0.183	0.502025111	25.43	0.069	0.072	0.0010086	12.61	123.6719913	8.919001672		4.415075123	
13	3BM	0.040097205	0.020	0.366140138	0.183	0.489469421	28.36	0.071	0.075	0.0012621	11.24	110.216692	8.318531415		4.514461112	
14	3BN	0.030579182	0.015	0.253138923	0.127	0.355407047	18.09	0.073	0.078	0.000734	12.32	120.8804863	9.388185083		5.200271632	
15	3BO	0.034629405	0.017	0.256379101	0.128	0.360672337	22.98	0.074	0.082	0.0009414	12.21	119.7372638				
16	3BP	0.034831916	0.017	0.254151478	0.127	0.368165249	12.22	0.075	0.081	0.0009524	6.42	62.93407281	5.122100048		2.977079352	
17	3BQ	0.035844471	0.018	0.202511138	0.101	0.303766707	19.8	0.080	0.091	0.0010086	9.82	96.2919948	8.806656195		5.681227693	
18	3BR	0.035844471	0.018	0.213041717	0.107	0.322600243	26.41	0.079	0.089	0.0010086	13.09	128.4379587		StDev		StDev
	AVE	0.036	0.018	0.258	0.129	0.371	16.774	0.076	0.083	0.001	8.478	83.173	6.308	2.322043	3.623	1.235111

		Fiber Diameter	Fiber Radius, r	Bead Diameter D	Bead Radius, R	Bead Length L	Peak Load, g	*n*	ncoth(nL/r)	A, mm^2	Pmax/2A, kgf/mm^2	Pmax/2A, Mpa	IFSS(Shear Lag), Mpa		IFSS(imbedded length), Mpa	
1	4BA	0.033616849	0.017	0.248886189	0.124	0.353381936	14.18	0.074	0.081	0.0008871	7.992130626	78.40280145	6.373558777		3.729187691	
2	4BB	0.032604293	0.016	0.206763872	0.103	0.311259619	16.38	0.078	0.086	0.0008345	9.814420561	96.2794657	8.28204111		5.042613526	
3	4BC	0.035844471	0.018	0.218307007	0.109	0.326042932	21.27	0.078	0.088	0.0010086	10.54443893	103.4409459	9.104579058		5.686039574	
4	4BD	0.03381936	0.017	0.223774808	0.112	0.336573512	25.92	0.077	0.084	0.0008978	14.43459402	141.6033673	11.93511098		7.1142486	
5	4BE	0.032806804	0.016	0.248886189	0.124	0.358444714	27.87	0.074	0.080	0.0008449	16.49337215	161.7999808	12.96171668		7.404405902	
6	4BF	0.031591738	0.016	0.273187525	0.137	0.38072094	27.14	0.072	0.076	0.0007835	17.3206093	169.9151772	12.98613881		7.049672246	
7	4BG	0.034831916	0.017	0.217294451	0.109	0.302754151	16.63	0.078	0.089	0.0009524	8.730475023	85.64595997	7.624937273		4.926791008	
8	4BH	0.036857027	0.018	0.216079384	0.108	0.321790198	13.69	0.079	0.090	0.0010664	6.418938149	62.96978324				
9	4BI	0.036046983	0.018	0.21526934	0.108	0.319562576	14.18	0.079	0.089	0.00102	6.95086326	68.18796858	6.07584327		3.845835997	
10	4BJ	0.032604293	0.016	0.23309032	0.117	0.341838801	14.91	0.075	0.082	0.0008345	8.933639229	87.63900083	7.175389023		4.179466568	
11	4BK	0.03381936	0.017	0.322802754	0.161	0.444106926	22.74	0.070	0.074	0.0008978	12.66368318	124.230732	9.166696559		4.73017151	
12	4BL	0.03381936	0.017	0.275212637	0.138	0.383758607	31.05	0.073	0.078	0.0008978	17.29144075	169.6290338	13.29054411		7.474419168	
13	4BM	0.034831916	0.017	0.350141758	0.175	0.468205751	34.23	0.069	0.073	0.0009524	17.97018401	176.2875051	12.83301333		6.557407197	
14	4BN	0.033616849	0.017	0.453624949	0.227	0.583232078	42.05	0.065	0.067	0.0008871	23.70021811	232.4991397	15.52195812		6.70049604	
15	4BO	0.032806804	0.016	0.382948562	0.191	0.511745646	24.94	0.067	0.069	0.0008449	14.75940802	144.7897927	10.03397487		4.641065772	
16	4BP	0.032604293	0.016	0.266707169	0.133	0.354394492	21.03	0.073	0.079	0.0008345	12.60056559	123.6115485	9.783102926		5.686131229	
17	4BQ	0.03381936	0.017	0.30072904	0.150	0.405022276	22.98	0.071	0.076	0.0008978	12.79733683	125.5418743	9.560132467		5.241373252	
18	4BR	0.036857027	0.018	0.248886189	0.124	0.345889024	34.47	0.076	0.086	0.0010664	16.16222045	158.5513826	13.55745996		8.44740973	
19	4BS	0.03381936	0.017	0.28999595	0.145	0.406237343	30.32	0.072	0.077	0.0008978	16.88491091	165.640976	12.68790252		6.894826269	
20	4BT	0.036046983	0.018	0.237343054	0.119	0.349129202	20.78	0.077	0.085	0.00102	10.18610286	99.92566905	8.498253846	StDev	5.158575723	StDev
	AVE	0.034	0.017	0.271	0.136	0.380	23.838	0.074	0.080	0.001	13.132	128.830	10.392	2.757317	5.816	1.365447

		Fiber Diameter	Fiber Radius, r	Bead Diameter D	Bead Radius, R	Bead Length L	Peak Load, g	*n*	ncoth(nL/r)	A, mm^2	Pmax/2A, kgf/mm^2	Pmax/2A, Mpa	IFSS(Shear Lag), Mpa		IFSS(imbedded length), Mpa	
1	5BA	0.033616849	0.017	0.257391657	0.129	0.355407047	21.76	0.074	0.081	0.0008871	12.26436971	120.3134668	9.706463799		5.690038602	
2	5BB	0.032806804	0.016	0.258404212	0.129	0.356419603	18.09	0.073	0.080	0.0008449	10.70560109	105.0219466	8.368531854		4.833396408	
3	5BC	0.032604293	0.016	0.237343054	0.119	0.329080599	19.07	0.075	0.082	0.0008345	11.42619048	112.0909286	9.246187235		5.552812157	
4	5BD	0.032604293	0.016	0.210814095	0.105	0.292223572	13.94	0.077	0.088	0.0008345	8.352443383	81.93746959	7.170644838		4.571009218	
5	5BE	0.030579182	0.015	0.287970838	0.144	0.381733495	9.29	0.070	0.075	0.000734	6.327968931	62.07737521				
6	5BF	0.032604293	0.016	0.203523694	0.102	0.296273795	6.36	0.078	0.088	0.0008345	3.810727397	37.38323577				
7	5BG	0.031794249	0.016	0.225799919	0.113	0.320575132	27.63	0.075	0.083	0.0007935	17.40941183	170.78633	14.1545618		8.469189456	
8	5BH	0.031591738	0.016	0.162413933	0.081	0.249898744	15.16	0.082	0.096	0.0007835	9.675034523	94.91208867	9.064609067		5.999305443	
9	5BI	0.03381936	0.017	0.229850142	0.115	0.335358445	58.68	0.076	0.084	0.0008978	32.67831702	320.57429	26.91392867		16.16422295	
10	5BJ	0.03381936	0.017	0.437626569	0.219	0.564398542	21.52	0.066	0.068	0.0008978	11.98427714	117.5657587	7.937834507		3.522332562	
11	5BK	0.03381936	0.017	0.656136087	0.328	0.795261239	15.65	0.061	0.062	0.0008978	8.715331653	85.49740351	5.266695815		1.817935623	
12	5BL	0.030579182	0.015	0.173957068	0.087	0.271162414	13.94	0.080	0.090	0.000734	9.495359192	93.14947368	8.375286226		5.252266813	
13	5BM	0.03381936	0.017	0.26164439	0.131	0.373430539	14.67	0.074	0.080	0.0008978	8.169579255	80.14357249	6.380152756		3.629060902	
14	5BN	0.036857027	0.018	0.262656946	0.131	0.376670717	18.09	0.075	0.083	0.0010664	8.482000811	83.20842796	6.865140615		4.07094997	
15	5BO	0.033616849	0.017	0.524098825	0.262	0.39327663	15.89	0.064	0.070	0.0008871	8.955920709	87.85758216	6.188362886		3.754984201	
16	5BP	0.037869583	0.019	0.228837586	0.114	0.337586067	16.87	0.079	0.089	0.0011258	7.49263175	73.50271747	6.522872593		4.122677914	
17	5BQ	0.03908465	0.020	0.22235723	0.111	0.131834751	22.98	0.080	0.162	0.0011992	9.581597542	93.99547188	15.25864179		13.93327655	
18	5BR	0.03381936	0.017	0.214864318	0.107	0.294248684	11	0.078	0.089	0.0008978	6.125792216	60.09402164				
19	5BS	0.031591738	0.016	0.252126367	0.126	0.355609559	34.47	0.073	0.079	0.0007835	21.99857784	215.8060486	17.00162922		9.585917875	
20	5BT	0.030579182	0.015	0.429323613	0.215	0.561158364	17.85	0.065	0.066	0.000734	12.15869165	119.2767651	7.868908946		3.249872163	
21	5BU	0.027339004	0.014	0.237343054	0.119	0.344876468	13.94	0.072	0.076	0.0005867	11.87948889	116.537786	8.816846393		4.619084294	
22	5BV	0.031591738	0.016	0.241595788	0.121	0.35236938	18.83	0.074	0.080	0.0007835	12.01720977	117.8888278	9.381589542	StDev	5.284671592	StDev
	AVE	0.033	0.017	0.283	0.141	0.367	19.349	0.074	0.084	0.001	11.350	111.346	10.026	5.149817	6.006	3.658921

Appendix C. 15-Days Microbond Data

Report Date: Feb 15, 2002

North Carolina State Univ.
College of Textiles
2401 Research Dr
Raleigh NC 27695-8301

Sample ID: CHRIS1A – CONTROL 15 DAYS
Method: Tensile microbond – 5lb
Data Path: C:\GRAD13

Test Date: Feb 15, 2002
Operator ID: GRAD

Sample Inputs:

Name	
Class/Project	
Type of Test	Straight
Grip Pressure	
Lab Conditions	70F, 65% R

	Denier	Adj gage len1	Peak Load	Elong @ Pk Ld	%Strn @ Pk Ld	Energy to Pk Ld	Fiber Modulus	Fiber Tenacity
	Denier	mm	Gm	mm	%	Gm-cm	Gm/Denier	Gm/Denier
1	7.00	50.044	11.00	0.4	0.76132	0.26	401.74	1.57
2	7.00	50.051	13.69	0.3	0.65339	0.30	734.15	1.96
3	7.00	50.124	8.80	0.4	0.88047	0.25	208.31	1.26
4	7.00	50.127	4.16	0.1	0.10768	0.01	551.45	0.59
5	7.00	50.102	9.78	0.1	0.17744	0.10	392.18	1.40
6	7.00	50.070	9.05	0.1	0.29803	0.08	528.79	1.29
7	7.00	50.041	9.78	0.5	0.95806	0.30	734.01	1.40
8	7.00	50.140	5.38	0.3	0.54458	0.09	154.44	0.77
9	7.00	50.054	6.60	0.5	0.95836	0.17	224.34	0.94
10	7.00	50.260	4.65	0.3	0.60644	0.04	-1105.83	0.66
11	7.00	50.146	10.51	0.2	0.41295	0.16	377.45	1.50
12	7.00	50.063	7.82	0.5	0.92592	0.21	360.84	1.12
13	7.00	50.283	4.89	-0.2	-0.48620	-0.01	******	0.70
14	7.00	50.178	7.58	0.1	0.16941	0.03	579.61	1.08
15	7.00	50.362	8.56	-0.2	-0.32859	0.04	488.85	1.22
16	7.00	50.029	3.42	0	0.03808	0.01	******	0.49
17	7.00	50.051	11.49	0.4	0.77882	0.20	512.64	1.64
18	7.00	50.130	30.56	0.6	1.13370	1.21	661.78	4.37
19	7.00	50.070	20.54	0.6	1.10188	0.63	637.79	2.93
20	7.00	50.063	15.89	0.3	0.55175	0.21	529.57	2.27
21	7.00	50.083	21.27	0.4	0.86218	0.48	436.97	3.04
Mean	7.00	50.118	10.734	0.271	0.529	0.227	389.952	1.533
Stdv	0.00	0.088	6.639	0.233	0.453	0.277	398.220	0.949

North Carolina State Univ.
College of Textiles
2401 Research Dr
Raleigh NC 27695-8301

Sample ID: CHRIS2A – HE/O2/AIR 30SEC 15 DAYS
Method: Tensile microbond – 5lb — Test Date: Feb 15, 2002
Data Path: C:\GRAD13 — Operator ID: GRAD

Sample Inputs:

Name	
Class/Project	
Type of Test	Straight
Grip Pressure	
Lab Conditions	70F, 65% R

	Denier	Adj gage len1	Peak Load	Elong @ Pk Ld	%Strn @ Pk Ld	Energy to Pk Ld	Fiber Modulus	Fiber Tenacity
	Denier	mm	Gm	mm	%	Gm-cm	Gm/Denier	Gm/Denier
1	7.00	50.133	6.60	-0.1	-0.10766	0.02	696.65	0.94
2	7.00	50.076	5.38	0.4	0.75100	0.09	267.10	0.77
3	7.00	50.076	13.45	0.4	0.73548	0.19	514.16	1.92
4	7.00	50.352	9.54	-0.2	-0.46031	0.05	461.61	1.36
5	7.00	50.273	3.42	0.1	0.13119	0.01	******	0.49
6	7.00	50.187	31.30	0.4	0.71487	0.90	460.09	4.47
7	7.00	50.076	15.16	0.1	0.18645	0.10	688.61	2.17
8	7.00	50.079	8.80	0	0.05072	0.05	462.78	1.26
9	7.00	50.102	31.05	0.4	0.74144	0.63	664.23	4.44
10	7.00	50.168	7.09	0.5	0.95563	0.19	347.49	1.01
11	7.00	50.156	19.80	0.3	0.63936	0.34	461.94	2.83
12	7.00	50.032	23.23	0.4	0.87746	0.57	379.59	3.32
13	7.00	50.060	21.27	0.2	0.42494	0.18	1003.09	3.04
14	7.00	50.140	7.82	0.2	0.37361	0.09	324.46	1.12
15	7.00	50.073	10.27	0.1	0.10779	0.07	******	1.47
16	7.00	50.568	8.80	0.1	0.26370	0.06	438.30	1.26
17	7.00	50.200	24.69	0.4	0.88569	0.80	392.71	3.53
18	7.00	50.054	18.58	0.3	0.61529	0.26	619.47	2.65
19	7.00	50.156	8.80	0.1	0.12661	0.02	965.58	1.26
20	7.00	50.038	19.80	0.3	0.63452	0.33	680.84	2.83
21	7.00	50.146	17.36	0.3	0.65283	0.37	474.42	2.48
22	7.00	50.025	9.78	0.2	0.32224	0.08	429.95	1.40
Mean	7.00	50.144	14.636	0.223	0.437	0.245	536.654	2.092
Stdv	0.00	0.124	8.148	0.182	0.368	0.261	197.482	1.164

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Sample ID: CHRIS3A – HE/O2/AIR 1MIN 15 DAYS
Method: Tensile microbond – 5lb　　　Test Date: Feb 15, 2002
Data Path: C:\GRAD13　　　Operator ID: GRAD

Sample Inputs:

Name	
Class/Project	
Type of Test	Straight
Grip Pressure	
Lab Conditions	70F, 65% R

	Denier	Adj gage len1	Peak Load	Elong @ Pk Ld	%Strn @ Pk Ld	Energy to Pk Ld	Fiber Modulus	Fiber Tenacity
	Denier	mm	Gm	mm	%	Gm-cm	Gm/Denier	Gm/Denier
1	7.00	50.016	10.76	0.1	0.15870	0.05	902.37	1.54
2	7.00	50.054	23.72	0.2	0.48208	0.42	1326.55	3.39
3	7.00	50.025	8.07	0.4	0.76161	0.13	308.72	1.15
4	7.00	50.038	11.25	0.4	0.88134	0.27	519.89	1.61
5	7.00	50.162	6.85	0.3	0.63151	0.07	312.70	0.98
6	7.00	50.010	15.89	0.4	0.86062	0.45	564.63	2.27
7	7.00	50.020	21.27	0.3	0.58394	0.36	621.30	3.04
8	7.00	50.210	22.25	0.5	1.01176	0.82	355.09	3.18
9	7.00	50.079	21.27	0.4	0.83337	0.53	341.05	3.04
10	7.00	50.019	14.43	0.6	1.11717	0.45	408.26	2.06
11	7.00	50.324	12.47	0.1	0.23344	0.07	771.10	1.78
12	7.00	50.044	21.52	0.3	0.53293	0.30	727.50	3.07
13	7.00	50.019	13.94	0.3	0.60547	0.19	481.48	1.99
14	7.00	50.035	6.60	0.4	0.82578	0.10	355.12	0.94
15	7.00	50.019	18.83	0.6	1.14256	0.55	362.37	2.69
16	7.00	50.022	12.71	0.1	0.28936	0.07	825.44	1.82
17	7.00	50.133	25.18	0.3	0.60165	0.40	693.84	3.60
18	7.00	50.070	19.56	1.6	3.15174	0.48	511.47	2.79
19	7.00	50.070	14.91	0.4	0.86874	0.28	449.35	2.13
20	7.00	50.054	12.22	0.6	1.17348	0.23	399.66	1.75
21	7.00	50.000	14.67	0.4	0.81280	0.31	396.55	2.10
Mean	7.00	50.068	15.637	0.414	0.836	0.311	554.021	2.234
Stdv	0.00	0.079	5.564	0.310	0.602	0.200	251.189	0.795

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Sample ID: CHRIS3A – HE/AIR 2MIN 15 DAYS
Method: Tensile microbond – 5lb — Test Date: Feb 15, 2002
Data Path: C:\GRAD13 — Operator ID: GRAD

Sample Inputs:

Name	
Class/Project	
Type of Test	Straight
Grip Pressure	
Lab Conditions	70F, 65% R

	Denier	Adj gage len1	Peak Load	Elong @ Pk Ld	%Strn @ Pk Ld	Energy to Pk Ld	Fiber Modulus	Fiber Tenacity
	Denier	mm	Gm	mm	%	Gm-cm	Gm/Denier	Gm/Denier
1	7.00	50.022	17.60	0.4	0.86898	0.42	639.53	2.51
2	7.00	50.000	13.94	0.4	0.82550	0.35	565.77	1.99
3	7.00	50.016	22.49	0.4	0.71097	0.43	523.38	3.21
4	7.00	50.060	17.60	0.4	0.89427	0.39	926.20	2.51
5	7.00	50.067	20.54	0.5	0.93073	0.63	611.98	2.93
6	7.00	50.022	14.91	0.4	0.70395	0.28	639.05	2.13
7	7.00	50.181	19.80	0.6	1.15153	0.44	700.15	2.83
8	7.00	50.073	13.69	0.7	1.31887	0.60	525.23	1.96
9	7.00	50.079	19.32	0.5	1.08125	0.42	448.90	2.76
10	7.00	50.079	7.58	0.2	0.31556	0.07	422.37	1.08
11	7.00	50.079	34.96	0.2	0.44380	0.50	929.01	4.99
12	7.00	50.000	34.96	0.7	1.32080	1.06	718.43	4.99
13	7.00	50.060	21.76	0.3	0.60887	0.30	627.20	3.11
14	7.00	50.035	17.11	0.5	0.98991	0.34	456.07	2.44
15	7.00	50.044	30.07	0.6	1.10593	0.92	760.27	4.30
16	7.00	50.117	35.94	0.8	1.66614	1.83	962.34	5.13
17	7.00	50.022	29.10	0.4	0.79340	0.62	786.14	4.16
18	7.00	50.006	26.65	0.3	0.65397	0.46	662.64	3.81
19	7.00	50.003	27.14	0.5	0.95532	0.66	479.56	3.88
20	7.00	50.051	15.40	0.6	1.13807	0.43	616.68	2.20
Mean	7.00	50.051	22.028	0.470	0.924	0.558	650.045	3.146
Stdv	0.00	0.045	7.969	0.163	0.318	0.371	160.698	1.138

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Sample ID: CHRIS3A – HE/AIR 4MIN 15 DAYS
Method: Tensile microbond – 5lb | Test Date: Feb 15, 2002
Data Path: C:\GRAD13 | Operator ID: GRAD
Sample Inputs:

Name	
Class/Project	
Type of Test	Straight
Grip Pressure	
Lab Conditions	70F, 65% R

	Denier	Adj gage len1	Peak Load	Elong @ Pk Ld	%Strn @ Pk Ld	Energy to Pk Ld	Fiber Modulus	Fiber Tenacity
	Denier	mm	Gm	mm	%	Gm-cm	Gm/Denier	Gm/Denier
1	7.00	50.013	20.05	0.5	1.05383	0.57	758.88	2.86
2	7.00	50.054	24.45	0.2	0.45671	0.34	814.00	3.49
3	7.00	50.035	13.69	0.2	0.48671	0.15	642.17	1.96
4	7.00	50.102	19.80	0.2	0.46323	0.26	627.72	2.83
5	7.00	50.022	10.76	0.5	0.48162	0.22	409.19	1.54
6	7.00	50.041	22.00	0.9	0.96477	1.11	591.28	3.14
7	7.00	50.063	17.36	0.3	1.82095	0.31	402.47	2.48
8	7.00	50.054	25.18	0.2	0.68493	0.36	1365.60	3.60
9	7.00	50.038	23.72	0.1	0.49072	0.19	1081.28	3.39
10	7.00	50.060	17.60	0.2	0.25840	0.21	774.44	2.51
11	7.00	50.057	38.14	0.6	0.35054	1.17	532.92	5.45
12	7.00	50.073	28.61	0.6	1.14660	1.06	459.04	4.09
13	7.00	50.063	33.25	0.1	1.22520	0.37	2822.59	4.75
14	7.00	50.095	21.27	0.3	0.28539	0.43	927.46	3.04
15	7.00	50.073	24.94	0.2	0.50703	0.35	739.72	3.56
16	7.00	50.117	23.72	0.5	0.37410	0.50	492.27	3.39
17	7.00	50.063	37.65	0.7	0.93126	1.34	470.64	5.38
18	7.00	50.137	42.30	0.3	1.30500	0.66	957.56	6.04
19	7.00	50.067	30.56	0.2	0.65155	0.42	814.20	4.37
20	7.00	50.092	32.52	0.6	0.43609	0.92	654.39	4.65
21	7.00	50.038	31.05	0.5	1.25917	0.76	499.66	4.44
22	7.00	50.048	38.39	0.9	1.83000	1.87	353.94	5.48
Mean	7.00	50.064	26.228	0.400	0.794	0.617	781.428	3.747
Stdv	0.00	0.030	8.466	0.243	0.473	0.451	518.230	1.209

$$n = \left[\frac{E_m}{E_f(1+\nu_m)\ln(R/r)}\right]^{1/2}$$

Em = 1.4 Gpa, young's modulus of matrix
Vm= 0.4, possion's ratio
Ef= 90 Gpa, tensile modulus of Spectra
R=bead's radius
r=fiber radius

$$\tau_i = \frac{nP_{\max}\coth(nL/r)}{2A}$$

Pmax=peak load
A=cross-section area of fiber
L=bead length

$$\bar{\tau}_i = \frac{P_{\max}}{S_f L}$$

Sf=circumference of fiber

		Fiber Diameter	Fiber Radius, r	Bead Diameter D	Bead Radius, R	Bead Length L	Peak Load, g	n	ncoth(nL/r)	A, mm^2	Pmax/2A, kgf/mm^2	Pmax/2A, Mpa	IFSS(Shear Lag), Mpa		IFSS(imbedded length), Mpa	
1	15AA	0.030579182	0.015	0.197245849	0.099	0.295261239	11	0.077	0.085	0.000734	7.492751156	73.50388884	6.280967889		3.806271336	
2	15AB	0.031794249	0.016	0.218307007	0.109	0.325030377	13.69	0.076	0.083	0.0007935	8.625944551	84.62051604				
3	15AC	0.032604293	0.016	0.124341839	0.062	0.205751316	8.8	0.091	0.111	0.0008345	5.272704575	51.72523188	5.763092998		4.098308235	
4	15AD	0.034831916	0.017	0.141352774	0.071	0.240583232	4.16	0.089	0.106	0.0009524	2.183931214	21.42436521	2.264387457		1.550922061	
5	15AE	0.037869583	0.019	0.131834751	0.066	0.192993115	9.78	0.094	0.127	0.0011258	4.343683374	42.6115339	5.397085017		4.180669905	
6	15AF	0.038072094	0.019	0.212029162	0.106	0.288983394	9.05	0.080	0.096	0.0011378	3.976815103	39.01255616	3.735905775		2.569853034	
7	15AG	0.036857027	0.018	0.2509113	0.125	0.355407047	9.78	0.076	0.085	0.0010664	4.585625646	44.98498759	3.807808714		2.332554912	
8	15AH	0.035844471	0.018	0.230052653	0.115	0.333333333	5.38	0.077	0.087	0.0010086	2.667093627	26.16418849	2.264400089		1.406762261	
9	15AI	0.036046983	0.018	0.212029162	0.106	0.297286351	6.6	0.079	0.092	0.00102	3.235239599	31.73770047	2.911206331		1.92415214	
10	15AJ	0.034831916	0.017	0.22782503	0.114	0.31855002	4.65	0.077	0.087	0.0009524	2.441173112	23.94790823	2.077081413		1.309294411	
11	15AK	0.034831916	0.017	0.201498582	0.101	0.287970838	10.51	0.080	0.092	0.0009524	5.517576217	54.12742269	4.974755098		3.27352908	
12	15AL	0.031591738	0.016	0.188740381	0.094	0.276225192	7.82	0.079	0.090	0.0007835	4.990684035	48.95861038	4.383050101		2.799685931	
13	15AM	0.030579182	0.015	0.201498582	0.101	0.303766707	4.89	0.077	0.084	0.000734	3.330868468	32.67581968	2.757716861		1.644682924	
14	15AN	0.03381936	0.017	0.322600243	0.161	0.433576347	7.58	0.070	0.074	0.0008978	4.221227727	41.410244	3.069941407		1.615018858	
15	15AO	0.035844471	0.018	0.242608343	0.121	0.331308222	8.56	0.076	0.086	0.0010086	4.243554173	41.62926644	3.576276133		2.251949926	
16	15AP	0.034831916	0.017	0.258404212	0.129	0.356419603	3.42	0.074	0.082	0.0009524	1.79544345	17.61330025	1.442221416		0.860649898	
17	15AQ	0.037869583	0.019	0.171931956	0.086	0.275415148	11.49	0.086	0.101	0.0011258	5.103161755	50.06201682	5.063342537		3.441763656	
18	15AR	0.036857027	0.018	0.387201296	0.194	0.526326448	30.56	0.069	0.071	0.0010664	14.32890795	140.566587				
19	15AS	0.032604293	0.016	0.320575132	0.160	0.445119482	20.54	0.070	0.073	0.0008345	12.30697181	120.7313935				
20	15AT	0.034831916	0.017	0.30255164	0.151	0.431551235	15.89	0.072	0.076	0.0009524	8.341987259	81.83489501	6.212979732		3.302581403	
21	15AU	0.036857027	0.018	0.32381531	0.162	0.452409883	21.27	0.072	0.076	0.0010664	9.973032463	97.83544846		StDev		StDev
	AVE	0.035	0.017	0.232	0.116	0.332	10.734	0.078	0.089	0.001	5.666	55.580	3.881	1.5267	2.492	1.044203

		Fiber Diameter	Fiber Radius, r	Bead Diameter D	Bead Radius, R	Bead Length L	Peak Load, g	n	ncoth(nL/r)	A, mm^2	Pmax/2A, kgf/mm^2	Pmax/2A, Mpa	IFSS(Shear Lag), Mpa		IFSS(imbedded length), Mpa	
1	15BA	0.037869583	0.019	0.405832321	0.203	0.571688943	6.6	0.068	0.071	0.0011258	2.931320068	28.75624987	2.0323612		0.952429813	
2	15BB	0.040097205	0.020	0.26164439	0.131	0.355407047	5.38	0.077	0.088	0.0012621	2.131348236	20.9085262	1.834089637		1.179455324	
3	15BC	0.035844471	0.018	0.244633455	0.122	0.353381936	13.45	0.076	0.084	0.0010086	6.667734069	65.41047121	5.496847585		3.317379199	
4	15BD	0.036857027	0.018	0.254151478	0.127	0.374443094	9.54	0.076	0.083	0.0010664	4.473094955	43.88106151	3.648540642		2.15964121	
5	15BE	0.037869583	0.019	0.202511138	0.101	0.300526529	3.42	0.081	0.095	0.0011258	1.518956763	14.90096584				
6	15BF	0.035844471	0.018	0.161401377	0.081	0.250101256	31.3	0.086	0.103	0.0010086	15.5167343	152.2191635				
7	15BG	0.029566626	0.015	0.248886189	0.124	0.329080599	15.16	0.072	0.078	0.0006862	11.04577032	108.3590068	8.480219337		4.86782	
8	15BH	0.029566626	0.015	0.230862697	0.115	0.320575132	8.8	0.074	0.080	0.0006862	6.411792798	62.89968735	5.022539627		2.900617294	
9	15BI	0.030579182	0.015	0.127784528	0.064	0.204536249	31.05	0.088	0.107	0.000734	21.14999304	207.4814317				
10	15BJ	0.032806804	0.016	0.195018226	0.098	0.275415148	7.09	0.079	0.091	0.0008449	4.195838126	41.16117201	3.743245092		2.45151098	
11	15BK	0.032604293	0.016	0.222559741	0.111	0.326852977	19.8	0.076	0.084	0.0008345	11.86358529	116.3817717	9.731949776		5.804667053	
12	15BL	0.032806804	0.016	0.214054273	0.107	0.326042932	23.23	0.077	0.085	0.0008449	13.74743578	134.862345				
13	15BM	0.037869583	0.019	0.358647226	0.179	0.472458485	21.27	0.070	0.075	0.0011258	9.446845129	92.67355071	6.91732761		3.714092153	
14	15BN	0.036857027	0.018	0.160388821	0.080	0.251923856	7.82	0.087	0.105	0.0010664	3.666625005	35.9695913	3.766803155		2.631216084	
15	15BO	0.036046983	0.018	0.182462535	0.091	0.291008505	10.27	0.083	0.095	0.00102	5.034228892	49.38578543	4.694225642		3.058688172	
16	15BP	0.038882139	0.019	0.185500203	0.093	0.292223572	8.8	0.084	0.099	0.0011868	3.707513436	36.3707068	3.595033108		2.419672802	
17	15BQ	0.038882139	0.019	0.209801539	0.105	0.315512353	24.69	0.081	0.094	0.0011868	10.40210304	102.0446308	9.564737131		6.28773078	
18	15BR	0.036857027	0.018	0.241393277	0.121	0.361684893	18.58	0.077	0.085	0.0010664	8.711750972	85.46227703	7.246798482		4.354460924	
19	15BS	0.037667072	0.019	0.287970838	0.144	0.399756987	8.8	0.074	0.081	0.0011138	3.950565825	38.75505074	3.124171875		1.825845856	
20	15BT	0.034831916	0.017	0.381936006	0.191	0.498987444	19.8	0.068	0.071	0.0009524	10.39467261	101.9717383	7.232008674		3.559078527	
21	15BU	0.032604293	0.016	0.268934791	0.134	0.360672337	17.36	0.073	0.079	0.0008345	10.40160812	102.0397756	8.02682153		4.612129106	
22	15BV	0.031591738	0.016	0.301741596	0.151	0.388213852	9.78	0.070	0.075	0.0007835	6.241546018	61.22956644	4.578406075	StDev	2.491343861	StDev
	AVE	0.035	0.018	0.243	0.122	0.346	14.636	0.077	0.087	0.001	7.891	77.415	5.485	2.470242	3.255	1.475066

		Fiber Diameter	Fiber Radius, r	Bead Diameter D	Bead Radius, R	Bead Length L	Peak Load, g	n	ncoth(nL/r)	A, mm^2	Pmax/2A, kgf/mm^2	Pmax/2A, Mpa	IFSS(Shear Lag), Mpa		IFSS(imbedded length), Mpa	
1	15CA	0.034831916	0.017	0.210814095	0.105	0.31855002	10.76	0.079	0.088	0.0009524	5.65	55.41494464	4.874520421		3.029679109	
2	15CB	0.03381936	0.017	0.235115431	0.118	0.356622114	23.72	0.076	0.082	0.0008978	13.21	129.584563				
3	15CC	0.031591738	0.016	0.246861077	0.123	0.337586067	8.07	0.074	0.080	0.0007835	5.15	50.52378335	4.049514271		2.364040253	
4	15CD	0.036857027	0.018	0.137100041	0.069	0.201498582	11.25	0.092	0.120	0.0010664	5.27	51.7465348	6.229664735		4.732597655	
5	15CE	0.037869583	0.019	0.256379101	0.128	0.360672337	6.85	0.076	0.085	0.0011258	3.04	29.84550176	2.53873467		1.566846948	
6	15CF	0.031591738	0.016	0.273187525	0.137	0.372215472	15.89	0.072	0.077	0.0007835	10.14	99.48239373	7.641718275		4.221777318	
7	15CG	0.032806804	0.016	0.236330498	0.118	0.339611179	21.27	0.075	0.082	0.0008449	12.59	123.483516				
8	15CH	0.032604293	0.016	0.263669502	0.132	0.349129202	22.25	0.073	0.080	0.0008345	13.33	130.7825465				
9	15CI	0.032604293	0.016	0.258404212	0.129	0.351154313	21.27	0.073	0.080	0.0008345	12.74	125.0222366				
10	15CJ	0.036857027	0.018	0.252126367	0.126	0.347104091	14.43	0.076	0.085	0.0010664	6.77	66.37355531	5.656124432		3.52391688	
11	15CK	0.036857027	0.018	0.245848522	0.123	0.367152693	12.47	0.077	0.084	0.0010664	5.85	57.35815902	4.825828706		2.878980955	
12	15CL	0.036857027	0.018	0.301539085	0.151	0.42709599	21.52	0.073	0.078	0.0010664	10.09	98.98537146	7.709528621		4.271061547	
13	15CM	0.035844471	0.018	0.214054273	0.107	0.315309842	13.94	0.079	0.089	0.0010086	6.91	67.79345492	6.056924829		3.853385203	
14	15CN	0.034831916	0.017	0.239368165	0.120	0.286755772	6.6	0.076	0.090	0.0009524	3.46	33.99057942	3.042188225		2.064399598	
15	15CO	0.034831916	0.017	0.264682058	0.132	0.376468206	18.83	0.074	0.080	0.0009524	9.89	96.97615311	7.788141481		4.486255604	
16	15CP	0.034831916	0.017	0.243620899	0.122	0.329080599	12.71	0.076	0.085	0.0009524	6.67	65.45761583	5.550801324		3.464218438	
17	15CQ	0.033616849	0.017	0.416565411	0.208	0.53908465	25.18	0.066	0.068	0.0008871	14.19	139.2230282	9.514626283		4.340913352	
18	15CR	0.034831916	0.017	0.324827866	0.162	0.443904415	19.56	0.071	0.075	0.0009524	10.27	100.7357172	7.507118816		3.952222481	
19	15CS	0.035844471	0.018	0.248886189	0.124	0.364925071	14.91	0.076	0.083	0.0010086	7.39	72.51079002	6.017668959		3.561157002	
20	15CU	0.03381936	0.017	0.150668287	0.075	0.244633455	12.22	0.086	0.102	0.0008978	6.81	66.75899495	6.792192395		4.614549733	
21	15CT	0.032604293	0.016	0.224584852	0.112	0.326042932	14.67	0.076	0.084	0.0008345	8.79	86.22831269	7.203674228	StDev	4.311415635	StDev
	AVE	0.035	0.017	0.250	0.125	0.350	15.637	0.076	0.085	0.001	8.486	83.251	6.059	1.90728	3.602	0.938941

		Fiber Diameter	Fiber Radius, r	Bead Diameter D	Bead Radius, R	Bead Length L	Peak Load, g	n	ncoth(nL/r)	A, mm^2	Pmax/2A, kgf/mm^2	Pmax/2A, Mpa	IFSS(Shear Lag), Mpa		IFSS(imbedded length), Mpa	
1	15DA	0.040097205	0.020	0.26690968	0.133	0.377480761	17.6	0.077	0.086	0.0012621	6.972440327	68.39963961	5.857621173		3.632813477	
2	15DB	0.03908465	0.020	0.275212637	0.138	0.374443094	13.94	0.075	0.084	0.0011992	5.812335497	57.01901123				
3	15DC	0.036857027	0.018	0.271162414	0.136	0.399756987	22.49	0.075	0.081	0.0010664	10.54506347	103.4470727	8.349924777		4.768836684	
4	15DD	0.040097205	0.020	0.32381531	0.162	0.44835966	17.6	0.073	0.079	0.0012621	6.972440327	68.39963961				
5	15DE	0.035844471	0.018	0.326852977	0.163	0.455650061	20.54	0.071	0.075	0.0010086	10.18254705	99.89078652	7.478148382		3.929037603	
6	15DF	0.038072094	0.019	0.207776428	0.104	0.301741596	14.91	0.081	0.094	0.0011378	6.55185781	64.27372512	6.067373305		4.054852457	
7	15DG	0.038882139	0.019	0.297286351	0.149	0.398744431	19.8	0.074	0.081	0.0011868	8.34190523	81.83409031	6.661112454		3.989879466	
8	15DH	0.037869583	0.019	0.221344674	0.111	0.325840421	13.69	0.079	0.090	0.0011258	6.080268444	59.64743344	5.391876116		3.466149799	
9	15DI	0.035844471	0.018	0.245646011	0.123	0.363912515	19.32	0.076	0.083	0.0010086	9.577741428	93.95764341	7.822683526		4.627296295	
10	15DJ	0.037869583	0.019	0.223572296	0.112	0.334345889	7.58	0.079	0.089	0.0011258	3.366576684	33.02611727				
11	15DK	0.035844471	0.018	0.341838801	0.171	0.473471041	34.96	0.070	0.074	0.0010086	17.33115116	170.0185928	12.53372544		6.435690961	
12	15DL	0.032806804	0.016	0.367962738	0.184	0.5	34.96	0.068	0.070	0.0008449	20.68921028	202.9611528	14.20854846		6.658506837	
13	15DM	0.034629405	0.017	0.256379101	0.128	0.371405427	21.76	0.074	0.081	0.0009414	11.5576407	113.3804552	9.167588913		5.285730056	
14	15DN	0.036857027	0.018	0.228837586	0.114	0.348116646	17.11	0.078	0.087	0.0010664	8.022500491	78.70072982	6.819400332		4.166239915	
15	15DO	0.036857027	0.018	0.342851357	0.171	0.454637505	30.07	0.071	0.075	0.0010664	14.09915779	138.3127379	10.38152808		5.606440601	
16	15DP	0.032604293	0.016	0.258404212	0.129	0.371405427	35.94	0.073	0.079	0.0008345	21.53420482	211.2505493	16.61613527		9.272447774	
17	15DQ	0.034831916	0.017	0.28999595	0.145	0.377075739	29.1	0.072	0.079	0.0009524	15.27701883	149.8675547	11.8380347		6.921917136	
18	15DR	0.034831916	0.017	0.31308222	0.157	0.40927501	26.65	0.071	0.076	0.0009524	13.99080934	137.2498396	10.47790877		5.840418708	
19	15DS	0.035844471	0.018	0.279465371	0.140	0.375658161	27.14	0.074	0.081	0.0010086	13.45444629	131.9881181	10.6403241		6.297007253	
20	15DT	0.034831916	0.017	0.244835966	0.122	0.334345889	15.4	0.075	0.084	0.0009524	8.084745361	79.31135199	6.685227241	StDev	4.131299982	StDev
	AVE	0.037	0.018	0.279	0.140	0.390	22.028	0.074	0.081	0.001	10.922	107.147	9.235	3.189334	5.240	1.53176

		Fiber Diameter	Fiber Radius, r	Bead Diameter D	Bead Radius, R	Bead Length L	Peak Load, g	n	ncoth(nL/r)	A, mm^2	Pmax/2A, kgf/mm^2	Pmax/2A, Mpa	IFSS(Shear Lag), Mpa		IFSS(imbedded length), Mpa	
1	15EA	0.03381936	0.017	0.26164439	0.131	0.363912515	20.05	0.074	0.080	0.0008978	11.16564854	109.5350122	8.778474409		5.089690326	
2	15EB	0.030579182	0.015	0.59072499	0.295	0.725597408	24.45	0.061	0.062	0.000734	16.65434234	163.3790984	10.06807595		3.442679857	
3	15EC	0.029566626	0.015	0.287970838	0.144	0.38618874	13.69	0.070	0.074	0.0006862	9.974709478	97.85189998	7.201370892		3.745772784	
4	15ED	0.032806804	0.016	0.235115431	0.118	0.317537465	19.8	0.075	0.084	0.0008449	11.71757333	114.9493943	9.631005957		5.93807458	
5	15EE	0.032604293	0.016	0.209801539	0.105	0.288983394	10.76	0.077	0.088	0.0008345	6.447079685	63.24585171	5.561318102		3.567828355	
6	15EF	0.029566626	0.015	0.173957068	0.087	0.248886189	22	0.079	0.091	0.0006862	16.029482	157.2492184	14.31186621		9.340270904	
7	15EG	0.033616849	0.017	0.161401377	0.081	0.23835561	17.36	0.084	0.101	0.0008871	9.784422008	95.9853761	9.713176905		6.768722359	
8	15EH	0.032604293	0.016	0.283718104	0.142	0.381733495	25.18	0.072	0.077	0.0008345	15.08712514	148.0046976	11.37290035		6.320625016	
9	15EI	0.03381936	0.017	0.204738761	0.102	0.316322398	23.72	0.079	0.087	0.0008978	13.20943558	129.584563	11.31680983		6.927215757	
10	15EJ	0.032806804	0.016	0.208991495	0.104	0.328068044	17.6	0.077	0.085	0.0008449	10.41562074	102.1772394	8.662938603		5.108861971	
11	15EK	0.034831916	0.017	0.237343054	0.119	0.35236938	38.14	0.076	0.083	0.0009524	20.02286935	196.4243484				
12	15EL	0.031591738	0.016	0.180437424	0.090	0.287970838	28.61	0.080	0.089	0.0007835	18.25875579	179.1183943				
13	15EM	0.037869583	0.019	0.23309032	0.117	0.336371	33.25	0.078	0.089	0.0011258	14.76763519	144.8705012	12.82931084		8.15496199	
14	15EN	0.034831916	0.017	0.179222357	0.090	0.267922236	21.27	0.082	0.097	0.0009524	11.1663983	109.5423673	10.57678789		7.120667868	
15	15EO	0.034831916	0.017	0.248886189	0.124	0.354394492	24.94	0.075	0.083	0.0009524	13.09308762	128.4431895	10.60562889		6.312065314	
16	15EP	0.038072094	0.019	0.204536249	0.102	0.30072904	23.72	0.081	0.095	0.0011378	10.42321041	102.2516942	9.692504523		6.472497812	
17	15EQ	0.035844471	0.018	0.248886189	0.124	0.342851357	37.65	0.076	0.085	0.0010086	18.66469797	183.1006871				
18	15ER	0.032806804	0.016	0.316524909	0.158	0.433576347	42.3	0.070	0.074	0.0008449	25.03299756	245.5737061				
19	15ES	0.031591738	0.016	0.218307007	0.109	0.325840421	30.56	0.076	0.083	0.0007835	19.50323582	191.3267434				
20	15ET	0.030579182	0.015	0.351154313	0.176	0.469420818	32.52	0.067	0.070	0.000734	22.15129705	217.3042241				
21	15EU	0.032604293	0.016	0.345889024	0.173	0.451397327	31.05	0.069	0.072	0.0008345	18.60425876	182.5077784	13.09222437		6.591240987	
22	15EV	0.03381936	0.017	0.352166869	0.176	0.458687728	38.39	0.069	0.072	0.0008978	21.37901483	209.7281355		StDev		StDev
	AVE	0.033	0.017	0.261	0.130	0.363	26.228	0.075	0.083	0.001	15.161	148.734	10.228	2.249315	6.060	1.655946

Appendix D. 30-Days Microbond Data

Report Date: Mar 1, 2002

North Carolina State Univ.
College of Textiles
2401 Research Dr
Raleigh NC 27695-8301

Sample ID: CHRIS1A – CONTROL 30 DAYS
Method: Tensile microbond – 5lb
Data Path: C:\GRAD13

Test Date: Mar 1, 2002
Operator ID: GRAD

Sample Inputs:

Name	
Class/Project	
Type of Test	Straight
Grip Pressure	
Lab Conditions	70F, 65% R

	Denier	Adj gage len1	Peak Load	Elong @ Pk Ld	%Strn @ Pk Ld	Energy to Pk Ld	Fiber Modulus	Fiber Tenacity
	Denier	mm	Gm	mm	%	Gm-cm	Gm/Denier	Gm/Denier
1	7.00	50.000	5.38	0.3	0.64770	..02	359.82	0.77
2	7.00	50.000	7.09	0.5	0.91440	0.04	493.39	1.01
3	7.00	50.000	7.09	0.2	0.38735	0.04	598.17	1.01
4	7.00	50.000	7.34	0.3	0.57150	0.09	366.88	1.05
5	7.00	50.000	8.56	0.3	0.50165	0.05	453.20	1.22
6	7.00	50.060	9.54	0.3	0.62155	0.12	528.94	1.36
7	7.00	50.067	15.90	0.3	0.66197	0.25	332.71	2.27
8	7.00	50.019	20.79	0.3	0.56350	0.31	550.53	2.97
9	7.00	50.032	21.77	0.4	0.71506	0.43	479.29	3.11
10	7.00	50.000	8.81	0.5	0.93345	0.14	641.20	1.26
11	7.00	50.019	33.02	0.3	0.52050	0.43	945.78	4.72
12	7.00	50.000	17.12	0.2	0.41910	0.19	670.70	2.45
13	7.00	50.000	10.76	0.3	0.66040	0.10	550.32	1.54
14	7.00	50.102	35.47	0.7	1.30844	1.60	768.07	5.07
15	7.00	50.048	9.05	0.5	1.04041	0.08	367.23	1.29
16	7.00	50.041	14.43	0.3	0.56468	0.10	1078.60	2.06
17	7.00	50.063	12.72	0.1	0.20294	0.07	944.60	1.82
18	7.00	50.054	13.94	0.3	0.53917	0.21	472.21	1.99
19	7.00	50.076	13.45	0.2	0.38676	0.14	523.60	1.92
20	7.00	50.000	14.43	0.2	0.48260	0.19	428.03	2.06
21	7.00	50.013	10.52	0.3	0.69832	0.13	375.31	1.50
Mean	7.00	50.028	14.151	0.324	0.635	0.236	568.028	2.021
Stdv	0.00	0.032	8.006	0.134	0.248	0.341	209.545	1.145

North Carolina State Univ.
College of Textiles
2401 Research Dr
Raleigh NC 27695-8301

Sample ID: CHRIS2A – HE/O2/AIR 30SEC 30 DAYS
Method: Tensile microbond – 5lb — Test Date: Mar 1, 2002
Data Path: C:\GRAD13 — Operator ID: GRAD

Sample Inputs:

Name	
Class/Project	
Type of Test	Straight
Grip Pressure	
Lab Conditions	70F, 65% R

	Denier	Adj gage len1	Peak Load	Elong @ Pk Ld	%Strn @ Pk Ld	Energy to Pk Ld	Fiber Modulus	Fiber Tenacity
	Denier	mm	Gm	mm	%	Gm-cm	Gm/Denier	Gm/Denier
1	7.00	50.000	12.48	0.3	0.62865	0.11	1048.23	1.78
2	7.00	50.000	14.19	0.3	0.59690	0.23	536.56	2.03
3	7.00	50.394	8.81	0.1	0.18901	0.04	739.54	1.26
4	7.00	50.000	14.19	0.3	0.52705	0.18	522.80	2.03
5	7.00	50.251	17.86	0.4	0.89088	0.44	355.55	2.55
6	7.00	50.010	28.62	0.3	0.58205	0.39	927.03	4.09
7	7.00	50.314	14.1/	-0.2	-0.40386	0.07	830.67	2.03
8	7.00	50.333	15.41	-0.2	-0.35324	0.12	751.84	2.20
9	7.00	50.025	16.88	0.3	0.57061	0.20	550.60	2.41
10	7.00	50.000	21.77	0.5	0.92075	0.48	497.91	3.11
11	7.00	50.013	15.90	0.3	0.50009	0.18	619.27	2.27
12	7.00	50.016	21.53	0.4	0.88237	0.37	660.59	3.08
13	7.00	50.006	21.04	0.4	0.88889	0.34	550.39	3.01
14	7.00	50.025	24.71	0.4	0.85047	0.55	479.55	3.53
15	7.00	50.022	22.75	0.3	0.61568	0.29	1234.02	3.25
16	7.00	50.010	22.99	0.3	0.67297	0.30	1081.87	3.28
17	7.00	50.000	21.77	0.2	0.38100	0.21	928.66	3.11
18	7.00	50.000	14.19	0.1	0.24130	0.10	678.73	2.03
19	7.00	50.124	8.56	0.1	0.27238	0.06	424.37	1.22
Mean	7.00	50.081	17.981	0.242	0.498	0.245	706.220	2.541
Stdv	0.00	0.133	5.506	0.189	0.381	0.151	244.049	0.775

North Carolina State Univ.
College of Textiles
2401 Research Dr
Raleigh NC 27695-8301

Sample ID: CHRIS3A – HE/O2/AIR 1MIN 30 DAYS
Method: Tensile microbond – 5lb
Data Path: C:\GRAD13

Test Date: Mar 1, 2002
Operator ID: GRAD

Sample Inputs:

Name	
Class/Project	
Type of Test	Straight
Grip Pressure	
Lab Conditions	70F, 65% R

	Denier	Adj gage len1	Peak Load	Elong @ Pk Ld	%Strn @ Pk Ld	Energy to Pk Ld	Fiber Modulus	Fiber Tenacity
	Denier	mm	Gm	mm	%	Gm-cm	Gm/Denier	Gm/Denier
1	7.00	50.010	7.34	0.3	0.57139	0.10	582.80	1.05
2	7.00	50.000	18.10	0.3	0.53975	0.19	817.14	2.59
3	7.00	50.000	15.90	0.3	0.55880	0.16	746.86	2.27
4	7.00	50.003	9.30	0.4	0.82545	0.08	609.32	1.33
5	7.00	50.010	13.94	0.4	0.83660	0.33	366.95	1.99
6	7.00	50.222	14.43	0.2	0.44253	0.17	583.47	2.06
7	7.00	50.013	17.12	0.3	0.56357	0.26	637.37	2.45
8	7.00	50.200	16.39	0.3	0.60574	0.24	491.13	2.34
9	7.00	50.010	14.43	0.3	0.60948	0.21	352.27	2.06
10	7.00	50.000	33.51	1.1	2.18296	1.78	363.42	4.79
11	7.00	50.000	30.09	0.6	1.11760	0.58	742.29	4.30
12	7.00	50.000	15.66	0.3	0.62865	0.18	761.98	2.24
13	7.00	50.000	17.12	0.5	1.09855	0.22	550.32	2.45
14	7.00	50.000	17.86	0.3	0.50165	0.25	489.17	2.55
15	7.00	50.003	10.27	0.3	0.60321	0.10	361.17	1.47
16	7.00	50.346	11.01	-0.3	-0.55496	0.02	1200.61	1.57
17	7.00	50.010	12.48	0.2	0.39363	0.07	963.24	1.78
18	7.00	50.038	9.30	0.1	0.26650	0.05	786.77	1.33
19	7.00	50.086	13.45	0.2	0.32330	0.11	620.17	1.92
20	7.00	50.013	25.20	0.5	1.00332	0.56	471.82	3.60
21	7.00	50.019	30.58	0.6	1.29862	1.01	550.53	4.37
Mean	7.00	50.047	16.832	0.343	0.686	0.317	621.371	2.405
Stdv	0.00	0.093	7.242	0.256	0.511	0.405	213.284	1.035

North Carolina State Univ.
College of Textiles
2401 Research Dr
Raleigh NC 27695-8301

Sample ID: CHRIS3A – HE/AIR 2MIN 30 DAYS
Method: Tensile microbond – 5lb Test Date: Mar 1, 2002
Data Path: C:\GRAD13 Operator ID: GRAD

Sample Inputs:

Name	
Class/Project	
Type of Test	Straight
Grip Pressure	
Lab Conditions	70F, 65% R

	Denier	Adj gage len1	Peak Load	Elong @ Pk Ld	%Strn @ Pk Ld	Energy to Pk Ld	Fiber Modulus	Fiber Tenacity
	Denier	mm	Gm	mm	%	Gm-cm	Gm/Denier	Gm/Denier
1	7.00	50.184	19.81	0.2	0.41124	0.22	773.28	2.83
2	7.00	50.003	26.91	0.3	0.60321	0.41	733.80	3.84
3	7.00	50.000	19.57	0.4	0.83185	0.34	550.32	2.80
4	7.00	50.010	17.86	0.4	0.84439	0.30	450.35	2.55
5	7.00	50.000	20.06	0.3	0.60181	0.13	1034.60	2.87
6	7.00	50.000	28.38	0.5	0.90805	0.53	842.68	4.05
7	7.00	50.000	20.03	0.5	0.90497	0.21	724.81	2.90
8	7.00	50.000	35.96	0.6	1.17475	1.03	550.32	5.14
9	7.00	50.000	19.57	0.3	0.69850	0.32	450.26	2.80
10	7.00	50.000	27.40	0.5	1.03505	0.40	917.20	3.91
11	7.00	50.003	24.46	0.4	0.87153	0.30	738.28	3.49
12	7.00	50.006	22.02	0.4	0.84301	0.32	525.37	3.15
13	7.00	50.003	19.81	0.6	1.25578	0.33	434.49	2.83
14	7.00	50.000	23.48	0.5	0.92710	0.53	408.30	3.35
15	7.00	50.000	29.11	0.2	0.41910	0.31	1018.09	4.16
16	7.00	50.000	18.35	0.2	0.41275	0.15	790.20	2.62
17	7.00	50.000	30.82	0.5	0.94615	0.62	715.41	4.40
18	7.00	50.000	28.38	0.7	1.49860	0.73	521.35	4.05
19	7.00	50.000	31.80	0.8	1.62560	0.95	444.94	4.54
20	7.00	50.000	28.38	0.8	1.59385	0.78	398.10	4.05
21*	7.00	50.006	10.27	0.4	0.71991	0.04	835.78	1.47
Mean	7.00	50.010	24.608	0.455	0.920	0.446	651.108	3.517
Stdv	0.00	0.041	5.263	0.182	0.364	0.256	204.364	0.749

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Sample ID: CHRIS3A – HE/AIR 4MIN 30 DAYS
Method: Tensile microbond – 5lb Test Date: Mar 1, 2002
Data Path: C:\GRAD13 Operator ID: GRAD
Sample Inputs:

Name	
Class/Project	
Type of Test	Straight
Grip Pressure	
Lab Conditions	70F, 65% R

	Denier	Adj gage len1	Peak Load	Elong @ Pk Ld	%Strn @ Pk Ld	Energy to Pk Ld	Fiber Modulus	Fiber Tenacity
	Denier	mm	Gm	mm	%	Gm-cm	Gm/Denier	Gm/Denier
1	7.00	50.000	15.41	0.4	0.71120	0.10	884.44	2.20
2	7.00	50.003	22.50	0.3	0.51432	0.29	639.60	3.21
3	7.00	50.003	23.24	0.5	1.00180	0.40	535.07	3.32
4	7.00	50.010	13.94	0.4	0.83804	0.20	366.95	1.99
5	7.00	50.013	37.43	0.5	0.96987	1.01	1206.77	5.35
6	7.00	50.010	19.08	0.2	0.48886	0.14	978.53	2.73
7	7.00	50.016	17.37	0.2	0.43801	0.15	754.96	2.48
8	7.00	50.000	28.62	0.6	1.14300	0.71	598.88	4.09
9	7.00	50.000	47.94	1.2	2.38125	2.84	440.25	6.85
10	7.00	50.000	30.58	0.6	1.19380	1.00	453.20	4.37
11	7.00	50.073	39.63	0.3	0.53119	0.53	1013.35	5.66
12	7.00	50.000	34.00	0.4	0.74930	0.53	928.66	4.86
13	7.00	50.006	29.84	0.3	0.60952	0.47	722.39	4.26
14	7.00	50.022	44.03	0.6	1.22501	1.40	566.76	6.29
15	7.00	50.010	10.76	0.2	0.41267	0.09	440.34	1.54
16	7.00	50.019	57	1.1	2.13914	3.26	448.58	8.14
17	7.00	50.032	27.15	0.3	0.69806	0.24	1292.87	3.88
18	7.00	50.000	36.45	0.5	0.91931	0.54	990.57	5.21
19	7.00	50.006	29.11	0.5	1.09452	0.47	770.54	4.16
20	7.00	50.003	27.15	0.8	1.56691	0.50	600.39	3.88
21	7.00	50.006	32.78	0.8	1.62396	0.98	495.35	4.68
22	7.00	50.006	41.10	0.9	1.78903	1.98	448.46	5.87
Mean	7.00	50.011	30.232	0.527	1.047	0.810	708.042	4.319
Stdv	0.00	0.016	11.596	0.281	0.552	0.861	267.771	1.656

$$n = \left[\frac{E_m}{E_f (1+\nu_m)\ln(R/r)} \right]^{1/2}$$

Em = 1.4 Gpa, young's modulus of matrix
Vm= 0.4, possion's ratio
Ef= 90 Gpa, tensile modulus of Spectra
R=bead's radius
r=fiber radius

$$\tau_i = \frac{nP_{max}\coth(nL/r)}{2A}$$

Pmax=peak load
A=cross-section area of fiber
L=bead length

$$\bar{\tau}_i = \frac{P_{max}}{S_f L}$$

Sf=circumference of fiber

		Fiber Diameter	Fiber Radius, r	Bead Diameter D	Bead Radius, R	Bead Length L	Peak Load, g	*n*	ncoth(nL/r)	A, mm^2	Pmax/2A, kgf/mm^2	Pmax/2A, Mpa	IFSS(Shear Lag), Mpa		IFSS(imbedded length), Mpa	
1	30AA	0.044957473	0.022	0.230660186	0.115	0.326245443	5.38	0.082	0.099	0.0015866	1.695426026	16.63212931	1.646765164		1.14597539	
2	30AB	0.044957473	0.022	0.272782503	0.136	0.400769542	7.09	0.079	0.089	0.0015866	2.234306789	21.9185496	1.943670974		1.229388077	
3	30AC	0.043742406	0.022	0.310652086	0.155	0.448562171	7.09	0.075	0.082	0.001502	2.360158946	23.15315926	1.909618981		1.128912506	
4	30AD	0.043539895	0.022	0.247468611	0.124	0.388213852	7.34	0.080	0.090	0.0014881	2.466162325	24.19305241	2.171666017		1.356678734	
5	30AE	0.046375051	0.023	0.406439854	0.203	0.551235318	8.56	0.072	0.076	0.0016883	2.535159678	24.86991644	1.901977229		1.046144538	
6	30AF	0.042324828	0.021	0.269947347	0.135	0.390846497	9.54	0.077	0.087	0.0014062	3.392019352	33.27570984	2.889763523		1.807715895	
7	30AG	0.040704739	0.020	0.340218712	0.170	0.476711219	15.9	0.072	0.077	0.0013006	6.112340342	59.96205876	4.640661056		2.559977445	
8	30AH	0.044957473	0.022	0.286755772	0.143	0.413527744	20.79	0.077	0.087	0.0015866	6.55165559	64.27174134	5.588736377		3.493713658	
9	30AI	0.043539895	0.022	0.253138923	0.127	0.376873228	21.77	0.079	0.090	0.0014881	7.314489621	71.75514318	6.478908659		4.144910205	
10	30AJ	0.04090725	0.020	0.292628595	0.146	0.40927501	8.81	0.075	0.083	0.0013136	3.353325321	32.8961214	2.729089045		1.643992212	
11	30AK	0.046375051	0.023	0.684892669	0.342	0.884568651	33.02	0.064	0.065	0.0016883	9.779319226	95.93512161	6.255160446		2.514782835	
12	30AL	0.043539895	0.022	0.303766707	0.152	0.442891859	17.12	0.076	0.083	0.0014881	5.752138829	56.42848191	4.680005667		2.773690812	
13	30AM	0.044957473	0.022	0.267112191	0.134	0.392264075	10.76	0.079	0.090	0.0015866	3.390852052	33.26425863	2.983198249		1.906212033	
14	30AN	0.042122317	0.021	0.335965978	0.168	0.461320373	35.47	0.073	0.079	0.0013928	12.73318466	124.9125415	9.910357335		5.702767479	
15	30AO	0.045159984	0.023	0.264277035	0.132	0.376873228	9.05	0.079	0.091	0.0016009	2.826450421	27.72747863	2.534187511		1.66126484	
16	30AP	0.049210207	0.025	0.410692588	0.205	0.579384366	14.43	0.072	0.077	0.001901	3.795389071	37.23276679	2.878881594		1.581188803	
17	30AQ	0.049210207	0.025	0.36836776	0.184	0.507695423	12.72	0.074	0.082	0.001901	3.34562363	32.82056781	2.676815049		1.590625843	
18	30AR	0.046577562	0.023	0.334750911	0.167	0.482381531	13.94	0.075	0.082	0.001703	4.092697258	40.1493601	3.295074651		1.938361214	
19	30AS	0.047792629	0.024	0.350141758	0.175	0.509113001	13.45	0.075	0.081	0.001793	3.750600414	36.79339006	2.986094605		1.72697694	
20	30AT	0.047792629	0.024	0.326245443	0.163	0.466990684	14.43	0.076	0.084	0.001793	4.023878362	39.47424673	3.326099597		2.019931099	
21	30AU	0.050627785	0.025	0.32199271	0.161	0.479546375	10.52	0.077	0.086	0.0020121	2.614196575	25.6452684	2.210201159	StDev	1.353740942	StDev
	AVE	0.045	0.023	0.328	0.164	0.465	14.151	0.076	0.084	0.002	4.482	43.967	3.602	2.028921	2.111	1.140124

		Fiber Diameter	Fiber Radius, r	Bead Diameter D	Bead Radius, R	Bead Length L	Peak Load, g	*n*	ncoth(nL/r)	A, mm^2	Pmax/2A, kgf/mm^2	Pmax/2A, Mpa	IFSS(Shear Lag), Mpa		IFSS(imbedded length), Mpa	
1	30BA	0.046375051	0.023	0.350141758	0.175	0.509113001	12.48	0.074	0.080	0.0016883	3.696120652	36.2589436	2.9037425		1.651411711	
2	30BB	0.046375051	0.023	0.244835966	0.122	0.385378696	14.19	0.082	0.093	0.0016883	4.202560261	41.22711616	3.84607754		2.480559538	
3	30BC	0.044957473	0.022	0.251923856	0.126	0.374038072	8.81	0.080	0.092	0.0015866	2.776338901	27.23588462	2.511569517		1.636807359	
4	30BD	0.046375051	0.023	0.364317537	0.182	0.542932361	14.19	0.073	0.078	0.0016883	4.202560261	41.22711616	3.227789586		1.760725401	
5	30BE	0.047792629	0.024	0.265897124	0.133	0.420615634	17.86	0.080	0.091	0.001793	4.980351181	48.85724509	4.422894117		2.775712528	
6	30BF	0.046375051	0.023	0.371405427	0.186	0.54272985	28.62	0.073	0.078	0.0016883	8.476199765	83.1515197	6.487203977		3.552555599	
7	30BG	0.047792629	0.024	0.244633455	0.122	0.385378696	14.19	0.082	0.095	0.001793	3.95695315	38.8177104	3.683379369		2.406983619	
8	30BH	0.049210207	0.025	0.237748076	0.119	0.385378696	15.41	0.084	0.097	0.001901	4.053149382	39.76139544	3.857795529		2.538628243	
9	30BI	0.045159984	0.023	0.248886189	0.124	0.392466586	16.88	0.081	0.091	0.0016009	5.271876587	51.71710931	4.710372189		2.975468364	
10	30BJ	0.047792629	0.024	0.347306602	0.174	0.493722155	21.77	0.075	0.082	0.001793	6.070674424	59.5533161	4.881155384		2.882400041	
11	30BK	0.043944917	0.022	0.339003645	0.170	0.507695423	15.9	0.074	0.079	0.001516	5.244211221	51.44571207	4.053731261		2.226509677	
12	30BL	0.049210207	0.025	0.407857432	0.204	0.594775213	21.53	0.072	0.077	0.001901	5.662836223	55.55242335	4.276319054		2.298133959	
13	30BM	0.047792629	0.024	0.32199271	0.161	0.478128797	21.04	0.076	0.084	0.001793	5.867110238	57.55635144	4.827501825		2.876598674	
14	30BN	0.050627785	0.025	0.34163629	0.171	0.514580802	24.71	0.076	0.083	0.0020121	6.140379977	60.23712757	5.028156996		2.963258932	
15	30BO	0.044957473	0.022	0.338801134	0.169	0.503442689	22.75	0.074	0.080	0.0015866	7.16932009	70.33103009	5.606926882		3.140283322	
16	30BP	0.047792629	0.024	0.358647226	0.179	0.524503848	22.99	0.074	0.080	0.001793	6.410877584	62.8907091	5.0426317		2.865290994	
17	30BQ	0.046375051	0.023	0.440259214	0.220	0.614418793	21.77	0.070	0.074	0.0016883	6.447479696	63.24977582	4.664069484		2.386980663	
18	30BR	0.045159984	0.023	0.388011341	0.194	0.541312272	14.19	0.072	0.077	0.0016009	4.431749334	43.47546097	3.330512355		1.813510624	
19	30BS	0.043539895	0.022	0.257391657	0.129	0.383961118	8.56	0.079	0.089	0.0014881	2.876069415	28.21424096	2.523273676	STDEV	1.599699843	STDEV
	AVE	0.047	0.023	0.322	0.161	0.479	17.781	0.077	0.084	0.002	5.155	50.566	4.204	1.042691	2.465	0.570813

		Fiber Diameter	Fiber Radius, r	Bead Diameter D	Bead Radius, R	Bead Length L	Peak Load, g	*n*	ncoth(nL/r)	A, mm^2	Pmax/2A, kgf/mm^2	Pmax/2A, Mpa	IFSS(Shear Lag), Mpa		IFSS(imbedded length), Mpa	
1	30CA	0.050627785	0.025	0.279667882	0.140	0.410692588	7.34	0.081	0.093	0.0020121	1.82	17.89318156	1.670196893		1.102883479	
2	30CB	0.047792629	0.024	0.258606723	0.129	0.392264075	18.1	0.081	0.093	0.001793	5.05	49.51378142	4.618694045		3.016327417	
3	30CC	0.045159984	0.023	0.337586067	0.169	0.500607533	15.9	0.074	0.080	0.0016009	4.97	48.71457572	3.899097041		2.197279609	
4	30CD	0.043539895	0.022	0.230457675	0.115	0.351761847	9.3	0.082	0.094	0.0014881	3.12	30.65332253	2.888217916		1.897082425	
5	30CE	0.043742406	0.022	0.246051033	0.123	0.359862292	13.94	0.080	0.093	0.001502	4.64	45.52257264	4.212701549		2.766706722	
6	30CF	0.047792629	0.024	0.337586067	0.169	0.464155529	14.43	0.075	0.084	0.001793	4.02	39.47424673	3.312150094		2.032269247	
7	30CG	0.046375051	0.023	0.302349129	0.151	0.444309437	17.12	0.077	0.085	0.0016883	5.07	49.73983289	4.25201413		2.595811698	
8	30CH	0.046577562	0.023	0.265694613	0.133	0.37545565	16.39	0.080	0.093	0.001703	4.81	47.20573974	4.392125954		2.928079865	
9	30CI	0.049210207	0.025	0.265897124	0.133	0.399351964	14.43	0.081	0.094	0.001901	3.80	37.23276679	3.48887027		2.294006676	
10	30CJ	0.06055083	0.030	0.597610369	0.299	0.786148238	33.51	0.070	0.074	0.0028781	5.82	57.10887137	4.197916117		2.199324129	
11	30CK	0.047792629	0.024	0.413527744	0.207	0.573714054	30.09	0.072	0.076	0.001793	8.39	82.31324214	6.2956844		3.428507791	
12	30CL	0.046375051	0.023	0.267314702	0.134	0.400769542	15.66	0.080	0.090	0.0016883	4.64	45.49800134	4.116947119		2.632400785	
13	30CM	0.044957473	0.022	0.271567436	0.136	0.413527744	17.12	0.079	0.088	0.0015866	5.40	52.92603231	4.648610822		2.87697825	
14	30CN	0.042122317	0.021	0.330498177	0.165	0.46982584	17.86	0.073	0.079	0.0013928	6.41	62.89647565	4.981709642		2.819497184	
15	30CO	0.046375051	0.023	0.282705549	0.141	0.43600648	10.27	0.078	0.087	0.0016883	3.04	29.838089	2.598173638		1.586837525	
16	30CP	0.047792629	0.024	0.406439854	0.203	0.572296476	11.01	0.072	0.077	0.001793	3.07	30.11860405	2.312103402		1.257606256	
17	30CQ	0.047792629	0.024	0.34872418	0.174	0.499392467	12.48	0.075	0.082	0.001793	3.48	34.13988906	2.787261269		1.633619996	
18	30CR	0.046375051	0.023	0.277237748	0.139	0.427501013	9.3	0.079	0.088	0.0016883	2.75	27.01988586	2.376224462		1.465550417	
19	30CS	0.044957473	0.022	0.371202916	0.186	0.509113001	13.45	0.073	0.078	0.0015866	4.24	41.58032328	3.250973797		1.835885396	
20	30CU	0.047792629	0.024	0.299513973	0.150	0.433171324	25.2	0.078	0.088	0.001793	7.03	68.93631446	6.043146225		3.802938338	
21	30CT	0.047792629	0.024	0.398136898	0.199	0.558323208	30.58	0.072	0.077	0.001793	8.53	83.65367048	6.481853922	StDev	3.580389233	StDev
	AVE	0.047	0.024	0.323	0.162	0.466	16.832	0.077	0.085	0.002	4.767	46.761	3.944	1.118871	2.379	0.657052

		Fiber Diameter	Fiber Radius, r	Bead Diameter D	Bead Radius, R	Bead Length L	Peak Load, g	*n*	ncoth(nL/r)	A, mm^2	Pmax/2A, kgf/mm^2	Pmax/2A, Mpa	IFSS(Shear Lag), Mpa		IFSS(imbedded length), Mpa	
1	30DA	0.046375051	0.023	0.426083435	0.213	0.579586877	19.81	0.071	0.075	0.0016883	5.866999209	57.55526224	4.317615941		2.302612693	
2	30DB	0.045159984	0.023	0.420413123	0.210	0.573714054	26.91	0.071	0.075	0.0016009	8.404395672	82.44712154	6.149958531		3.244918479	
3	30DC	0.045159984	0.023	0.366950182	0.183	0.531591738	19.57	0.073	0.078	0.0016009	6.112003839	59.95875766	4.659145871		2.546819611	
4	30DD	0.043539895	0.022	0.360064804	0.180	0.499189955	17.86	0.073	0.078	0.0014881	6.000770998	58.86756349	4.587504409		2.567246684	
5	30DE	0.04090725	0.020	0.417577967	0.209	0.561158364	20.06	0.069	0.072	0.0013136	7.635380924	74.90308686	5.418448812		2.730137774	
6	30DF	0.046375051	0.023	0.504860267	0.252	0.698865938	28.38	0.068	0.070	0.0016883	8.405120522	82.45423232	5.81218838		2.735731556	
7	30DG	0.047792629	0.024	0.302349129	0.151	0.421425678	20.3	0.078	0.088	0.001793	5.660757502	55.53203109	4.906471481		3.148860965	
8	30DH	0.047792629	0.024	0.254556501	0.127	0.392466586	35.96	0.082	0.094	0.001793	10.02762757	98.3710265	9.2015058		5.989567145	
9	30DI	0.044957473	0.022	0.499189955	0.250	0.659578777	19.57	0.068	0.071	0.0015866	6.167190953	60.50014324	4.26571958		2.06187163	
10	30DJ	0.043742406	0.022	0.251721345	0.126	0.362899959	27.4	0.080	0.092	0.001502	9.121065601	89.47765355	8.220501926		5.392626441	
11	30DK	0.044957473	0.022	0.261441879	0.131	0.400769542	24.46	0.079	0.089	0.0015866	7.708200853	75.61745037	6.758614616		4.241302168	
12	30DL	0.043742406	0.022	0.329080599	0.165	0.485216687	22.02	0.074	0.080	0.001502	7.330141042	71.90868362	5.747734167		3.241292918	
13	30DM	0.040704739	0.020	0.325030377	0.163	0.468205751	19.81	0.073	0.078	0.0013006	7.615437873	74.70744553	5.854693449		3.247447351	
14	30DN	0.046577562	0.023	0.198258404	0.099	0.317942487	23.48	0.088	0.105	0.001703	6.893581895	67.62603839	7.116033051		4.953499627	
15	30DO	0.047792629	0.024	0.344471446	0.172	0.499392467	29.11	0.075	0.082	0.001793	8.117470486	79.63238547	6.516004404		3.810471	
16	30DP	0.047792629	0.024	0.378290806	0.189	0.539894694	18.35	0.073	0.079	0.001793	5.116990155	50.19767342	3.957191699		2.2218025	
17	30DQ	0.042122317	0.021	0.345889024	0.173	0.490684488	30.82	0.073	0.078	0.0013928	11.06390615	108.5369193	8.43750689		4.658621383	
18	30DR	0.045159984	0.023	0.317739976	0.159	0.464155529	28.38	0.075	0.083	0.0016009	8.863498669	86.95092194	7.179234341		4.22994232	
19	30DS	0.04090725	0.020	0.344673957	0.172	0.4963548	31.8	0.072	0.077	0.0013136	12.10394384	118.739689	9.104916788		4.892985962	
20	30DT	0.04799514	0.024	0.365532604	0.183	0.520251114	28.38	0.074	0.080	0.0018083	7.847263175	76.98165175	6.175151311	StDev	3.550924769	StDev
	AVE	0.045	0.022	0.351	0.175	0.498	24.622	0.074	0.081	0.002	7.803	76.548	6.219	1.602459	3.588	1.138109

		Fiber Diameter	Fiber Radius, r	Bead Diameter D	Bead Radius, R	Bead Length L	Peak Load, g	*n*	ncoth(nL/r)	A, mm^2	Pmax/2A, kgf/mm^2	Pmax/2A, Mpa	IFSS(Shear Lag), Mpa		IFSS(imbedded length), Mpa	
1	30EA	0.044957473	0.022	0.18691778	0.093	0.316524909	15.41	0.088	0.104	0.0015866	4.856229165	47.63961203	4.970019409		3.383235403	
2	30EB	0.043539895	0.022	0.219319563	0.110	0.345889024	22.5	0.083	0.096	0.0014881	7.559761896	74.1612642	7.098566451		4.66764397	
3	30EC	0.047792629	0.024	0.345889024	0.173	0.506277845	23.24	0.075	0.081	0.001793	6.480591347	63.57460111	5.1789612		3.000721172	
4	30ED	0.042324828	0.021	0.2490887	0.125	0.385378696	13.94	0.079	0.089	0.0014062	4.956472721	48.6229974	4.305913483		2.67004899	
5	30EE	0.043539895	0.022	0.237748076	0.119	0.364317537	37.43	0.081	0.092	0.0014881	12.5760839	123.3713831	11.40744556		7.372108771	
6	30EF	0.04799514	0.024	0.454232483	0.227	0.630012151	19.08	0.070	0.074	0.0018083	5.275749873	51.75510625				
7	30EG	0.044957473	0.022	0.336168489	0.168	0.493519644	17.37	0.074	0.080	0.0015866	5.473894065	53.69890077	4.308202972		2.445867044	
8	30EH	0.049210207	0.025	0.263061968	0.132	0.420413123	28.62	0.081	0.092	0.001901	7.527653168	73.84627757	6.805661628		4.321928095	
9	30EI	0.045159984	0.023	0.253138923	0.127	0.39509923	47.94	0.080	0.091	0.0016009	14.97237936	146.8790415	13.30386481		8.394163571	
10	30EJ	0.052045362	0.026	0.565411098	0.283	0.740988254	30.58	0.068	0.071	0.0021263	7.190742769	70.54118656	5.015991827		2.477327814	
11	30EK	0.049210207	0.025	0.372620494	0.186	0.54981774	39.63	0.074	0.080	0.001901	10.42351136	102.2546464	8.149105366		4.576036663	
12	30EL	0.047792629	0.024	0.542932361	0.271	0.700486027	34	0.068	0.070	0.001793	9.481071678	93.00931316	6.532527347		3.172910943	
13	30EM	0.028959093	0.014	0.337586067	0.169	0.487849332	29.84	0.067	0.069	0.0006583	22.66361911	222.3301034				
14	30EN	0.047792629	0.024	0.347509113	0.174	0.494937222	44.03	0.075	0.082	0.001793	12.27798782	120.4470605	9.864327705		5.815365443	
15	30EO	0.049210207	0.025	0.499189955	0.250	0.670716889	10.76	0.069	0.073	0.001901	2.830103008	27.76331051				
16	30EP	0.049210207	0.025	0.213851762	0.107	0.352976914	57	0.087	0.103	0.001901	14.99218136	147.0732992				
17	30EQ	0.050627785	0.025	0.656743621	0.328	0.856419603	27.15	0.066	0.067	0.0020121	6.746714544	66.18526967	4.460399291		1.956291962	
18	30ES	0.042324828	0.021	0.386796274	0.193	0.541514783	36.45	0.071	0.075	0.0014062	12.96007394	127.1383253	9.502214003		4.968569558	
19	30ET	0.049210207	0.025	0.441676792	0.221	0.613203726	29.11	0.071	0.075	0.001901	7.656533323	75.1105919	5.661793587		3.013849708	
20	30EU	0.044957473	0.022	0.240583232	0.120	0.36836776	27.15	0.081	0.094	0.0015866	8.555913866	83.93351503	7.850566901		5.121836266	
21	30EV	0.043539895	0.022	0.279870393	0.140	0.420615634	32.78	0.077	0.085	0.0014881	11.01373311	108.0447218	9.237131341		5.592107652	
22	30EW	0.047792629	0.024	0.374240583	0.187	0.527541515	41.1	0.073	0.079	0.001793	11.46094253	112.4318462	8.931700066	StDev	5.092882093	StDev
	AVE	0.046	0.023	0.355	0.177	0.508	30.232	0.075	0.083	0.002	9.451	92.719	7.366	2.616518	4.336	1.756812

Appendix E. Compiled Microbond data for graphs

Data collected from Microbond tests to generate comparison curves between Control / 30sec He-air plasma / 1min He-air plasma / 2min He-O2-air plasma / 4min He-O2-air plasma treated UHMPE fibers over a thirty day time study.

0 DAYS				
		IFSS(Shear Lag), MPa	**SD**	**SD/(n)^-2**
Control	0 Days	3.76	1.30	0.298104
He/O2 30 sec.	0 Days	5.28	2.49	0.587155
He/O2 1.0 min.	0 Days	6.19	2.04	0.509988
He/Air 2.0 min.	0 Days	10.32	4.36	1.000716
He/Air 4.0 min.	0 Days	10.14	2.27	0.521082

3 DAYS				
Control	3 Days	3.68	0.96	0.233526
He/O2 30 sec.	3 Days	5.52	1.88	0.43111
He/O2 1.0 min.	3 Days	6.31	2.32	0.580511
He/Air 2.0 min.	3 Days	10.39	2.76	0.632572
He/Air 4.0 min.	3 Days	10.026	5.150	1.181449

15 DAYS				
Control	15 Days	3.88	1.53	0.370279
He/O2 30 sec.	15 Days	5.49	2.47	0.582242
He/O2 1.0 min.	15 Days	6.06	1.91	0.462583
He/Air 2.0 min.	15 Days	9.24	3.19	0.773527
He/Air 4.0 min.	15 Days	10.23	2.25	0.580771

30 DAYS				
Control		3.60	2.03	0.442747
He/O2 30 sec.	30 Days	4.20	1.04	0.23921
He/O2 1.0 min.	30 Days	3.94	1.12	0.244158
He/Air 2.0 min.	30 Days	6.22	1.60	0.358321
He/Air 4.0 min.	30 Days	7.37	2.62	0.616719

Control	0 Days	3.76	1.30	0.298104
Control	3 Days	3.68	0.96	0.233526
Control	15 Days	3.88	1.53	0.370279
Control	30 Days	3.60	2.03	0.442747

He/O2 30 sec.	0 Days	5.28	2.49	0.587155
He/O2 30 sec.	3 Days	5.52	1.88	0.43111
He/O2 30 sec.	15 Days	5.49	2.47	0.582242
He/O2 30 sec.	30 Days	4.20	1.04	0.23921

He/O2 1.0 min.	0 Days	6.19	2.04	0.509988
He/O2 1.0 min.	3 Days	6.31	2.32	0.580511
He/O2 1.0 min.	15 Days	6.06	1.91	0.462583
He/O2 1.0 min.	30 Days	3.94	1.12	0.244158

He/Air 2.0 min.	0 Days	10.32	4.36	1.000716
He/Air 2.0 min.	3 Days	10.39	2.76	0.632572
He/Air 2.0 min.	15 Days	9.24	3.19	0.773527
He/Air 2.0 min.	30 Days	6.22	1.60	0.358321

He/Air 4.0 min.	0 Days	10.14	2.27	0.521082
He/Air 4.0 min.	3 Days	10.026	5.150	1.181449
He/Air 4.0 min.	15 Days	10.23	2.25	0.580771
He/Air 4.0 min.	30 Days	7.37	2.62	0.616719

Appendix F. Random Order data for Epoxy bead placement

Each set of samples prepared for the Microbond test had five frames with four fibers hanging off each frame. Each fiber had five beads applied to it. Each of the five frames had a different fiber treatment:
1. Control, 2. He/O2/air 30sec, 3. He/O2/air 1min, 4. He/air 2min, 5. He/air 4min.
A random number generator was used (table below) to apply the beads to the five sets of fibers to ensure no bias during the Microbond testing.

Frame	Random Order	Frame	Random Order	Frame	Random Order	Frame	Random Order
4	-2.01468	1	-0.92649	2	-1.98165	2	-1.82127
1	-1.85763	4	-0.65821	4	-1.1789	5	-0.23193
3	-0.18745	5	-0.65389	1	0.09422	1	0.13823
5	0.87657	3	-0.4488	3	0.2498	4	0.2671
2	1.4978	2	0.47048	5	1.04751	3	1.384
2	-0.60411	4	-1.25992	1	-0.19002	5	-0.46324
4	-0.36742	1	-1.09858	3	-0.07863	1	0.33763
3	0.6108	2	0.10579	2	0.32124	3	0.70703
1	0.62671	3	0.81324	4	0.66857	4	0.96365
5	0.71128	5	0.83772	5	0.74887	2	1.4664
1	-2.40921	1	-1.83672	2	-0.34809	2	-1.32133
4	-2.21455	4	-0.31126	4	-0.24884	3	-0.96542
3	0.93066	3	-0.02517	3	-0.23031	4	-0.1672
5	1.31748	5	0.53554	5	0.46928	1	-0.12352
2	1.48191	2	1.21169	1	1.68994	5	0.41486
2	-2.39524	2	-1.68592	1	-1.25695	3	-1.09921
5	-1.90171	5	-1.5164	2	0.07928	1	-0.77541
1	0.72756	3	-0.25731	5	0.54662	4	-0.76795
3	1.24946	4	0.07416	4	1.47501	2	0.55889
4	1.46836	1	0.19021	3	1.53586	5	1.09178
3	-1.07659	3	0.12313	2	-1.27427	5	-2.40896
1	0.10829	2	0.43696	5	-1.12189	1	-0.79859
4	0.88234	4	0.7147	3	-0.39762	3	-0.42847
5	1.0191	1	0.76549	1	0.20849	4	-0.22523
2	1.4328	5	2.54009	4	0.85957	2	0.65959

Appendix G. Single fiber tensile data

Test Method: FiberTensNoSlackCp(3822)-5lb c

Sample I. D.	Spcmn No.	Denier Denier	Peak Load Gm	Elong @ Pk Ld mm	Break Load Gm	Elong @ Break mm	%Strn @ Break %	Fiber Modulus Gm/Denier	Fiber Tenacity Gm/Denier	Time @ Break Sec
CONTROL	1	8	281.03	4.6	279.07	4.56	4.56	1076.56	35.12	5.5
30 Days	2	8	297.64	4.7	297.64	4.69	4.69	1193.8	37.21	5.6
	3	8	314.99	4.8	314.75	4.81	4.81	1192.99	39.37	5.8
	4	8	266.36	4.3	160.55	2.22	2.22	1104.97	33.3	2.7
	5	8	271.25	4.3	271.25	4.35	4.35	1078.39	33.91	5.2
	6	8	263.68	4.4	263.68	4.38	4.38	1081.7	32.96	5.3
	7	8	275.69	4.7	275.45	4.67	4.67	1066.11	34.46	5.6
	8	8	268.6	4.5	268.6	4.46	4.46	1069.72	33.58	5.4
	9	8	282.78	5	282.78	5.01	5.01	1076.56	35.35	6
	10	8	252.23	4.4	252.23	4.42	4.42	1026.74	31.53	5.3
	11*	8	162.78	28.6	162.78	28.62	28.62	114.5	20.35	34.3
	12	8	274.71	4.2	274.71	4.23	4.23	1138.19	34.34	5.1
	13	8	290.85	4.7	290.85	4.66	4.66	1111.46	36.36	5.6
	14	8	287.91	5.2	287.91	5.19	5.19	1045.72	35.99	6.2
	15	8	301.11	4.8	301.11	4.78	4.78	1123.48	37.64	5.7
	16	8	275.45	5	275.45	4.99	4.99	1053.67	34.43	6
	17	8	270.32	4.8	270.32	4.78	4.78	982.62	33.79	5.7
	18	8	276.43	4.5	276.43	4.53	4.53	1109.4	34.55	5.4
	19	8	279.11	4.6	279.11	4.62	4.62	1110.64	34.89	5.5
	20	8	271.29	4.7	271.29	4.75	4.75	1123.5	33.91	5.7
	21	8	291.58	5.3	291.58	5.33	5.33	1069.15	36.45	6.4
	22	8	290.6	4.7	290.36	4.73	4.73	1136.26	36.33	5.7
He/O2/air										
30sec	1	8	252.47	4.6	250.76	4.62	4.62	972.64	31.56	5.6
30 Days	2	8	256.63	4.7	256.63	4.72	4.72	876.23	32.08	5.7
	3	8	251.5	4.5	251.5	4.53	4.53	893.5	31.44	5.4
	4	8	305.51	5	305.51	5	5	1000.93	38.19	6
	5	8	302.58	5.5	291.09	5.47	5.47	1045.72	37.82	6.6
	6	8	240.01	3.9	240.01	3.92	3.92	1003.18	30	4.7
	7	8	286.2	4.7	286.2	4.71	4.71	1075.12	35.78	5.7
	8	8	298.67	5.2	297.69	5.18	5.18	1077.13	37.33	6.2
	9	8	283.76	5.3	283.76	5.26	5.26	995.71	35.47	6.3
	10	8	271.05	4.8	271.05	4.83	4.83	986.17	33.88	5.8
	11	8	250.27	4.7	250.27	4.68	4.68	972.47	31.28	5.6
	12	8	282.78	4.6	282.78	4.62	4.62	1072.49	35.35	5.5
	13	8	276.18	4.6	275.94	4.58	4.58	1066.57	34.52	5.5
	14	8	229.25	4.7	229.25	4.68	4.68	907.39	28.66	5.6
	15	8	277.65	4.9	277.65	4.93	4.93	1056.57	34.71	5.9
	16	8	291.33	5	281.07	5.05	5.05	1038.45	36.42	6.1
	17	8	282.29	5.1	282.29	5.14	5.14	1013.37	35.29	6.2
	18	8	261.76	4.6	261.76	4.58	4.58	948.36	32.72	5.5
	19	8	253.21	4.7	253.21	4.74	4.74	986.05	31.65	5.7
	20	8	271.05	4.6	271.05	4.56	4.56	983.04	33.88	5.5
	21	8	253.45	4.5	253.45	4.51	4.51	990.4	31.68	5.4
	22	8	273.49	5	273.49	5	5	1036.25	34.19	6
He/O2/air										
1min	1	8	306.73	5.2	306.73	5.22	5.22	1070.53	38.34	6.3
30 Days	2	8	283.02	4.4	281.8	4.45	4.45	1075.44	35.38	5.3
	3	8	280.82	4.7	280.82	4.66	4.66	1033.36	35.1	5.6
	4	8	280.82	4.6	272.03	4.65	4.65	1105.92	35.1	5.6
	5	8	269.09	4.6	268.85	4.58	4.58	977.21	33.64	5.5
	6	8	281.8	5	281.31	4.96	4.96	979.27	35.23	6
	7	8	278.87	4.8	278.87	4.77	4.77	976.96	34.86	5.7
	8	8	292.31	5	292.31	5	5	923.75	36.54	6

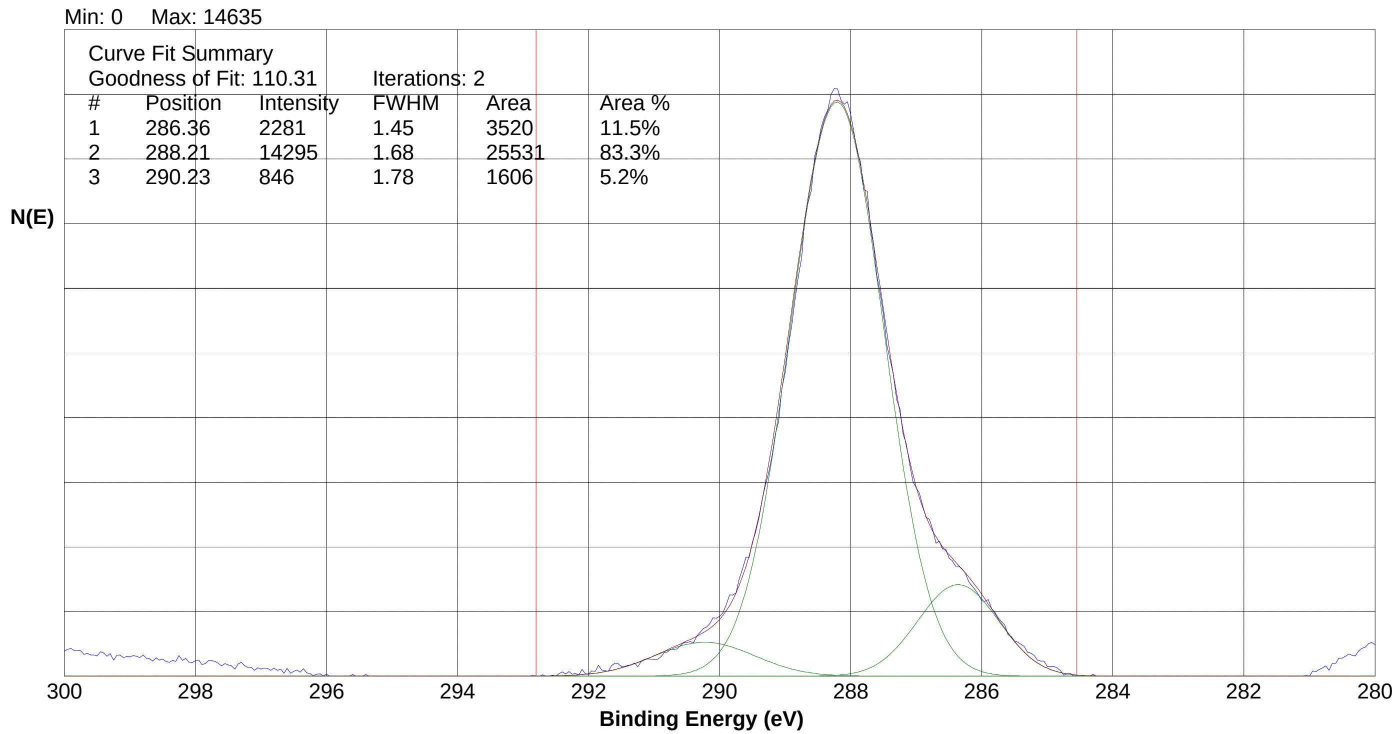
	9*	8	270.8	5.7	270.8	5.76	5.76	865.84	33.85	6.9
	10	8	280.58	4.9	280.34	4.88	4.88	951.7	35.07	5.9
	11	8	297.44	4.9	296.71	4.88	4.88	1056.74	37.18	5.9
	12	8	273.25	3.8	273.25	3.8	3.8	1070.24	34.16	4.6
	13	8	274.71	4.4	273.49	4.38	4.38	988.24	34.34	5.3
	14	8	283.51	5	283.51	5	5	932.82	35.44	6
	15	8	262.98	4.4	262.74	4.42	4.42	951.78	32.87	5.3
	16	8	272.76	5.2	272.76	5.18	5.18	874.38	34.09	6.2
	17	8	284.98	4.5	284.98	4.5	4.5	1026.12	35.62	5.4
	18	8	269.83	4.5	269.83	4.46	4.46	982.08	33.73	5.4
	19	8	306	4.4	306	4.42	4.42	1218.34	38.25	5.3
	20	8	271.05	4.8	271.05	4.77	4.77	860.28	33.88	5.7
	21	8	283.51	4.7	283.51	4.75	4.75	1069.75	35.44	5.7
	22	8	290.85	5	290.85	4.98	4.98	1046.1	36.36	6
	23	8	296.71	5.2	296.22	5.2	5.2	969.64	37.09	6.2
He/air 2min	1	8	284.74	4.6	279.85	4.65	4.65	1015.69	35.59	5.6
30 Days	2	8	294.27	4.7	294.27	4.68	4.68	1166.35	36.78	5.6
	3	8	253.7	5.1	250.27	5.11	5.11	1013.69	31.71	6.1
	4	8	233.65	4.4	233.65	4.36	4.36	920.4	29.21	5.2
	5	8	241.23	4.5	241.23	4.47	4.47	903.56	30.15	5.4
	6	8	262.49	4.6	258.58	4.66	4.66	1038.54	32.81	5.6
	7	8	276.09	5.6	264.61	5.61	5.61	974.46	34.51	6.7
	8	8	270.96	5.1	270.96	5.08	5.08	1009.79	33.87	6.1
	9	8	256.3	4.8	254.83	4.84	4.84	1008.84	32.04	5.8
	10*	8	296.61	5.5	296.61	5.49	5.49	1144.5	37.08	6.6
	11	8	231.87	4.2	231.13	4.19	4.19	1255.26	28.98	5
	12	8	284.4	4.4	284.4	4.42	4.42	1134.28	35.55	5.3
	13	8	285.86	4.7	285.62	4.66	4.66	1166.12	35.73	5.6
	14*	8	261.43	5.3	261.43	5.31	5.31	1140.99	32.68	6.4
	15	8	213.05	3.7	213.05	3.73	3.73	924.63	26.63	4.5
	16	8	273.16	4.9	273.16	4.94	4.94	1230.08	34.14	5.9
	17	8	300.77	4.9	300.77	4.92	4.92	1140.99	37.6	5.9
	18*	8	139.51	3.9	139.51	3.87	3.87	679.39	17.44	4.6
	19	8	274.62	4.8	274.62	4.78	4.78	1187.55	34.33	5.7
	20	8	243.35	4.6	242.62	4.65	4.65	915.67	30.42	5.6
He/air 4min	1	8	291.24	4.8	291.24	4.79	4.79	1147.09	36.4	5.8
30 Days	2	8	288.3	5.5	279.51	5.58	5.58	1036.93	36.04	6.7
	3	8	303.45	5	291.73	5.05	5.05	1065.9	37.93	6.1
	4	8	267.05	4.7	266.8	4.73	4.73	1023.64	33.38	5.7
	5	8	276.58	5.3	276.58	5.27	5.27	970.62	34.57	6.3
	6	8	258.99	4.2	258.99	4.19	4.19	1296.2	32.37	5
	7	8	279.75	4.6	279.26	4.57	4.57	1085.37	34.97	5.5
	8	8	246.04	4.3	246.04	4.35	4.35	1000.17	30.75	5.2
	9	8	285.13	4.8	284.88	4.77	4.77	1104.42	35.64	5.7
	10	8	277.8	4.8	277.8	4.83	4.83	1010.01	34.72	5.8
	11	8	284.15	5.5	284.15	5.47	5.47	1097.39	35.52	6.6
	12	8	299.79	4.8	299.54	4.84	4.84	1094.42	37.47	5.8
	13	8	274.87	4.6	274.62	4.63	4.63	1076.2	34.36	5.6
	14	8	285.37	5	285.37	5	5	998.49	35.67	6
	15	8	258.01	5	258.01	5	5	917.74	32.25	6
	16	8	272.67	4.7	267.29	4.67	4.67	1018.5	34.08	5.6
	17	8	255.08	4.8	254.34	4.84	4.84	987.68	31.88	5.8
	18	8	281.46	4.5	281.46	4.48	4.48	1145.4	35.18	5.4
	19	8	250.43	5	250.43	5	5	903.87	31.3	6
	20	8	247.75	4.1	247.75	4.12	4.12	1028.25	30.97	4.9
	21	8	292.21	4.6	291.97	4.63	4.63	1092.01	36.53	5.6
	22	8	246.77	4.2	246.77	4.23	4.23	1047.29	30.85	5.1
	23	8	259.96	4.7	259.96	4.68	4.68	1067.67	32.5	5.6

* Exclude due to slippage or error

AugerScan 2
PE - t=0,30s,1min, Sample #: 4, Angle: 45

F:\chris\0Days XPS\0 control.ASN
Acquired: Wednesday, May 08, 2002 18:13:37

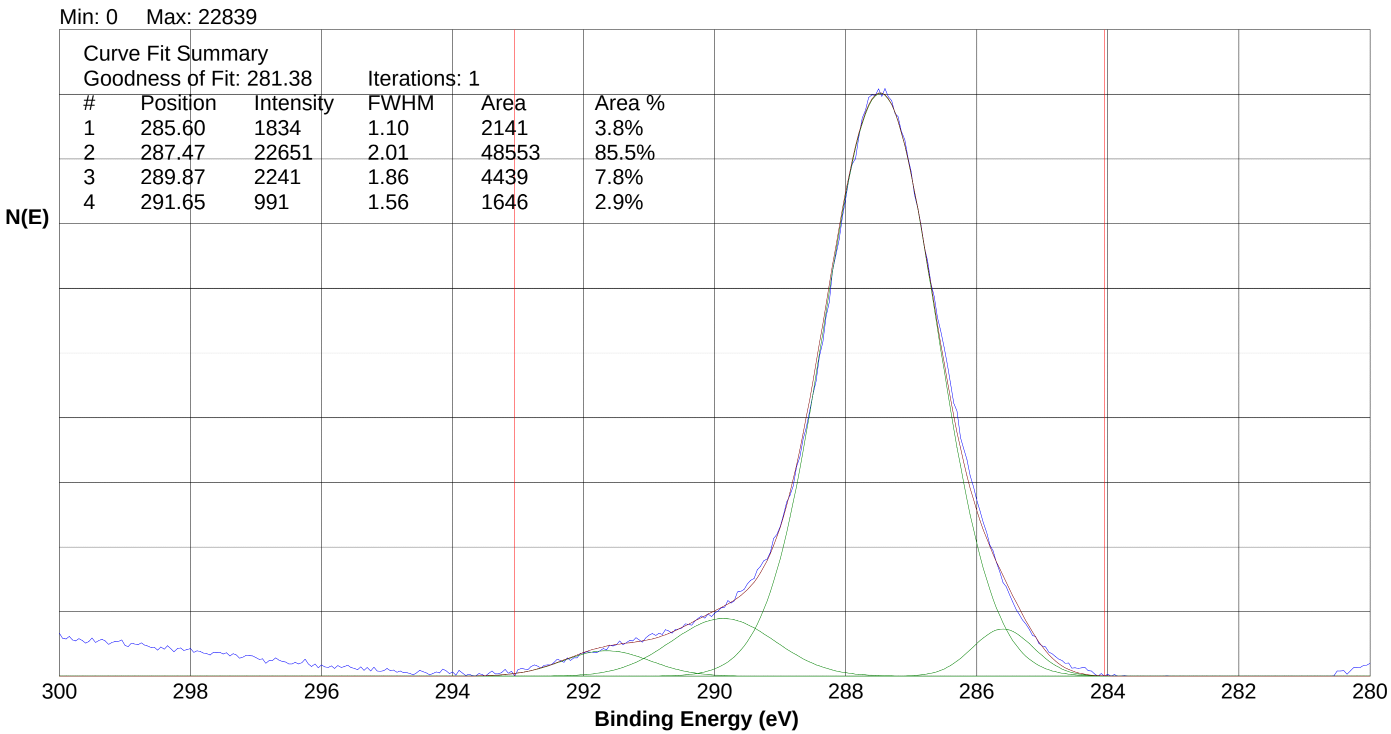
XPS Multiplex
C 1s
EV/Step: 0.05 eV, Time/Step: 100 mSec, Sweeps: 10
Source: Mg, Pass Energy: 35.75 eV, Work Function: 4 eV



AugerScan 2
PE - t=0,30s,1min,   Sample #: 4,   Angle: 45

F:\chris\0Days XPS\0 O2 30sec.ASN
Acquired: Wednesday, May 08, 2002 19:05:56

XPS Multiplex
C 1s
EV/Step: 0.05 eV,   Time/Step: 100 mSec,   Sweeps: 10
Source: Mg,   Pass Energy: 35.75 eV,   Work Function: 4 eV



AugerScan 2
PE - t=0,30s,1min,   Sample #: 4,   Angle: 45

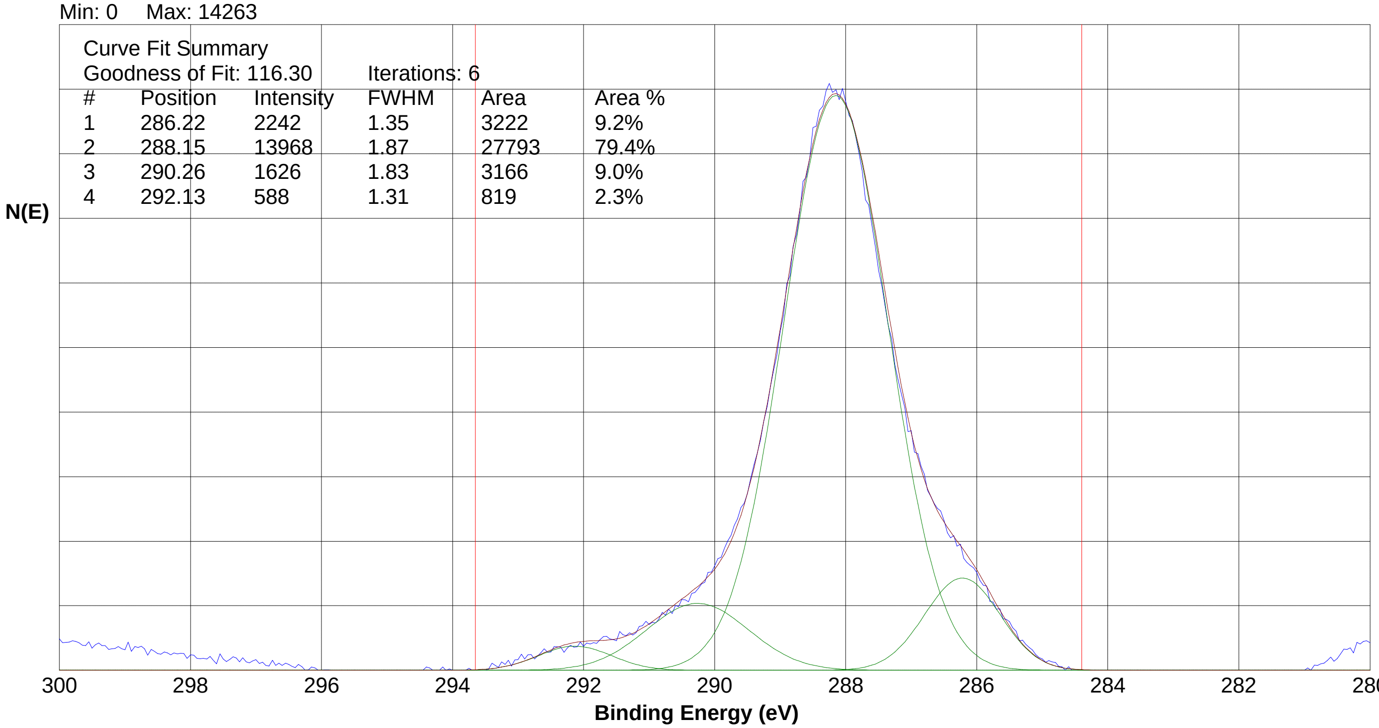
F:\chris\0Days XPS\0 O2 1min.ASN
Acquired: Wednesday, May 08, 2002 19:47:59

XPS Multiplex
C 1s
EV/Step: 0.05 eV,   Time/Step: 100 mSec,   Sweeps: 10
Source: Mg,   Pass Energy: 35.75 eV,   Work Function: 4 eV

Min: 0   Max: 14263

Curve Fit Summary
Goodness of Fit: 116.30   Iterations: 6

#	Position	Intensity	FWHM	Area	Area %
1	286.22	2242	1.35	3222	9.2%
2	288.15	13968	1.87	27793	79.4%
3	290.26	1626	1.83	3166	9.0%
4	292.13	588	1.31	819	2.3%



AugerScan 2
PE - t=2, 4 min,   Sample #: 5,   Angle: 45

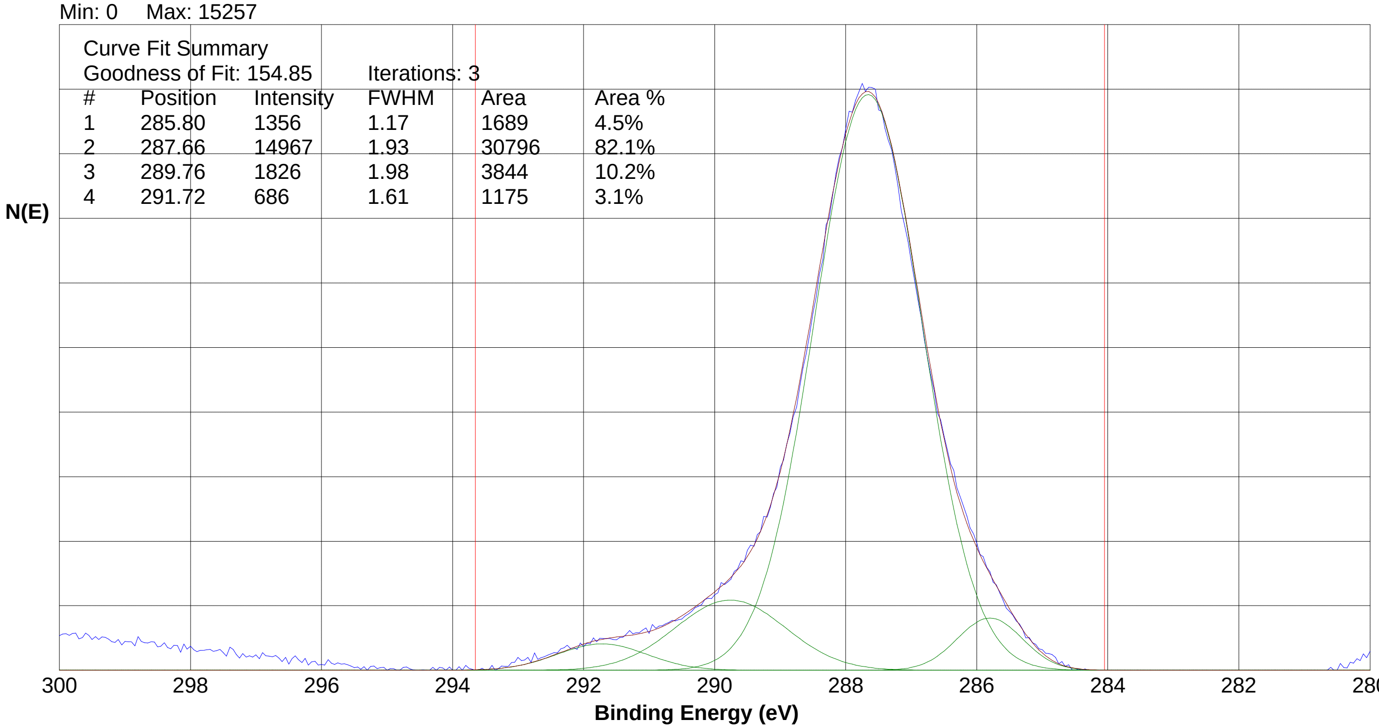
F:\chris\0Days XPS\0 Air2min.ASN
Acquired: Wednesday, May 08, 2002 21:04:05

XPS Multiplex
C 1s
EV/Step: 0.05 eV,   Time/Step: 100 mSec,   Sweeps: 10
Source: Mg,   Pass Energy: 35.75 eV,   Work Function: 4 eV

Min: 0   Max: 15257

Curve Fit Summary
Goodness of Fit: 154.85   Iterations: 3

#	Position	Intensity	FWHM	Area	Area %
1	285.80	1356	1.17	1689	4.5%
2	287.66	14967	1.93	30796	82.1%
3	289.76	1826	1.98	3844	10.2%
4	291.72	686	1.61	1175	3.1%



AugerScan 2
PE - t=2, 4 min,   Sample #: 5,   Angle: 45

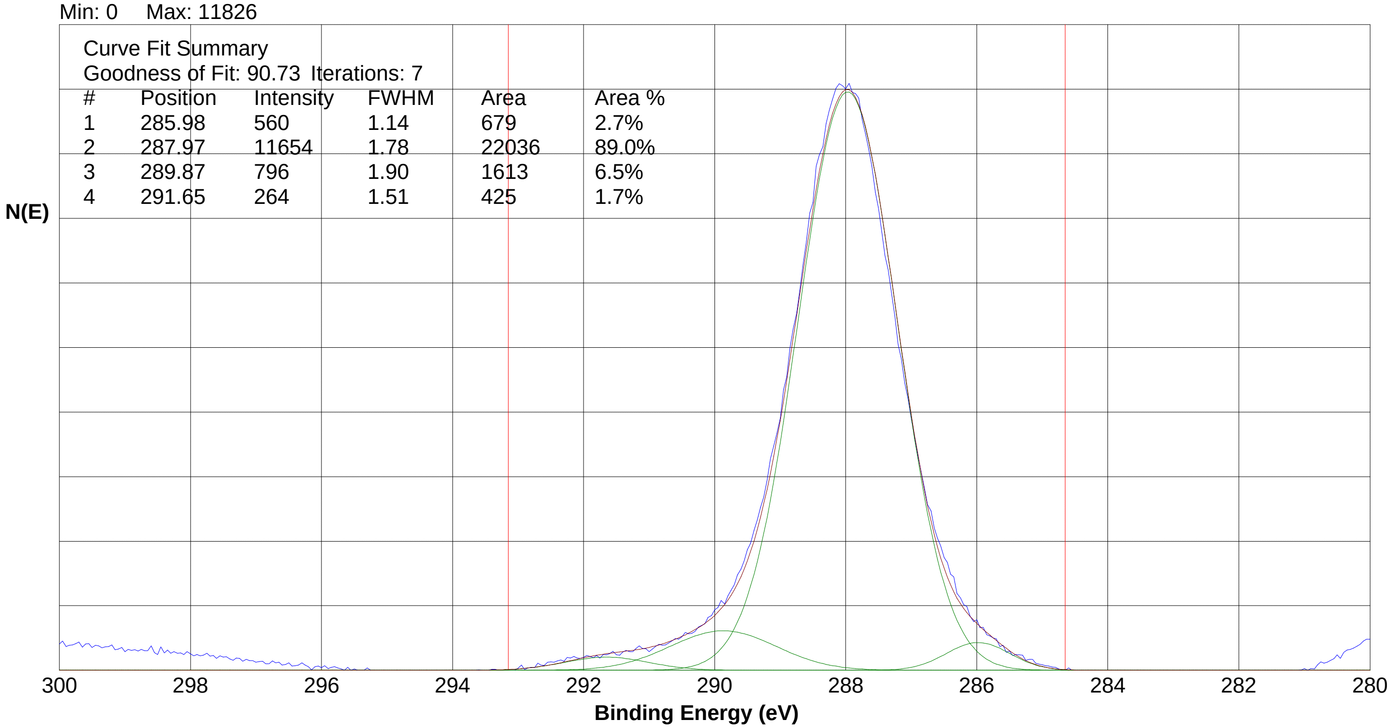
F:\chris\0Days XPS\0 Air 4 min.ASN
Acquired: Thursday, May 09, 2002 00:29:08

XPS Multiplex
C 1s
EV/Step: 0.05 eV,   Time/Step: 100 mSec,   Sweeps: 10
Source: Mg,   Pass Energy: 35.75 eV,   Work Function: 4 eV

Min: 0   Max: 11826

Curve Fit Summary
Goodness of Fit: 90.73 Iterations: 7

#	Position	Intensity	FWHM	Area	Area %
1	285.98	560	1.14	679	2.7%
2	287.97	11654	1.78	22036	89.0%
3	289.87	796	1.90	1613	6.5%
4	291.65	264	1.51	425	1.7%



AugerScan 2
Fibers 1, Sample #: 5, Angle: 45

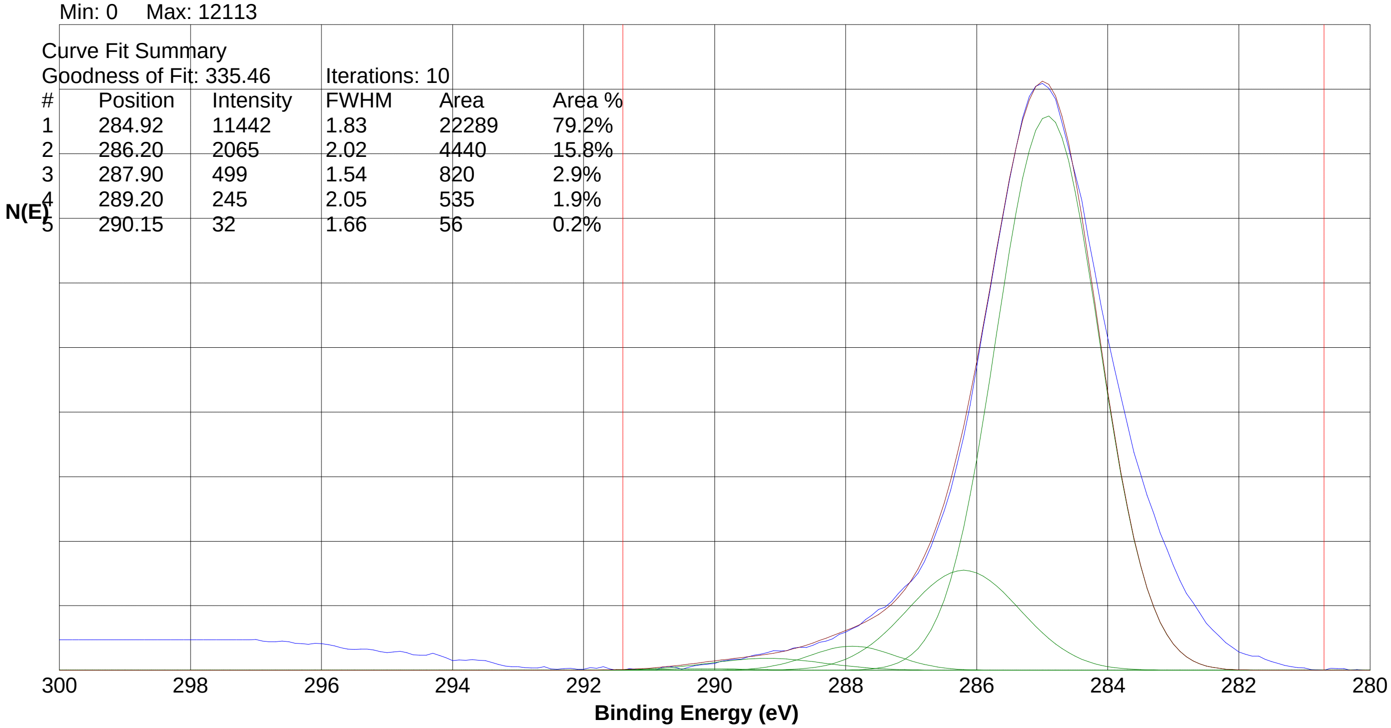
D:\XPS 30+Days\Control30.ASN
Acquired: Monday, June 24, 2002 10:36:21

XPS Multiplex
C 1s
EV/Step: 0.1 eV, Time/Step: 100 mSec, Sweeps: 15
Source: Mg, Pass Energy: 35.75 eV, Work Function: 4 eV

Min: 0 Max: 12113

Curve Fit Summary
Goodness of Fit: 335.46 Iterations: 10

#	Position	Intensity	FWHM	Area	Area %
1	284.92	11442	1.83	22289	79.2%
2	286.20	2065	2.02	4440	15.8%
3	287.90	499	1.54	820	2.9%
4	289.20	245	2.05	535	1.9%
5	290.15	32	1.66	56	0.2%



AugerScan 2
Fibers 1, Sample #: 5, Angle: 45

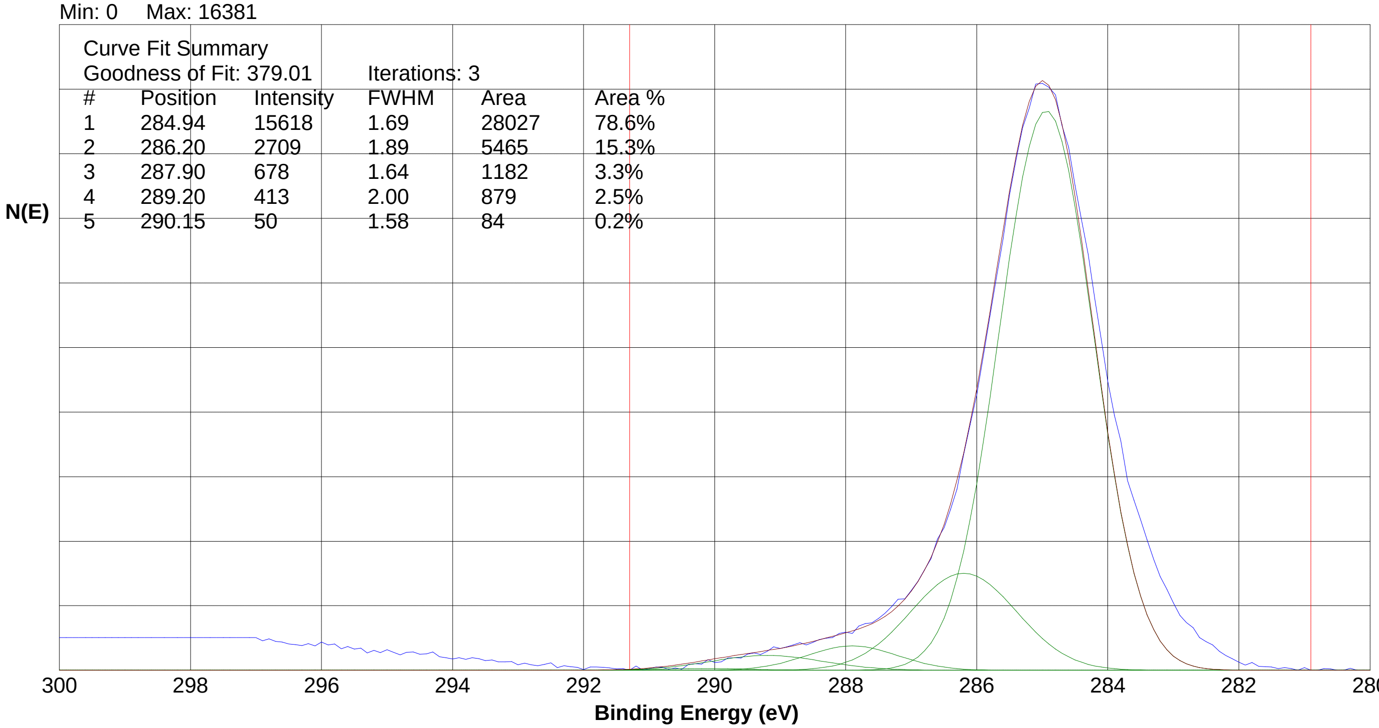
D:\XPS 30+Days\30day30secO2.ASN
Acquired: Monday, June 24, 2002 11:12:01

XPS Multiplex
C 1s
EV/Step: 0.1 eV, Time/Step: 100 mSec, Sweeps: 15
Source: Mg, Pass Energy: 35.75 eV, Work Function: 4 eV

Min: 0 Max: 16381

Curve Fit Summary
Goodness of Fit: 379.01 Iterations: 3

#	Position	Intensity	FWHM	Area	Area %
1	284.94	15618	1.69	28027	78.6%
2	286.20	2709	1.89	5465	15.3%
3	287.90	678	1.64	1182	3.3%
4	289.20	413	2.00	879	2.5%
5	290.15	50	1.58	84	0.2%



AugerScan 2
Fibers 1, Sample #: 5, Angle: 45

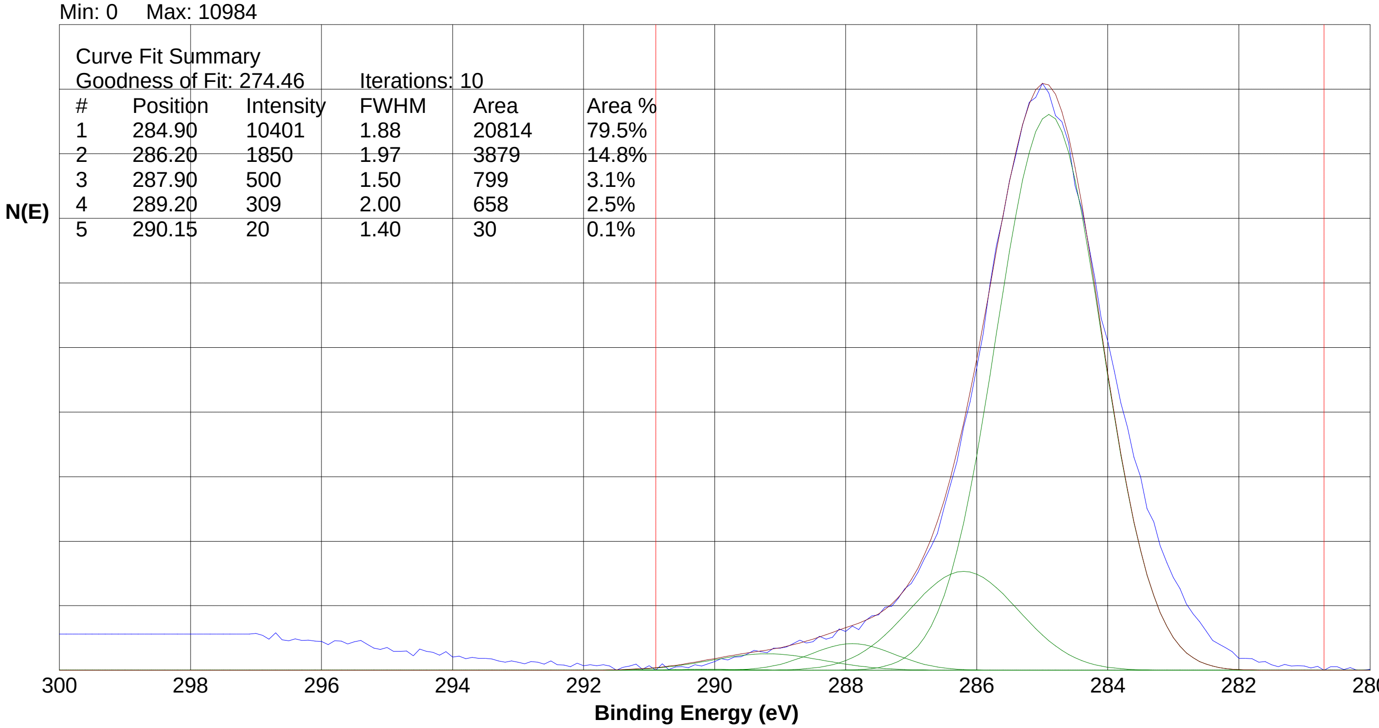
D:\XPS 30+Days\30day1minO2.ASN
Acquired: Monday, June 24, 2002 11:47:42

XPS Multiplex
C 1s
EV/Step: 0.1 eV, Time/Step: 100 mSec, Sweeps: 15
Source: Mg, Pass Energy: 35.75 eV, Work Function: 4 eV

Min: 0 Max: 10984

Curve Fit Summary
Goodness of Fit: 274.46 Iterations: 10

#	Position	Intensity	FWHM	Area	Area %
1	284.90	10401	1.88	20814	79.5%
2	286.20	1850	1.97	3879	14.8%
3	287.90	500	1.50	799	3.1%
4	289.20	309	2.00	658	2.5%
5	290.15	20	1.40	30	0.1%



AugerScan 2
Fibers 2, Sample #: 4, Angle: 45

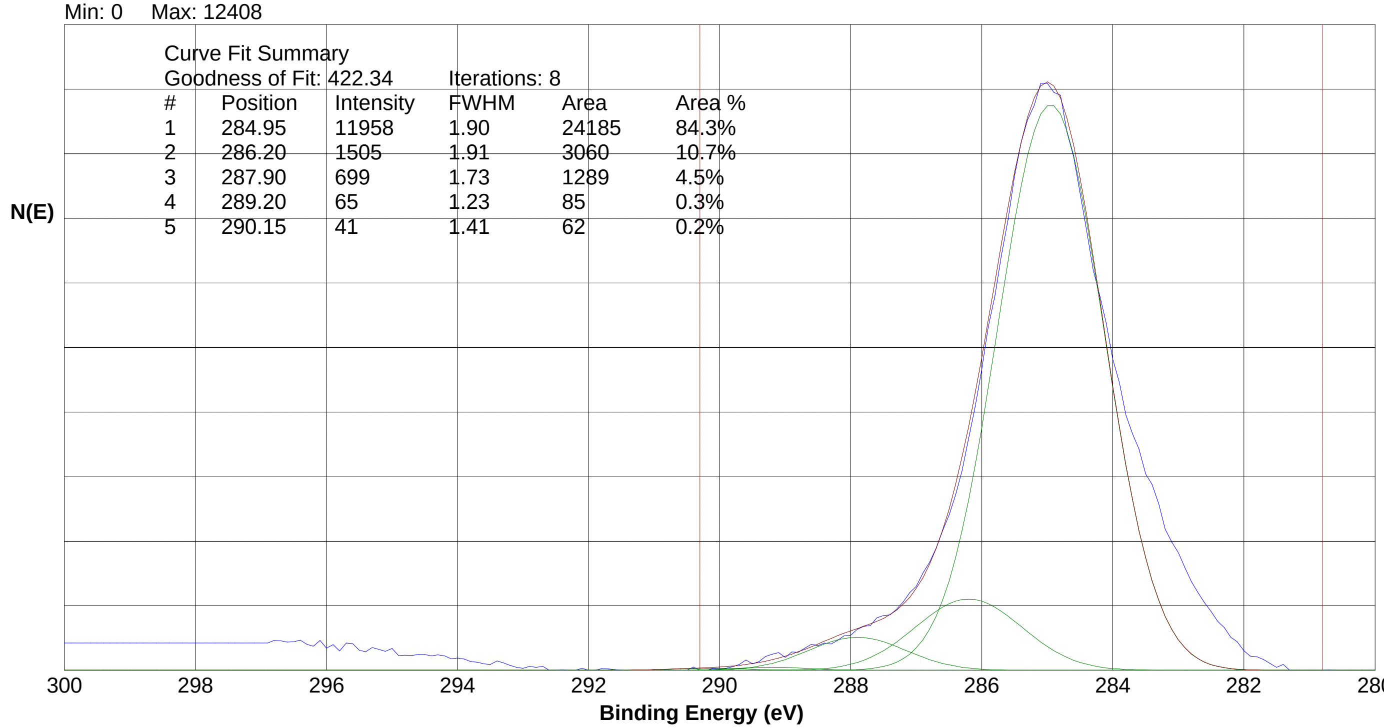
D:\XPS 30+Days\30day2minAir.ASN
Acquired: Monday, June 24, 2002 12:45:12

XPS Multiplex
C 1s
EV/Step: 0.1 eV, Time/Step: 100 mSec, Sweeps: 15
Source: Mg, Pass Energy: 35.75 eV, Work Function: 4 eV

Min: 0 Max: 12408

Curve Fit Summary
Goodness of Fit: 422.34 Iterations: 8

#	Position	Intensity	FWHM	Area	Area %
1	284.95	11958	1.90	24185	84.3%
2	286.20	1505	1.91	3060	10.7%
3	287.90	699	1.73	1289	4.5%
4	289.20	65	1.23	85	0.3%
5	290.15	41	1.41	62	0.2%



AugerScan 2
Fibers 2, Sample #: 4, Angle: 45

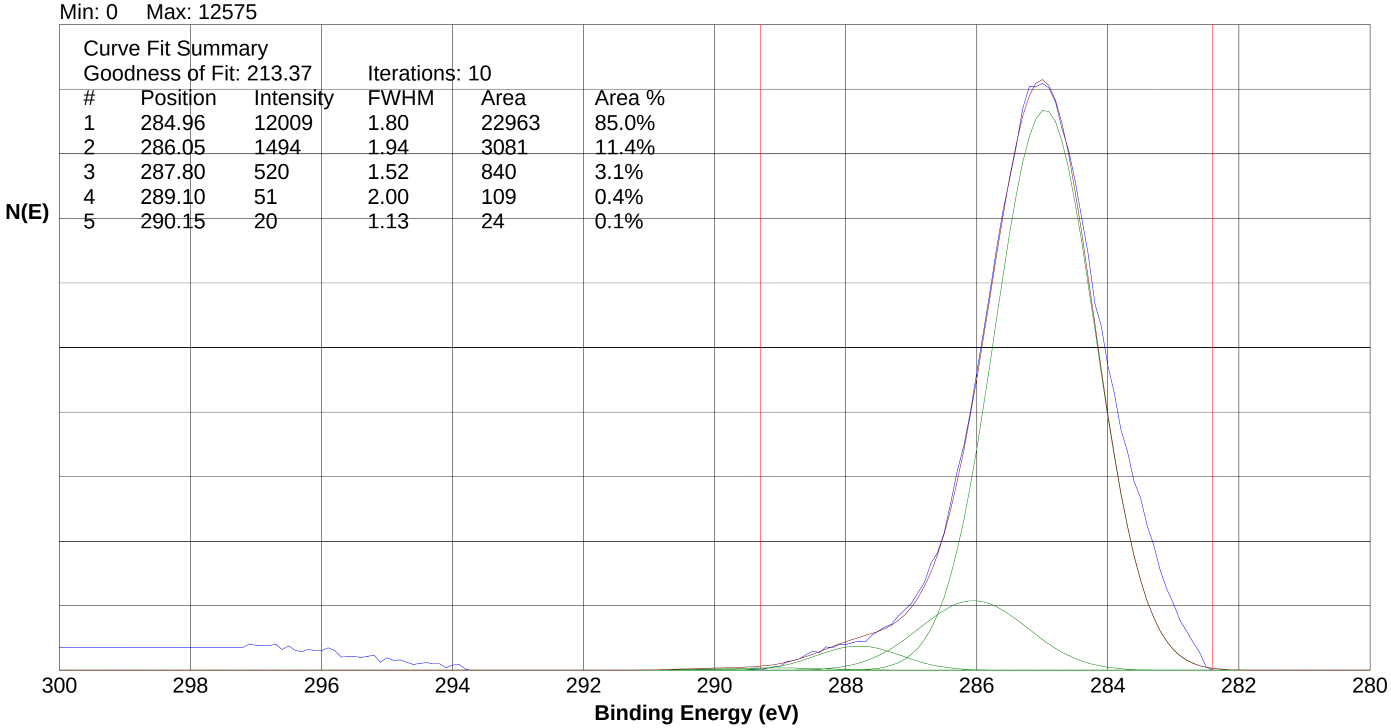
D:\XPS 30+Days\30Day4minAir.ASN
Acquired: Monday, June 24, 2002 13:16:01

XPS Multiplex
C 1s
EV/Step: 0.1 eV, Time/Step: 100 mSec, Sweeps: 15
Source: Mg, Pass Energy: 35.75 eV, Work Function: 4 eV

Min: 0 Max: 12575

Curve Fit Summary
Goodness of Fit: 213.37 Iterations: 10

#	Position	Intensity	FWHM	Area	Area %
1	284.96	12009	1.80	22963	85.0%
2	286.05	1494	1.94	3081	11.4%
3	287.80	520	1.52	840	3.1%
4	289.10	51	2.00	109	0.4%
5	290.15	20	1.13	24	0.1%



Appendix I. Minitab Statistical Analysis

5/13/02 11:33:36 AM

One-way ANOVA: Time (Days) versus Control

```
Analysis of Variance for Time (Da
Source     DF        SS        MS        F        P
Control     3      0.80      0.27     0.11    0.952
Error      70    164.85      2.35
Total      73    165.65
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  --+---------+---------+---------+----
1          19     3.759     1.299     (-------------*-------------)
2          17     3.676     0.963   (--------------*-------------)
3          17     3.881     1.527       (--------------*-------------)
4          21     3.602     2.029   (------------*------------)
                                   --+---------+---------+---------+----
Pooled StDev =    1.535            3.00      3.50      4.00      4.50

Tukey's pairwise comparisons

    Family error rate = 0.0500
Individual error rate = 0.0105

Critical value = 3.72

Intervals for (column level mean) - (row level mean)

                 1           2           3

       2      -1.265
               1.431

       3      -1.470      -1.589
               1.226       1.180

       4      -1.121      -1.242      -1.037
               1.436       1.392       1.597

Fisher's pairwise comparisons

    Family error rate = 0.200
Individual error rate = 0.0500
Critical value = 1.994

Intervals for (column level mean) - (row level mean)

                   1           2           3

       2      -0.939
               1.104

       3      -1.144      -1.254
               0.900       0.845

       4      -0.811      -0.924      -0.719
               1.126       1.073       1.278
```

5/13/02 11:37:09 AM

```
Welcome to Minitab, press F1 for help.
```

One-way ANOVA: Time (Days) versus O2 30sec

```
Analysis of Variance for Time (Da
Source     DF        SS        MS        F        P
O2 30sec    3     21.83      7.28     1.74    0.166
Error      70    292.36      4.18
Total      73    314.20
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  --------+---------+---------+--------
1          18     5.283     2.491             (---------*--------)
2          19     5.519     1.879                (--------*---------)
3          18     5.485     2.470               (---------*--------)
4          19     4.204     1.043   (--------*--------)
                                   --------+---------+---------+--------
Pooled StDev =    2.044                 4.0       5.0       6.0

Tukey's pairwise comparisons

    Family error rate = 0.0500
Individual error rate = 0.0105

Critical value = 3.72

Intervals for (column level mean) - (row level mean)

                 1           2           3

       2      -2.005
               1.531

       3      -1.995      -1.734
               1.589       1.802

       4      -0.690      -0.429      -0.487
               2.846       3.059       3.049

Fisher's pairwise comparisons

    Family error rate = 0.200
Individual error rate = 0.0500

Critical value = 1.994

Intervals for (column level mean) - (row level mean)

                   1           2           3

       2      -1.577
               1.104

       3      -1.561      -1.306
               1.156       1.374

       4      -0.262      -0.007      -0.060
               2.419       2.637       2.621
```

5/13/02 11:39:24 AM

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One-way ANOVA: Time (Days) versus O2 1min

```
Analysis of Variance for Time (Da
Source     DF        SS        MS        F        P
O2 1min     3     74.27     24.76     7.08    0.000
Error      66    230.82      3.50
Total      69    305.09
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ----+---------+---------+---------+--
1          16     6.193     2.040                      (-------*------)
2          16     6.308     2.322                       (-------*------)
3          17     6.059     1.820                     (------*-------)
4          21     3.944     1.314  (------*------)
                                   ----+---------+---------+---------+--
Pooled StDev =    1.870              3.6       4.8       6.0       7.2

Tukey's pairwise comparisons

    Family error rate = 0.0500
Individual error rate = 0.0104

Critical value = 3.73

Intervals for (column level mean) - (row level mean)

                 1           2           3

       2      -1.859
               1.629

       3      -1.584      -1.469
               1.852       1.967

       4       0.612       0.727       0.505
               3.886       4.001       3.724


Fisher's pairwise comparisons

    Family error rate = 0.200
Individual error rate = 0.0500

Critical value = 1.997

Intervals for (column level mean) - (row level mean)

                 1           2           3

       2      -1.435
               1.206

       3      -1.166      -1.052
               1.435       1.550

       4       1.010       1.124       0.896
               3.488       3.603       3.333
```

5/13/02 11:41:14 AM

```
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```

One-way ANOVA: TIme (Days) versus He 2min

```
Analysis of Variance for TIme (Da
Source     DF        SS        MS        F        P
He 2min     3    225.38     75.13     7.72    0.000
Error      71    690.88      9.73
Total      74    916.26
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ------+---------+---------+---------+
1          19    10.317     4.362                      (-------*------)
2          19    10.392     2.757                       (------*------)
3          17     9.235     3.189                 (------*-------)
4          20     6.219     1.602  (------*------)
                                   ------+---------+---------+---------+
Pooled StDev =    3.119                6.0       8.0      10.0      12.0

Tukey's pairwise comparisons

    Family error rate = 0.0500
Individual error rate = 0.0105

Critical value = 3.72

Intervals for (column level mean) - (row level mean)

                 1           2           3

       2      -2.737
               2.587

       3      -1.657      -1.582
               3.822       3.896

       4       1.469       1.544       0.309
               6.727       6.802       5.723

Fisher's pairwise comparisons

    Family error rate = 0.200
Individual error rate = 0.0500

Critical value = 1.994

Intervals for (column level mean) - (row level mean)

                   1           2           3

       2      -2.093
               1.943

       3      -0.994      -0.919
               3.159       3.234

       4       2.105       2.180       0.964
               6.091       6.166       5.068
```

5/13/02 11:43:24 AM

```
Welcome to Minitab, press F1 for help.
```

One-way ANOVA: Time (Days) versus He 4min

```
Analysis of Variance for Time (Da
Source     DF        SS        MS        F        P
He 4min     3     102.6      34.2     3.02    0.036
Error      67     757.4      11.3
Total      70     860.0
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  --+---------+---------+---------+----
1          19    10.141     2.271               (-------*------)
2          19    10.026     5.150              (-------*-------)
3          15    10.228     2.249              (--------*--------)
4          18     7.366     2.617   (-------*-------)
                                   --+---------+---------+---------+----
Pooled StDev =    3.362            6.0       8.0      10.0      12.0

Tukey's pairwise comparisons

    Family error rate = 0.0500
Individual error rate = 0.0104

Critical value = 3.73

Intervals for (column level mean) - (row level mean)

                 1           2           3

       2      -2.762
               2.992

       3      -3.150      -3.265
               2.976       2.861

       4      -0.142      -0.257      -0.239
               5.692       5.577       5.962

Fisher's pairwise comparisons

    Family error rate = 0.200
Individual error rate = 0.0500

Critical value = 1.996

Intervals for (column level mean) - (row level mean)

                   1           2           3

       2      -2.062
               2.293

       3      -2.405      -2.520
               2.231       2.116

       4       0.568       0.452       0.516
               4.983       4.867       5.208
```

—— 4/26/02 12:26:17 PM ——

```
Welcome to Minitab, press F1 for help.
```

One-way ANOVA: MPa versus Treatment

```
Analysis of Variance for MPa
Source     DF        SS        MS        F        P
Treatmen    4    656.29    164.07    22.27    0.000
Error      86    633.66      7.37
Total      90   1289.95
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ----------+---------+---------+------
1          19     3.759     1.299  (----*----)
2          18     5.283     2.491        (----*----)
3          16     6.193     2.040           (-----*----)
4          19    10.317     4.362                          (----*----)
5          19    10.141     2.271                          (----*----)
                                   ----------+---------+---------+------
Pooled StDev =    2.714                    5.0       7.5      10.0

Tukey's pairwise comparisons

    Family error rate = 0.0500
Individual error rate = 0.00656

Critical value = 3.94

Intervals for (column level mean) - (row level mean)

                 1           2           3           4

       2      -4.011
               0.964

       3      -5.000      -3.509
               0.132       1.688

       4      -9.012      -7.522      -6.690
              -4.104      -2.547      -1.558

       5      -8.835      -7.346      -6.514      -2.277
              -3.928      -2.371      -1.382       2.630




Fisher's pairwise comparisons

    Family error rate = 0.281
Individual error rate = 0.0500

Critical value = 1.988



Intervals for (column level mean) - (row level mean)

                 1           2           3           4

       2      -3.298
               0.252
```

```
       3      -4.265      -2.765
              -0.603       0.944

       4      -8.309      -6.810      -5.955
              -4.807      -3.260      -2.293

       5      -8.132      -6.633      -5.779      -1.574
              -4.631      -3.083      -2.117       1.927
```

Results for: Worksheet 2

One-way ANOVA: MPa versus Treatment

```
Analysis of Variance for MPa
Source     DF        SS        MS        F        P
Treatmen    4    622.04    155.51    17.09    0.000
Error      85    773.50      9.10
Total      89   1395.54
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ---+---------+---------+---------+---
1          17     3.676     0.963  (----*----)
2          19     5.519     1.879         (---*----)
3          16     6.308     2.322           (----*----)
4          19    10.392     2.757                         (----*---)
5          19    10.026     5.150                        (---*----)
                                   ---+---------+---------+---------+---
Pooled StDev =    3.017             3.0       6.0       9.0      12.0

Tukey's pairwise comparisons

    Family error rate = 0.0500
Individual error rate = 0.00658

Critical value = 3.94

Intervals for (column level mean) - (row level mean)

                 1           2           3           4

       2      -4.649
               0.963

       3      -5.559      -3.640
               0.296       2.063

       4      -9.522      -7.600      -6.936
              -3.910      -2.146      -1.233

       5      -9.155      -7.233      -6.570      -2.360
              -3.544      -1.780      -0.866       3.093


Fisher's pairwise comparisons

    Family error rate = 0.281
Individual error rate = 0.0500

Critical value = 1.988

Intervals for (column level mean) - (row level mean)
```

```
               1           2           3           4

       2      -3.845
               0.159

       3      -4.720      -2.823
              -0.543       1.246

       4      -8.718      -6.819      -6.119
              -4.714      -2.927      -2.050

       5      -8.351      -6.452      -5.753      -1.579
              -4.347      -2.561      -1.683       2.312
```

Results for: Worksheet 3

One-way ANOVA: MPa versus Treatment

```
Analysis of Variance for MPa
Source     DF        SS        MS        F        P
Treatmen    4    461.73    115.43    21.33    0.000
Error      79    427.62      5.41
Total      83    889.36
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ---------+---------+---------+-------
1          17     3.881     1.527  (----*---)
2          18     5.485     2.470         (---*---)
3          17     6.059     1.820           (---*----)
4          17     9.235     3.189                       (----*---)
5          15    10.228     2.249                           (----*----)
                                   ---------+---------+---------+-------
Pooled StDev =    2.327                   5.0       7.5      10.0
```

```
Tukey's pairwise comparisons

Family error rate = 0.0500
Individual error rate = 0.00655
Critical value = 3.95
```

```
Intervals for (column level mean) - (row level mean)

               1           2           3           4

       2      -3.802
               0.594

       3      -4.406      -2.771
               0.051       1.624
```

```
       4      -7.583      -5.948      -5.405
              -3.125      -1.552      -0.947

       5      -8.648      -7.014      -6.471      -3.294
              -4.044      -2.470      -1.867       1.309
Fisher's pairwise comparisons

    Family error rate = 0.280
Individual error rate = 0.0500

Critical value = 1.990

Intervals for (column level mean) - (row level mean)

                   1           2           3           4

       2      -3.170
              -0.038

       3      -3.765      -2.139
              -0.589       0.992

       4      -6.942      -5.316      -4.764
              -3.766      -2.184      -1.588

       5      -7.986      -6.361      -5.809      -2.633
              -4.706      -3.124      -2.529       0.648
```

Results for: Worksheet 4

One-way ANOVA: MPa versus Treatment

```
Analysis of Variance for MPa
Source     DF        SS        MS        F        P
Treatmen    4    206.98     51.74    16.13    0.000
Error      94    301.59      3.21
Total      98    508.56
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  --+---------+---------+---------+----
1          21     3.602     2.029   (----*----)
2          19     4.204     1.043       (----*----)
3          21     3.944     1.314     (----*----)
4          20     6.219     1.602                   (----*-----)
5          18     7.366     2.617                           (----*-----)
                                   --+---------+---------+---------+----
Pooled StDev =    1.791            3.0       4.5       6.0       7.5


Tukey's pairwise comparisons

    Family error rate = 0.0500
Individual error rate = 0.00659

Critical value = 3.93

Intervals for (column level mean) - (row level mean)

                 1           2           3           4
```

```
       2      -2.179
               0.973

       3      -1.878      -1.316
               1.194       1.836

       4      -4.173      -3.609      -3.830
              -1.062      -0.420      -0.720

       5      -5.363      -4.799      -5.021      -2.764
              -2.165      -1.524      -1.823       0.471


Fisher's pairwise comparisons

    Family error rate = 0.281
Individual error rate = 0.0500

Critical value = 1.986

Intervals for (column level mean) - (row level mean)

                   1           2           3           4

       2      -1.729
               0.524

       3      -1.440      -0.866
               0.756       1.387

       4      -3.729      -3.154      -3.387
              -1.506      -0.875      -1.164

       5      -4.907      -4.331      -4.564      -2.302
              -2.621      -1.991      -2.279       0.009
```

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```
Retrieving project from file: F:\chris\Tensile.mpj
```

Results for: Worksheet 1
One-way ANOVA: Peak Load Gm versus Treatment

Analysis of Variance for Peak Loa

Source	DF	SS	MS	F	P
Treatmen	4	6110	1527	2.61	0.040
Error	105	61479	586		
Total	109	67589			

```
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ----+---------+---------+---------+--
1          22    274.84     28.66                 (-------*--------)
2          22    270.50     20.55             (-------*--------)
3          23    282.28     11.66                       (-------*--------)
4          20    258.90     36.77   (--------*--------)
5          23    273.17     17.41               (--------*-------)
                                   ----+---------+---------+---------+--
Pooled StDev =    24.20               252       264       276       288

Tukey's pairwise comparisons
Family error rate = 0.0500
Individual error rate = 0.00646
Critical value = 3.93

Intervals for (column level mean) - (row level mean)
                 1           2           3           4

       2      -15.94
               24.61

       3      -27.50      -31.83
               12.61        8.28

       4       -4.84       -9.17        2.82
               36.71       32.38       43.94

       5      -18.38      -22.72      -10.72      -34.82
               21.72       17.39       28.94        6.29

Fisher's pairwise comparisons
Family error rate = 0.282
Individual error rate = 0.0500
Critical value = 1.983

Intervals for (column level mean) - (row level mean)
                   1           2           3           4

       2      -10.14
               18.80

       3      -21.75      -26.08
                6.87        2.53

       4        1.11       -3.22        8.71
               30.76       26.43       38.05

       5      -12.64      -16.97       -5.04      -28.93
               15.98       11.65       23.26        0.41
```

Appendix J. Transverse Compression Machine Instructions

Instructions for Compression Tester:

1. Plug in all machines (four plugs total). Turn on computer. Switch on Load control machine at back. Press tare.
2. Turn on air at Fume hood.
3. Turn on air valve at Compression machine to read 25psi.
4. Open Quick Log Application. Immediately stop the program from running.
5. Go to File – Open Configuration – Chris50
6. Open API-mate application. Go to File – click on “1.68 micron run” and also, “backup sequence2”
7. For Compliance, run the device until a load of approx. 5000g (top machine read-out). The bottom machine read-out is the displacement, it should appear to get lower as the device is run and compression takes place.
8. To run device, click on >> (Play) on the APImate. Then immediately click RUN on the Quick log application.
9. Once the load reaches 5000g, click the STOP button on the APImate app. Then wait a few seconds before clicking the STOP on the Quick log app. This is because of a slight delay.
10. The file is saved in sequential order in the file CHRIS, in .txt format.
11. The .txt files can then be opened in excel and/or saved on a floppy to take to another computer for analysis.

Appendix K. Compliance Instructions

Instructions for taking compliance values into account for seven fiber bundle compression testing:

1. Find 100g Load. Delete, Shift up.

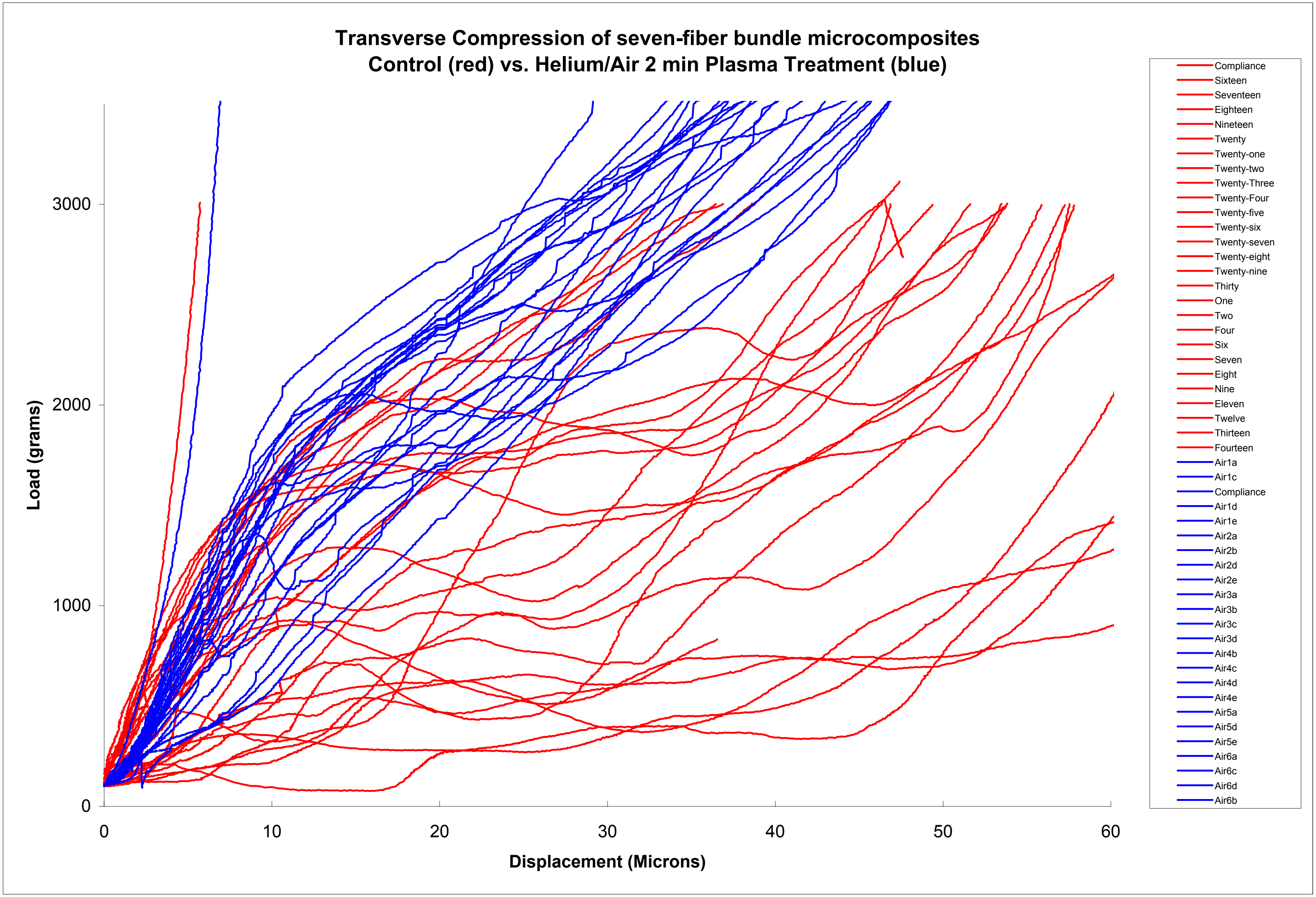
Time Disp. Load

2. B1 – B! New Column - Copy down. Copy and paste special values
3. Delete Column B
4. Save
5. Open Compliance .exe app
6. Type Tes3.txt
7. Then Tes3.out
8. In Excel, open tes.out. Type labels.

Time Load (g) Disp.(Microns)

9. Copy load and Displacement columns to tes2. And Graph

Reminder: Change displacement to X column and load to Y column in order to graph.



Transverse Compression of seven-fiber bundle microcomposites
Control (red) vs. Helium/Air 2 min Plasma Treatment (blue)
Load (grams)
Displacement (Microns)
0
1000
2000
3000
0
10
20
30
40
50
60
Compliance
Sixteen
Seventeen
Eighteen
Nineteen
Twenty
Twenty-one
Twenty-two
Twenty-Three
Twenty-Four
Twenty-five
Twenty-six
Twenty-seven
Twenty-eight
Twenty-nine
Thirty
One
Two
Four
Six
Seven
Eight
Nine
Eleven
Twelve
Thirteen
Fourteen
Air1a
Air1c
Compliance
Air1d
Air1e
Air2a
Air2b
Air2d
Air2e
Air3a
Air3b
Air3c
Air3d
Air4b
Air4c
Air4d
Air4e
Air5a
Air5d
Air5e
Air6a
Air6c
Air6d
Air6b

Appendix M. Transverse Compression data for Figure 3.11

2min He./Air Plasma

Displacement (Microns)	Load (Grams)	Load (Newtons)
0	101.661	0.996676471
0.0554581	105.36	1.032941176
0.0779445	107.747	1.056343137
0.104934	109.418	1.07272549
0.104238	113.238	1.110176471
0.123877	113.477	1.112519608
0.157034	116.581	1.14295098
0.254179	118.97	1.166372549
0.311677	121.837	1.194480392
0.303234	126.36	1.238823529
0.372778	127.075	1.245833333
0.39984	129.697	1.271539216
0.386504	133.989	1.313617647
0.395478	138.163	1.354539216
0.47358	139.952	1.372078431
0.503387	141.264	1.384941176
0.610701	142.696	1.398980392
0.618893	145.321	1.424715686
0.6744	147.111	1.442264706
0.675199	150.452	1.475019608
0.735209	153.914	1.508960784
0.768794	156.899	1.53822549
0.812364	158.212	1.551098039
0.88111	161.915	1.587401961
0.945806	165.14	1.619019608
0.960463	168.008	1.647137255
1.03022	169.92	1.665882353
1.04994	171.473	1.681107843
1.12752	171.354	1.679941176
1.0778	175.776	1.723294118
1.13625	177.45	1.739705882
1.11503	179.722	1.761980392
1.21816	180.559	1.770186275
1.21894	182.712	1.791294118
1.23608	185.463	1.818264706
1.2896	187.018	1.833509804
1.29457	191.086	1.873392157
1.35541	190.128	1.864
1.33418	192.283	1.885127451
1.35045	193.24	1.894509804
1.42637	194.437	1.906245098
1.42637	195.275	1.914460784
1.45207	196.352	1.925019608
1.47777	197.788	1.939098039
1.50347	199.105	1.952009804
1.52918	200.422	1.964921569
1.58058	203.057	1.990754902
1.65768	203.536	1.99545098
1.68338	204.015	2.000147059
1.69396	208.096	2.040156863
1.71692	208.335	2.0425
1.75459	209.529	2.054205882
1.77068	210.366	2.062411765
1.795	210.485	2.063578431
1.79226	210.724	2.065921569
1.8343	212.278	2.081156863
1.82741	214.19	2.099901961
1.87364	215.624	2.113960784
1.88936	218.374	2.140921569
1.93822	218.972	2.146784314
1.93873	218.852	2.145607843
1.92958	221.004	2.166705882
1.95223	221.722	2.173745098
1.97488	222.439	2.18077451
2.01721	224.472	2.200705882
2.06425	225.19	2.207745098
2.06352	225.31	2.208921569
2.07325	227.941	2.234715686
2.14703	228.539	2.240578431
2.17027	229.257	2.247617647
2.13843	231.052	2.265215686
2.20691	233.565	2.289852941
2.25625	234.163	2.295715686
2.2398	237.035	2.323872549
2.24728	239.07	2.343823529
2.28369	237.873	2.332088235
2.32758	238.711	2.340303922
2.30185	241.584	2.368470588
2.29435	242.423	2.376696078
2.33716	243.38	2.386078431
2.37997	245.536	2.407215686
2.37997	246.853	2.420127451
2.43136	246.614	2.417784314
2.45705	247.332	2.424823529
2.50844	245.177	2.403696078
2.50844	248.77	2.438921569
2.53413	250.207	2.453009804
2.58552	249.728	2.448313725
2.58552	252.363	2.474147059
2.61121	252.363	2.474147059
2.61121	254.041	2.490598039
2.61121	254.041	2.490598039
2.63212	257.996	2.529372549
2.65089	258.595	2.535245098
2.68149	260.393	2.552872549
2.65942	263.27	2.581078431
2.73465	263.869	2.58695098
2.78456	264.349	2.591656863
2.80289	266.747	2.615166667
2.82747	267.107	2.618696078
2.8681	270.465	2.651617647
2.86692	270.705	2.653970588
2.90058	274.303	2.689245098
2.90294	273.824	2.68454902
2.92095	275.383	2.699833333
2.94664	275.383	2.699833333
2.96119	279.223	2.737480392
3.01083	279.823	2.743362745
3.03199	281.384	2.758666667
3.05524	282.224	2.766901961
3.07606	283.904	2.783372549

Control

Displacement (Microns)	Load (Grams)	Load (Newtons)
0	101.869	0.998715686
0	106.282	1.041980392
0	110.1	1.079411765
0.0349892	109.622	1.07472549
0.0684538	108.907	1.067715686
0.0824445	112.367	1.101637255
0.0836845	115.589	1.13322549
0.130496	117.738	1.154294118
0.169251	120.125	1.177696078
0.238157	121.677	1.192911765
0.269648	125.021	1.225696078
0.262759	130.396	1.278392157
0.348786	133.622	1.310019608
0.397156	134.211	1.315794118
0.407053	137.429	1.347343137
0.393551	143.033	1.402284314
0.404412	145.299	1.4245
0.464649	146.968	1.440862745
0.440201	150.189	1.472441176
0.479472	153.172	1.501686275
0.553684	153.888	1.508705882
0.599009	157.349	1.542637255
0.601191	161.646	1.584764706
0.579585	165.587	1.623401961
0.666819	164.99	1.61754902
0.654406	167.259	1.639794118
0.640895	173.351	1.699519608
0.701819	174.904	1.714745098
0.730021	174.665	1.712401961
0.749047	177.772	1.742862745
0.781593	179.804	1.762784314
0.810422	183.629	1.800284314
0.801247	185.183	1.815519608
0.84207	186.977	1.833107843
0.881201	189.488	1.85772549
0.895517	192.12	1.883529412
0.938323	193.914	1.901117647
0.938323	193.914	1.901117647
0.969662	196.187	1.923401961
0.947474	198.7	1.948039216
0.972127	198.82	1.949215686
1.02564	198.58	1.946862745
1.04052	199.538	1.956254902
1.0443	202.889	1.989107843
1.07001	204.206	2.002019608
1.07001	206.6	2.025490196
1.14124	209.354	2.052490196
1.16507	209.473	2.053656863
1.17089	211.03	2.068921569
1.18815	212.467	2.083009804
1.20399	214.144	2.09945098
1.22687	214.624	2.104156863
1.22475	214.983	2.107676471
1.26748	216.435	2.121911765
1.28318	218.108	2.138313725
1.28604	221.932	2.175803922
1.31388	221.574	2.172294118
1.34244	221.096	2.167607843
1.37594	224.084	2.196901961
1.3843	226.953	2.225029412
1.40927	227.073	2.226205882
1.43425	227.193	2.227382353
1.45681	227.79	2.233235294
1.47011	230.78	2.26254902
1.48738	232.813	2.282480392
1.523	230.421	2.259029412
1.47875	234.368	2.29772549
1.51472	236.521	2.318833333
1.55499	234.488	2.298901961
1.54556	235.804	2.311803922
1.59779	239.273	2.345813725
1.55335	241.547	2.368107843
1.61406	240.59	2.35872549
1.61078	240.949	2.362245098
1.63321	243.821	2.390401961
1.65167	244.539	2.397441176
1.6653	245.736	2.409176471
1.691	246.454	2.416215686
1.7167	248.849	2.439696078
1.74239	251.483	2.465519608
1.76685	253.04	2.480784314
1.81948	251.962	2.470215686
1.8056	254.238	2.492529412
1.81992	255.315	2.503088235
1.7841	256.274	2.512490196
1.84055	255.795	2.507794118
1.88435	256.513	2.514833333
1.87166	257.831	2.527754902
1.89736	259.508	2.544196078
1.87166	259.269	2.541852941
1.96949	261.425	2.562990196
1.95785	263.103	2.579441176
1.91636	265.38	2.601764706
1.99178	265.62	2.604117647
2.02329	264.781	2.595892157
2.02651	268.376	2.631137255
2.02651	270.534	2.652294118
2.05221	270.175	2.64877451
2.05221	269.815	2.645245098
2.0779	272.213	2.668754902
2.0779	273.532	2.681686275
2.10797	274.971	2.695794118
2.1495	277.729	2.722833333
2.13785	279.769	2.742833333
2.14196	279.049	2.73577451
2.1656	279.409	2.739303922
2.19197	279.289	2.738127451
2.18223	282.888	2.773411765
2.20793	283.248	2.776941176
2.20793	284.088	2.785176471
2.285	286.488	2.808705882

2min He./Air Plasma

3.07149	285.825	2.802205882
3.07149	285.825	2.802205882
3.05063	288.587	2.829284314
3.102	289.067	2.833990196
3.12769	292.458	2.867235294
3.17906	295.693	2.89895098
3.20474	298.329	2.924794118
3.20474	297.97	2.92127451
3.20474	298.928	2.930666667
3.25612	301.685	2.957696078
3.30749	304.682	2.987078431
3.312	307.319	3.012931373
3.30142	308.519	3.024696078
3.30442	310.917	3.048205882
3.37061	311.637	3.055264706
3.32894	314.396	3.082313725
3.32921	317.035	3.108186275
3.34892	318.475	3.122303922
3.36863	319.915	3.136421569
3.38634	321.835	3.155245098
3.43771	323.755	3.174068627
3.51476	325.076	3.187019608
3.48907	326.756	3.203490196
3.54044	329.278	3.228215686
3.54044	332.28	3.257647059
3.56612	334.682	3.281196078
3.5918	334.562	3.280019608
3.61748	336.844	3.302392157
3.57089	340.208	3.335372549
3.61777	340.929	3.342441176
3.6315	342.852	3.361294118
3.66697	345.616	3.388392157
3.68435	347.659	3.408421569
3.67165	350.785	3.439068627
3.66663	352.589	3.456754902
3.74145	353.551	3.466186275
3.74006	354.152	3.472078431
3.78614	356.437	3.494480392
3.78113	358.602	3.515705882
3.79903	361.971	3.548735294
3.82415	363.294	3.561705882
3.8755	364.979	3.57822549
3.8755	366.543	3.593558824
3.90118	368.71	3.614803922
3.90118	368.95	3.617156863
3.96602	372.08	3.647843137
3.88601	374.903	3.675519608
3.92152	376.465	3.690833333
3.92401	379.588	3.72145098
3.93975	382.832	3.753254902
3.96432	383.193	3.756794118
3.93055	385.836	3.782705882
4.005	386.918	3.793313725
4.03068	389.803	3.821598039
4.05636	391.486	3.838098039
4.10771	392.929	3.852245098
4.13339	398.821	3.910009804
4.09987	401.829	3.9395
4.12106	403.272	3.953647059
4.16644	405.198	3.972529412
4.1798	408.326	4.003196078
4.18385	411.817	4.037421569
4.17789	412.78	4.046862745
4.25044	413.502	4.053941176
4.26166	415.91	4.07754902
4.24662	419.402	4.111784314
4.24248	420.366	4.121235294
4.25309	424.1	4.157843137
4.29738	425.907	4.175558824
4.30585	430.607	4.221637255
4.37995	431.45	4.229901961
4.34387	434.464	4.25945098
4.33848	438.925	4.303186275
4.38504	439.528	4.309098039
4.37835	440.372	4.317372549
4.39252	443.628	4.349294118
4.4182	447.729	4.3895
4.43523	450.384	4.415529412
4.41552	454.487	4.455754902
4.51127	455.332	4.464039216
4.44441	458.187	4.492029412
4.47176	463.486	4.543980392
4.47063	468.666	4.594764706
4.4963	469.871	4.606578431
4.54041	472.522	4.632568627
4.5639	479.393	4.699931373
4.58604	478.67	4.692843137
4.61641	479.635	4.702303922
4.64247	482.408	4.729490196
4.59935	486.871	4.773245098
4.62271	488.439	4.788617647
4.655	492.42	4.827647059
4.60928	496.524	4.867882353
4.68767	499.662	4.898647059
4.69055	504.009	4.941264706
4.70284	506.062	4.961392157
4.75417	506.907	4.969676471
4.76398	512.705	5.026519608
4.77002	514.155	5.040735294
4.76995	518.506	5.083392157
4.78187	523.341	5.130794118
4.80357	526.485	5.161617647
4.83666	527.694	5.173470588
4.8186	529.871	5.194813725
4.83235	536.888	5.263607843
4.88544	540.639	5.300382353
4.88431	543.643	5.329833333
4.88431	544.367	5.336931373
4.90998	547.748	5.370078431
4.91025	552.218	5.413901961
4.96158	554.996	5.441137255
4.98245	559.951	5.489715686
4.94912	561.885	5.508676471
5.0051	568.051	5.569127451

Control

2.27774	288.288	2.826352941
2.306	290.329	2.846362745
2.35466	290.569	2.848715686
2.36947	291.529	2.858127451
2.38564	292.37	2.866372549
2.36054	294.651	2.888735294
2.39079	297.052	2.91227451
2.40347	295.611	2.898147059
2.40063	298.854	2.929941176
2.4168	299.935	2.940539216
2.44217	299.971	2.940892157
2.49236	302.487	2.965558824
2.49236	306.801	3.007852941
2.51805	307.76	3.017254902
2.54373	307.28	3.01254902
2.55607	311.956	3.058392157
2.59825	314.833	3.086598039
2.62815	313.514	3.073666667
2.65461	313.274	3.071313725
2.68451	311.956	3.058392157
2.69946	315.313	3.091303922
2.6846	318.551	3.12304902
2.72845	317.231	3.110107843
2.69963	321.19	3.148921569
2.71283	324.789	3.184205882
2.7601	325.509	3.191264706
2.78578	325.509	3.191264706
2.82588	327.429	3.210088235
2.81946	328.389	3.2195
2.81303	333.19	3.266568627
2.84674	331.99	3.254803922
2.88446	334.03	3.274803922
2.85476	334.63	3.280686275
2.93161	337.632	3.310117647
2.98066	338.833	3.321892157
2.94073	342.436	3.357215686
2.98446	343.397	3.366637255
3.01511	344.839	3.38077451
3.05071	347.722	3.409039216
3.0859	350.486	3.436137255
3.13498	350.847	3.439676471
3.11645	353.13	3.462058824
3.15708	354.453	3.475029412
3.14441	356.015	3.490343137
3.13462	360.103	3.530421569
3.20849	360.464	3.533960784
3.21617	362.508	3.554
3.18716	366.839	3.596460784
3.2066	368.884	3.616509804
3.2167	369.967	3.627127451
3.26162	371.892	3.646
3.28529	372.494	3.651901961
3.29688	376.706	3.693196078
3.32016	378.632	3.712078431
3.37152	380.318	3.728607843
3.3972	379.355	3.719166667
3.44246	383.087	3.755754902
3.47685	386.15	3.785784314
3.44544	390.836	3.83172549
3.51024	392.639	3.849401961
3.49728	398.409	3.905970588
3.53596	396.725	3.889460784
3.56925	398.649	3.908323529
3.54144	399.971	3.921284314
3.57909	404.902	3.969627451
3.63045	404.782	3.96845098
3.65612	407.428	3.994392157
3.67867	408.992	4.00972549
3.68335	414.286	4.061627451
3.72937	415.61	4.074607843
3.75934	420.906	4.126529412
3.77841	422.712	4.144235294
3.78257	428.131	4.197362745
3.86161	427.89	4.195
3.84189	431.625	4.231617647
3.81499	432.709	4.242245098
3.88933	435.601	4.270598039
3.915	436.685	4.28122549
3.96634	439.457	4.308401961
3.9259	441.989	4.33322549
3.96745	448.379	4.395872549
3.96252	452.239	4.433715686
3.96783	455.254	4.46327451
4.04432	458.633	4.496401961
4.08932	459.478	4.504686275
4.09321	462.254	4.531901961
4.10493	463.582	4.544921569
4.14318	468.611	4.59422549
4.19153	472.224	4.629647059
4.22563	475.838	4.665078431
4.2513	476.2	4.668627451
4.26287	479.212	4.698156863
4.30327	485.963	4.764343137
4.32894	490.666	4.81045098
4.34035	493.802	4.841196078
4.33041	503.092	4.93227451
4.35607	504.299	4.944107843
4.35513	512.026	5.019862745
4.37588	512.751	5.026970588
4.68682	554.809	5.439303922
4.71864	559.399	5.484303922
4.74431	557.95	5.470098039
4.77013	561.695	5.506813725
4.81923	565.199	5.541166667
4.89289	569.55	5.583823529
4.87287	573.419	5.621754902
4.92419	575.716	5.64427451
4.92455	577.651	5.663245098
4.97161	580.917	5.695264706
4.96896	585.272	5.737960784
5.02221	587.45	5.759313725
5.05941	590.355	5.787794118
5.0569	594.228	5.825764706
5.10524	599.193	5.874441176

2min He./Air Plasma			Control			2min He./Air Plasma			Control		
4.99471	569.139	5.579794118	5.13453	604.401	5.9255	6.98192	1119.06	10.97117647	9.06466	1080.05	10.58872549
5.02435	573.856	5.626039216	5.15692	608.278	5.963509804	6.95402	1127.01	11.04911765	9.14946	1082.75	10.61519608
5.0138	578.937	5.675852941	5.20823	609.368	5.974196078	7.02029	1131.56	11.09372549	9.1599	1087.54	10.66215686
5.04528	583.899	5.7245	5.19275	615.307	6.032421569	7.02873	1138.94	11.16607843	9.16458	1091.6	10.70196078
5.06566	586.805	5.752990196	5.2346	618.702	6.065705882	7.0689	1145.58	11.23117647	9.18692	1094.55	10.73088235
5.09132	589.468	5.779098039	5.21829	620.521	6.083539216	7.06834	1150.26	11.27705882	9.2422	1099.34	10.77784314
5.09132	595.281	5.836088235	5.27817	625.129	6.128715686	7.05547	1155.31	11.32656863	9.26056	1101.68	10.80078431
5.14156	599.642	5.878843137	5.30403	627.919	6.156068627	7.09855	1161.59	11.38813725	9.29976	1105.74	10.84058824
5.16329	601.46	5.896666667	5.32245	630.831	6.184617647	7.08384	1168.98	11.46058824	9.34229	1108.82	10.87078431
5.15554	604.126	5.922803922	5.3849	634.107	6.216735294	7.15342	1176.26	11.53196078	9.40906	1112.38	10.90568627
5.13057	607.762	5.95845098	5.38466	637.511	6.250107843	7.18557	1181.68	11.58509804	9.47068	1116.32	10.94431373
5.21834	614.067	6.020264706	5.39706	641.87	6.292843137	7.15185	1189.57	11.66245098	9.53534	1120.76	10.98784314
5.20776	618.675	6.065441176	5.38408	647.079	6.343911765	7.2036	1193.77	11.70362745	9.53185	1123.46	11.01431373
5.2275	623.663	6.114343137	5.44197	649.866	6.371235294	7.23709	1201.3	11.77745098	9.56263	1127.28	11.05176471
5.18866	628.02	6.157058824	5.46762	652.047	6.392617647	7.26279	1208.46	11.84764706	9.63946	1131.59	11.09401961
5.24045	630.078	6.177235294	5.53962	657.38	6.444901961	7.28849	1213.01	11.8922549	9.66507	1133.32	11.11098039
5.28594	633.59	6.211666667	5.49363	660.411	6.474617647	7.32978	1220.28	11.96352941	9.7163	1134.92	11.12666667
5.29396	636.133	6.236598039	5.57059	662.593	6.496009804	7.34029	1225.71	12.01676471	9.76752	1140.78	11.18411765
5.33707	640.252	6.276980392	5.58114	665.625	6.525735294	7.38871	1232.12	12.07960784	9.83896	1142.37	11.19970588
5.33782	647.522	6.348254902	5.61451	669.871	6.567362745	7.36629	1240.39	12.16068627	9.86641	1147.17	11.24676471
5.33782	649.583	6.368460784	5.65458	671.327	6.581637255	7.39199	1246.94	12.22490196	9.8969	1151.35	11.2877451
5.35467	652.493	6.396990196	5.7245	676.181	6.62922549	7.4449	1251.76	12.27215686	9.94158	1153.2	11.30588235
5.38961	658.435	6.455245098	5.67425	681.279	6.679205882	7.49028	1258.18	12.33509804	10.0003	1158.49	11.3577451
5.41154	662.801	6.49804902	5.70537	686.986	6.735156863	7.49185	1264.48	12.39686275	9.99893	1162.8	11.4
5.41566	667.169	6.540872549	5.75156	689.901	6.763735294	7.51789	1271.04	12.46117647	10.1526	1165.76	11.42901961
5.44139	671.175	6.580147059	5.75191	694.517	6.808990196	7.47701	1276.23	12.51205882	10.1526	1168.1	11.45196078
5.45382	674.331	6.611088235	5.80321	696.826	6.831627451	7.5301	1284.77	12.59578431	10.2294	1169.57	11.46637255
5.45323	678.945	6.656323529	5.88016	700.35	6.866176471	7.5887	1291.83	12.665	10.2806	1174.5	11.51470588
5.52769	683.682	6.702764706	5.86688	704.97	6.911470588	7.59316	1296.79	12.71362745	10.352	1177.34	11.54254902
5.537	688.299	6.748029412	5.8805	707.888	6.940078431	7.61843	1304.46	12.78882353	10.3947	1180.54	11.57392157
5.51965	693.524	6.799254902	5.9318	711.658	6.977039216	7.58247	1310.27	12.84578431	10.4381	1183.5	11.60294118
5.54537	694.861	6.812362745	5.92017	715.429	7.014009804	7.60028	1315.71	12.89911765	10.5098	1185.23	11.61990196
5.59715	699.968	6.862431373	5.97487	720.816	7.066823529	7.63904	1322.27	12.96343137	10.5448	1189.42	11.66098039
5.6016	705.562	6.91727451	6.00944	725.551	7.113245098	7.72	1329.08	13.03019608	10.6121	1192.01	11.68637255
5.61932	707.873	6.939931373	6.00761	729.073	7.14777451	7.67737	1337.5	13.1127451	10.6565	1194.35	11.70931373
5.62081	713.859	6.998617647	6.03544	733.931	7.195401961	7.75446	1345.68	13.19294118	10.6975	1197.81	11.74323529
5.62947	718.473	7.043852941	6.06109	736.604	7.221607843	7.80585	1348.28	13.21843137	10.7796	1199.17	11.75656863
5.67595	719.565	7.054558824	6.06412	739.885	7.25377451	7.84714	1355.1	13.28529412	10.82	1201.51	11.7795098
5.68334	722.723	7.085519608	6.09155	745.234	7.306215686	7.8635	1359.56	13.32901961	10.8529	1204.84	11.81215686
5.67572	728.675	7.143872549	6.12676	748.151	7.334813725	7.85722	1367.13	13.40323529	10.9008	1205.46	11.81823529
5.68463	732.929	7.185578431	6.1874	750.097	7.353892157	7.85978	1375.82	13.48843137	10.9577	1209.54	11.85823529
5.72229	736.575	7.221323529	6.19693	755.084	7.402784314	7.82834	1382.31	13.55205882	11.0348	1210.28	11.8654902
5.72824	740.465	7.259460784	6.19511	758.612	7.437372549	7.83482	1389.63	13.62382353	11.1118	1212.5	11.8872549
5.75396	748.492	7.338156863	6.23583	763.357	7.483892157	7.93629	1395.33	13.67970588	11.1374	1216.82	11.92960784
5.77969	750.56	7.358431373	6.29318	769.566	7.544764706	7.95105	1401.16	13.73686275	11.2067	1218.92	11.95019608
5.83113	753.845	7.390637255	6.30181	772.732	7.575803922	7.98807	1408.85	13.8122549	11.2634	1224.45	12.00441176
5.75471	759.079	7.44195098	6.30569	777.603	7.623558824	8.01376	1415.55	13.87794118	11.3379	1225.19	12.01166667
5.80883	765.897	7.508794118	6.33475	779.918	7.646254902	8.0219	1422.88	13.94980392	11.3844	1226.67	12.02617647
5.79682	771.256	7.561333333	6.35846	784.426	7.69045098	8.05494	1428.84	14.00823529	11.454	1228.89	12.04794118
5.81485	774.302	7.591196078	6.43806	788.814	7.733470588	8.03865	1434.18	14.06058824	11.5013	1230.13	12.06009804
5.86158	776.861	7.616284314	6.45227	791.74	7.762156863	8.0727	1441.39	14.13127451	11.5673	1234.81	12.10598039
5.90383	785.149	7.697539216	6.46279	794.422	7.78845098	8.11751	1447.61	14.1922549	11.6136	1237.28	12.13019608
5.91197	788.442	7.729823529	6.54642	796.129	7.805186275	8.15527	1455.82	14.2727451	11.6853	1239.87	12.15558824
5.91476	791.003	7.754931373	6.52034	802.716	7.869764706	8.14349	1461.64	14.32980392	11.7598	1241.11	12.1677451
5.95605	797.642	7.820019608	6.52613	807.285	7.914558824	8.16918	1466.73	14.37970588	11.7837	1241.97	12.17617647
5.93646	803.85	7.880882353	6.56702	812.642	7.967078431	8.18543	1472.44	14.43568627	11.8828	1246.04	12.21607843
5.9879	808.721	7.928637255	6.57766	815.564	7.99572549	8.22095	1479.9	14.50882353	11.9597	1250.12	12.25607843
6.03934	812.253	7.963264706	6.62894	822.995	8.068578431	8.24664	1486.24	14.57098039	11.9828	1253.08	12.28509804
6.00658	817.614	8.015823529	6.68022	824.213	8.080519608	8.31102	1493.33	14.6404902	12.0558	1254.69	12.30088235
5.99246	822.61	8.064803922	6.75669	830.063	8.137872549	8.37261	1498.31	14.68931373	12.1602	1253.95	12.29362745
6.03595	826.877	8.106637255	6.79115	832.379	8.160578431	8.41073	1503.66	14.74176471	12.2049	1256.66	12.32019608
6.01556	831.633	8.153264706	6.80085	834.574	8.182098039	8.42714	1509.26	14.79666667	12.2779	1258.27	12.33598039
6.08843	836.268	8.198705882	6.8092	839.208	8.227529412	8.42476	1517.73	14.87970588	12.3787	1259.01	12.34323529
6.03961	843.345	8.268088235	6.88834	842.745	8.262205882	8.45791	1525.34	14.95431373	12.3985	1261.36	12.36627451
6.06794	846.885	8.302794118	6.89713	849.212	8.325607843	8.48048	1531.94	15.01901961	12.4732	1262.96	12.38196078
6.11106	849.57	8.329117647	6.94192	853.85	8.371078431	8.51137	1538.93	15.08754902	12.5502	1264.2	12.39411765
6.11961	856.653	8.398558824	6.89002	858.245	8.414166667	8.58111	1544.8	15.14509804	12.6272	1265.93	12.41107843
6.15594	859.952	8.430901961	6.93841	861.786	8.448882353	8.5862	1552.64	15.22196078	12.7032	1269.76	12.44862745
6.17036	867.65	8.506372549	7.00672	866.061	8.490794118	8.57267	1558.75	15.28186275	12.7805	1269.64	12.44745098
6.19607	870.217	8.531539216	7.03766	870.338	8.53272549	8.63899	1564.73	15.3404902	12.8571	1269.76	12.44862745
6.23353	876.18	8.59	7.02674	873.759	8.566264706	8.6515	1569.71	15.38931373	12.935	1269.39	12.445
6.21998	884.233	8.66895098	7.0929	879.749	8.624990196	8.69465	1578.57	15.47617647	12.9727	1274.46	12.49470588
6.26583	885.576	8.682117647	7.07745	885.13	8.677745098	8.7304	1583.31	15.52264706	13.045	1276.19	12.51166667
6.27032	890.58	8.731176471	7.10217	891.451	8.739715686	8.79187	1591.3	15.60098039	13.1153	1278.67	12.53598039
6.27458	898.029	8.804205882	7.17247	892.916	8.754078431	8.76337	1598.29	15.6695098	13.2054	1281.02	12.55901961
6.26095	901.328	8.83654902	7.18438	902.927	8.85222549	8.86611	1605.03	15.73558824	13.2094	1284.97	12.5977451
6.30103	905.848	8.880862745	7.22751	905.248	8.874980392	8.88679	1611.91	15.80303922	13.2728	1287.45	12.62205882
6.35246	910.126	8.922803922	7.63387	949.279	9.306656863	8.86668	1617.03	15.85323529	14.2541	1291.78	12.6645098
6.32675	918.807	9.007911765	7.63052	958.344	9.395529412	8.91804	1625.16	15.93294118	14.3347	1293.14	12.67784314
6.35814	923.7	9.055882353	7.6577	954.301	9.355892157	8.94373	1633.45	16.01421569	14.3736	1288.56	12.63294118
6.3788	929.573	9.113460784	7.69992	959.937	9.411147059	9.01281	1638.44	16.06313725	14.5105	1286.21	12.60990196
6.36564	932.632	9.14345098	7.73738	963.737	9.448401961	9.02943	1646.06	16.13784314	14.5922	1285.35	12.60147059
6.40524	938.509	9.201068627	7.76301	966.434	9.474843137	9.06972	1649.06	16.1672549	14.6745	1284.36	12.59176471
6.40524	943.162	9.246686275	7.81426	968.15	9.491666667	9.07658	1656.69	16.24205882	14.7163	1286.09	12.60872549
6.40524	950.513	9.318754902	7.86135	972.073	9.530127451	9.07418	1666.69	16.34009804	14.8492	1285.22	12.60019608
6.46525	953.822	9.351196078	7.90815	973.542	9.544529412	9.15051	1672.32	16.39529412	14.891	1286.95	12.61715686
6.48269	959.831	9.410107843	7.94564	978.069	9.588911765	9.20187	1678.45	16.45539216	14.9963	1286.46	12.61235294
6.492	964.846	9.45927451	7.9777	981.863	9.626107843	9.2107	1684.71	16.51676471	15.0658	1287.82	12.62568627
6.48311	970.229	9.51204902	7.99431	983.821	9.645303922	9.24457	1692.6	16.59411765	15.1684	1288.56	12.63294118
6.55122	974.758	9.55645098	8.09682	985.168	9.658509804	9.28487	1698.87	16.65558824	15.247	1289.18	12.63901961
6.56086	982.593	9.633264706	8.06995	989.821	9.704127451	9.30524	1704.63	16.71205882	15.3248	1287.33	12.62088235
6.55627	987.125	9.677696078	8.19571	990.801	9.713735294	9.38228	1711.66	16.78098039	15.4251	1288.69	12.63421569
6.58699	994.354	9.748568627	8.20735	996.558	9.770176471	9.43363	1717	16.83333333	15.5076	1286.71	12.61480392
6.58699	997.541	9.779813725	8.2509	1002.81	9.831470588	9.46953	1725.39	16.91558824	15.5516	1288.07	12.62813725
6.5698	1005.76	9.860392157	8.27091	1006.36	9.86627451	9.4926	1732.02	16.98058824	15.6628	1286.46	12.61235294
6.68763	1010.17	9.903627451	8.33129	1008.2	9.884313725	9.52701	1738.29	17.04205882	15.7356	1287.2	12.61960784
6.65861	1016.18	9.96254902	8.30695	1012	9.921568627	9.56322	1745.31	17.11088235	15.8523	1284.6	12.59411765
6.6452	1020.48	10.00470588	8.37368	1014.33	9.944411765	9.61431	1751.7	17.17352941	15.9245	1285.47	12.60264706
6.68761	1026.62	10.06490196	8.41881	1017.52	9.975686275	9.66566	1758.1	17.23627451	15.9825	1284.23	12.5904902
6.69148	1033.49	10.1322549	8.44779	1021.94	10.01901961	9.69133	1762.74	17.28176471	16.1188	1282.75	12.57598039
6.66577	1038.41	10.1804902	8.50319	1026.6	10.06470588	9.76542	1769.77	17.35068627	16.2193	1283.12	12.57960784
6.7686	1043.85	10.23382353	8.51133	1031.51	10.11284314	9.80001	1776.17	17.41343137	16.3022	1282.01	12.56872549
6.7686	1050.35	10.29754902	8.55064	1034.95	10.14656863	9.85455	1782.08	17.47137255	16.4081	1281.39	12.56264706
6.76975	1055.99	10.35284314	8.58286	1039.98	10.19588235	9.86333	1785.85	17.50833333	16.5228	1279.16	12.54078431
6.76403	1060.9	10.40098039	8.6498	1041.09	10.20676471	9.9491	1790.5	17.55392157	16.5882	1281.26	12.56137255
6.86205	1066.18	10.4527451	8.61187	1047.48	10.26941176	9.97477	1798.41	17.63147059	16.6566	1277.43	12.52382353
6.84675	1073.55	10.525	8.68874	1051.05	10.30441176	9.99418	1804.81	17.69421569	16.784	1277.68	12.52627451
6.86847	1079.32	10.58156863	8.79187	1052.89	10.32245098	10.0702	1811.34	17.75823529	16.8689	1274.71	12.49715686
6.87177	1082.64	10.61411765	8.83043	1057.1	10.36372549	10.1416	1816.36	17.80745098	16.9794	1271.74	12.46803922
6.87348	1089.89	10.68519608	8.86542	1061.27	10.40460784	10.2451	1823.02	17.8727451	17.1125	1269.89	12.44990196
6.92489	1095.18	10.73705882	8.89875	1064.09	10.4322549	10.2315	1829.05	17.93186275	17.1894	1269.89	12.44990196
6.91791	1103.18	10.8154902	8.91964	1068.88	10.47921569	10.3085	1835.96	17.99960784	17.2931	1268.03	12.43166667
6.9253	1108.35	10.86617647	8.97701	1071.58	10.50568627	10.3227	1842.63	18.065	17.3187	1264.57	12.3977451
6.99136	1115.49	10.93617647	8.97445	1076.61	10.555	10.3418	1848.29	18.1204902	17.4787	1259.75	12.3504902

2min He./Air Plasma			Control			2min He./Air Plasma			Control		
10.3944	1852.57	18.16245098	17.5915	1255.55	12.30931373	17.3485	2383.87	23.37127451	29.8556	1175	11.51960784
10.4277	1857.85	18.21421569	17.7022	1252.22	12.27666667	17.3938	2386.3	23.39509804	29.9006	1177.58	11.54490196
10.4927	1862.51	18.25990196	17.8308	1245.06	12.20647059	17.445	2388.85	23.42009804	29.9643	1182.52	11.59333333
10.5408	1869.31	18.32656863	17.9436	1238.64	12.14352941	17.5475	2395.75	23.4877451	30.0292	1186.34	11.63078431
10.5921	1874.73	18.37970588	18.1061	1234.32	12.10117647	17.5698	2401.75	23.54656863	30.0617	1191.15	11.67794118
10.6691	1880.45	18.43578431	18.2019	1227.41	12.03343137	17.6677	2404.56	23.57411765	30.1011	1195.09	11.71656863
10.7461	1886.48	18.49490196	18.3463	1222.61	11.98637255	17.7424	2405.84	23.58666667	30.1571	1201.14	11.77588235
10.7718	1890.64	18.53568627	18.4578	1220.16	11.96235294	17.8129	2409.8	23.6254902	30.212	1205.09	11.81460784
10.8026	1898.69	18.61460784	18.5726	1214.47	11.90656863	17.8577	2413.76	23.66431373	30.2666	1209.91	11.86186275
10.8491	1903.22	18.65901961	18.6606	1207.07	11.83401961	17.922	2420.93	23.73460784	30.2666	1215.09	11.91264706
10.9004	1909.52	18.72078431	18.8389	1202.62	11.79039216	17.9968	2422.08	23.74588235	30.4138	1218.55	11.94656863
11.003	1914.31	18.7677451	18.9646	1197.07	11.73598039	18.0634	2427.84	23.80235294	30.4576	1220.53	11.96598039
11.0479	1918.09	18.80480392	19.1053	1192.75	11.69362745	18.1114	2431.16	23.83490196	30.4953	1224.21	12.00205882
11.096	1924.27	18.86539216	19.1985	1188.19	11.64892157	18.1626	2434.88	23.87137255	30.5895	1226.67	12.02617647
11.1063	1931.33	18.93460784	19.337	1185.47	11.6222549	18.2394	2438.46	23.90647059	30.6496	1231.98	12.07823529
11.1833	1937.26	18.9927451	19.4452	1183.62	11.60411765	18.3132	2446.27	23.98303922	30.7146	1237.78	12.13509804
11.2551	1942.3	19.04215686	19.5551	1180.79	11.57637255	18.3597	2449.09	24.01068627	30.7108	1239.63	12.15323529
11.2975	1947.23	19.0904902	19.6355	1179.43	11.56303922	18.4554	2453.06	24.04960784	30.8048	1243.94	12.1954902
11.3634	1953.29	19.14990196	19.7444	1176.97	11.53892157	18.5247	2457.55	24.09362745	30.856	1246.79	12.22343137
11.4292	1958.85	19.20441176	19.8769	1174.38	11.51352941	18.5714	2460.24	24.12	30.956	1252.96	12.28392157
11.4215	1962.64	19.24156863	19.9793	1168.47	11.45558824	18.6378	2466.65	24.18284314	30.9978	1256.79	12.32147059
11.5432	1967.27	19.28696078	20.1073	1165.39	11.42539216	18.7058	2472.03	24.23558824	31.0946	1259.01	12.34323529
11.5945	1974.33	19.35617647	20.1841	1163.05	11.40245098	18.752	2476.25	24.27696078	31.1379	1262.22	12.37470588
11.6202	1978.24	19.3945098	20.3633	1159.11	11.36382353	18.8032	2482.4	24.3372549	31.2145	1268.77	12.43892157
11.6763	1985.18	19.46254902	20.4491	1156.28	11.33607843	18.9056	2488.16	24.39372549	31.257	1272.61	12.47656863
11.7393	1989.09	19.50088235	20.5645	1152.46	11.29862745	18.9272	2493.42	24.44529412	31.351	1275.7	12.50686275
11.7747	1996.42	19.5727451	20.6861	1148.28	11.25764706	19.0238	2497.52	24.4854902	31.4181	1279.04	12.53960784
11.826	1998.06	19.58882353	20.8269	1145.69	11.2322549	19.094	2502.26	24.53196078	31.4214	1283.12	12.57960784
11.903	2005.14	19.65823529	20.925	1141.39	11.19009804	19.1605	2509.31	24.60107843	31.4792	1286.58	12.61352941
11.98	2009.81	19.70401961	21.0279	1138.19	11.15872549	19.1798	2512.52	24.63254902	31.525	1289.06	12.63784314
12.0313	2017.02	19.77470588	21.1815	1135.41	11.13147059	19.2426	2519.58	24.70176471	31.6659	1293.89	12.68519608
12.1035	2021.19	19.81558824	21.2583	1132.33	11.10127451	19.3412	2526.51	24.76970588	31.7244	1296.61	12.71186275
12.1736	2024.99	19.85284314	21.3606	1127.28	11.05176471	19.3924	2529.72	24.80117647	31.756	1301.81	12.76284314
12.2455	2027.77	19.88009804	21.5615	1121.25	10.99264706	19.4436	2535.63	24.85911765	31.8472	1304.18	12.78607843
12.2611	2033.34	19.93470588	21.6579	1118.05	10.96127451	19.5268	2539.1	24.89313725	31.8779	1308.63	12.82970588
12.3327	2036.38	19.9645098	21.7976	1113.49	10.91656863	19.558	2543.34	24.93470588	31.926	1314.69	12.88911765
12.427	2041.06	20.01039216	21.848	1112.02	10.90215686	19.6114	2551.61	25.01578431	31.9896	1317.16	12.91333333
12.4442	2045.88	20.05764706	21.9864	1108.32	10.86588235	19.6704	2556.23	25.06107843	31.9633	1322.11	12.96186275
12.5297	2052.97	20.12715686	22.1265	1104.02	10.82372549	19.7092	2564.19	25.13911765	32.0555	1324.58	12.98607843
12.5452	2057.14	20.16803922	22.2578	1102.91	10.81284314	19.7826	2567.14	25.16803922	32.0888	1331.51	13.05401961
12.5965	2059.03	20.18656863	22.3479	1098.61	10.77068627	19.8739	2574.72	25.24235294	32.1728	1334.48	13.08313725
12.6991	2065.49	20.24990196	22.4791	1093.57	10.72127451	19.8925	2579.47	25.28892157	32.2535	1336.09	13.09892157
12.7504	2071.3	20.30686275	22.6438	1088.65	10.67303922	19.9923	2583.58	25.32921569	32.3147	1340.18	13.13901961
12.8274	2074.98	20.34294118	22.7911	1082.51	10.61284314	20.0692	2591.68	25.40862745	32.4073	1343.28	13.16941176
12.9043	2079.91	20.39127451	22.8529	1078.45	10.57303922	20.1206	2596.18	25.4527451	32.4531	1344.39	13.18029412
12.9556	2083.33	20.42480392	23.008	1074.28	10.53215686	20.1829	2600.3	25.49313725	32.489	1347.61	13.21186275
12.9968	2089.28	20.48313725	23.1722	1069.24	10.4827451	20.2284	2608.27	25.57127451	32.5437	1352.81	13.26284314
13.0534	2095.11	20.54029412	23.2818	1068.14	10.47196078	20.2751	2612.78	25.6154902	32.5817	1357.77	13.31147059
13.0959	2097.65	20.56519608	23.4553	1060.78	10.39980392	20.3521	2619.86	25.68490196	32.6538	1359.51	13.32852941
13.1821	2103.73	20.62480392	23.5662	1055.26	10.34568627	20.3777	2625.53	25.7404902	32.6666	1364.22	13.37470588
13.227	2107.28	20.65960784	23.6662	1054.52	10.33843137	20.4804	2629.65	25.78088235	32.7335	1367.82	13.41
13.2947	2112.48	20.71058824	23.7379	1052.89	10.32245098	20.5036	2635.42	25.83745098	32.8033	1372.66	13.45745098
13.3343	2118.96	20.77411765	23.8395	1050.43	10.29833333	20.565	2644.55	25.92696078	32.8534	1375.14	13.48176471
13.4008	2124.67	20.83009804	23.993	1049.57	10.28990196	20.6095	2648.54	25.96607843	32.891	1377.74	13.5072549
13.4697	2129.11	20.87362745	24.1209	1046.25	10.25735294	20.6736	2654.72	26.02666667	32.9223	1381.59	13.545
13.521	2132.47	20.90656863	24.2534	1041.95	10.21519608	20.7165	2658.71	26.06578431	33.0123	1383.95	13.56813725
13.5723	2134.11	20.92264706	24.383	1037.65	10.17303922	20.8144	2664.25	26.12009804	33.034	1388.6	13.61372549
13.6236	2140.83	20.98852941	24.5223	1034.34	10.14058824	20.8401	2668.76	26.16431373	33.1618	1390.83	13.63558824
13.7005	2145.39	21.03323529	24.6002	1033.97	10.13696078	20.8914	2673.91	26.21480392	33.1874	1395.17	13.67813725
13.803	2152.37	21.10166667	24.7097	1031.88	10.11647059	20.994	2681.77	26.29186275	33.2641	1399.26	13.71823529
13.8543	2155.29	21.13029412	24.8212	1029.3	10.09117647	21.0453	2688.48	26.35764706	33.2893	1403.59	13.76068627
13.9225	2160.61	21.18245098	25.008	1027.09	10.0695098	21.1094	2694.03	26.41205882	33.3621	1405.21	13.77656863
13.9709	2165.57	21.23107843	25.0919	1025.13	10.05029412	21.1745	2699.19	26.46264706	33.4269	1410.17	13.82519608
14.0149	2166.83	21.24343137	25.1923	1025.62	10.05509804	21.2582	2703.06	26.50058824	33.4724	1412.53	13.84833333
14.0985	2170.14	21.27588235	25.3038	1023.66	10.03588235	21.3216	2710.03	26.56892157	33.5352	1417.36	13.89568627
14.1235	2175.85	21.33186275	25.4092	1023.04	10.02980392	21.3529	2713.52	26.60313725	33.5554	1419.1	13.9127451
14.1914	2180.81	21.3804902	25.5213	1021.08	10.01058824	21.4156	2720.91	26.67558824	33.6229	1422.08	13.94196078
14.3123	2186.27	21.43401961	25.5838	1023.9	10.03823529	21.4823	2726.2	26.72745098	33.7132	1424.31	13.96382353
14.3626	2190.08	21.47137255	25.7446	1022.43	10.02382353	21.5208	2732.51	26.78931373	33.7387	1429.03	14.01009804
14.4334	2193.52	21.50509804	25.8256	1021.57	10.01539216	21.5615	2737.68	26.84	33.7765	1431.64	14.03568627
14.4755	2198.6	21.55490196	25.901	1021.82	10.01784314	21.6544	2742.58	26.88803922	33.8532	1438.35	14.10147059
14.5449	2202.8	21.59607843	25.9709	1023.16	10.03098039	21.6657	2749.94	26.96019608	33.8788	1440.09	14.11852941
14.6146	2207	21.6372549	26.0919	1024.52	10.04431373	21.713	2754.46	27.0045098	33.978	1443.32	14.15019608
14.6826	2212.22	21.68843137	26.1813	1027.83	10.07676471	21.7899	2761.05	27.06911765	33.9979	1445.44	14.17098039
14.6927	2218.8	21.75294118	26.228	1029.06	10.08882353	21.8925	2769.19	27.14892157	34.0672	1448.17	14.1977451
14.8064	2223.13	21.79539216	26.3064	1028.56	10.08392157	21.9181	2777.6	27.23137255	34.1602	1454.02	14.25509804
14.8782	2224.65	21.81029412	26.4355	1028.2	10.08039216	21.9951	2781.48	27.26941176	34.1857	1456.5	14.27941176
14.9423	2228.46	21.84764706	26.4748	1031.51	10.11284314	22.0463	2787.95	27.33284314	34.2368	1460.73	14.32088235
14.9838	2233.04	21.89254902	26.5702	1033.48	10.13215686	22.1225	2792.74	27.37980392	34.3048	1463.97	14.35264706
15.035	2239.01	21.95107843	26.6644	1035.81	10.155	22.1912	2796.75	27.41911765	34.3627	1467.58	14.38803922
15.1119	2241.94	21.97980392	26.7347	1037.65	10.17303922	22.233	2801.37	27.46441176	34.4231	1470.69	14.41852941
15.1888	2246.78	22.0272549	26.8369	1037.65	10.17303922	22.322	2808.73	27.53656863	34.4928	1472.03	14.43166667
15.2401	2251.36	22.07215686	26.8607	1041.95	10.21519608	22.3893	2814.42	27.59235294	34.5333	1475.75	14.46813725
15.317	2255.3	22.11078431	26.9071	1046.25	10.25735294	22.4343	2821.02	27.65705882	34.5954	1481.09	14.5204902
15.3426	2259.76	22.1545098	27.0093	1049.94	10.29352941	22.4957	2825.8	27.70392157	34.6209	1482.21	14.53147059
15.4656	2264.6	22.20196078	27.113	1053.17	10.32519608	22.6105	2831.89	27.76362745	34.7232	1485.19	14.56068627
15.5099	2268.29	22.23813725	27.1826	1059.18	10.38411765	22.6535	2836.42	27.80803922	34.7743	1489.17	14.59970588
15.557	2270.46	22.25941176	27.3001	1063.35	10.425	22.6684	2842.24	27.86509804	34.793	1493.65	14.64362745
15.6503	2276.07	22.31441176	27.3534	1067.04	10.46117647	22.7691	2847.81	27.91970588	34.9222	1493.03	14.63754902
15.7272	2278.36	22.33686275	28.1724	1099.84	10.7827451	22.8052	2853.65	27.97696078	34.9402	1496.39	14.6704902
15.8041	2283.97	22.39186275	28.289	1089.88	10.68509804	22.9158	2858.18	28.02137255	35.0354	1499.49	14.70088235
15.8297	2288.31	22.43441176	28.3356	1096.64	10.75137255	22.9068	2865.96	28.09764706	35.0507	1503.85	14.74362745
15.907	2290.99	22.46068627	28.4218	1094.92	10.7345098	22.9406	2868.94	28.12686275	35.1258	1504.47	14.74970588
15.9659	2295.2	22.50196078	28.4637	1096.52	10.75019608	22.9706	2875.43	28.1904902	35.2218	1506.96	14.77411765
16.0523	2300.45	22.55343137	28.5536	1100.45	10.78872549	23.0731	2879.84	28.23372549	35.2686	1508.7	14.79117647
16.1109	2304.52	22.59333333	28.6226	1102.91	10.81284314	23.15	2883.75	28.27205882	35.3086	1513.06	14.83392157
16.2065	2307.07	22.61833333	28.6641	1106.23	10.84539216	23.2269	2891.78	28.35078431	35.3842	1513.43	14.83754902
16.2402	2312.55	22.67205882	28.7523	1111.15	10.89362745	23.3038	2898.26	28.41431373	35.4626	1512.81	14.83147059
16.2966	2318.92	22.7345098	28.8254	1112.38	10.90568627	23.3519	2902.54	28.45627451	35.5098	1514.18	14.84490196
16.3681	2322.24	22.76705882	28.8865	1116.2	10.94313725	23.441	2908.64	28.51607843	35.6183	1511.94	14.82294118
16.445	2323.89	22.78323529	28.9627	1122.23	11.0022549	23.5112	2913.96	28.56823529	35.7226	1511.07	14.81441176
16.4962	2329.5	22.83823529	29.0246	1125.56	11.03490196	23.5698	2918.5	28.6127451	35.7926	1513.56	14.83882353
16.5987	2335.63	22.89833333	29.0295	1129.25	11.07107843	23.6046	2924.08	28.66745098	35.8899	1515.3	14.85588235
16.6211	2338.69	22.92833333	29.1123	1134.31	11.12068627	23.6312	2930.96	28.73490196	35.935	1517.42	14.87666667
16.7107	2342.77	22.96833333	29.1891	1137.82	11.15509804	23.7433	2938.49	28.80872549	36.0369	1517.54	14.87784314
16.7531	2345.58	22.99588235	29.2337	1142.62	11.20215686	23.7854	2943.43	28.85715686	36.089	1517.17	14.87421569
16.7866	2351.2	23.05098039	29.3196	1145.94	11.23470588	23.8564	2946.81	28.89029412	36.1828	1520.16	14.90352941
16.8554	2354.91	23.08735294	29.3617	1147.79	11.25284314	23.841	2955.39	28.97441176	36.2552	1521.53	14.91696078
16.9578	2359.76	23.13490196	29.4109	1154.18	11.3154902	23.9346	2959.03	29.01009804	36.3035	1522.28	14.92431373
17.0091	2364.49	23.18127451	29.5078	1155.78	11.33117647	23.9481	2963.98	29.05862745	36.4062	1522.15	14.92303922
17.0859	2368.83	23.22382353	29.5996	1160.71	11.3795098	24.0478	2969.25	29.11029412	36.5014	1524.02	14.94137255
17.1348	2370.24	23.23764706	29.5996	1162.68	11.39882353	24.0991	2975.87	29.17519608	36.5511	1524.4	14.94509804
17.1925	2376.38	23.29784314	29.6764	1167.11	11.4422549	24.1759	2981.72	29.23254902	36.6296	1523.9	14.94019608
17.3126	2378.94	23.32294118	29.7788	1172.9	11.49901961	24.2272	2988.22	29.29627451	36.7436	1520.53	14.90715686

2min He./Air Plasma			Control			2min He./Air Plasma			Control		
24.3297	2992.25	29.33578431	36.7888	1522.28	14.92431373	31.2205	3708.66	36.35941176	44.388	1845.8	18.09607843
24.3752	2997.71	29.38931373	36.8877	1523.15	14.93284314	31.2972	3713.31	36.405	44.4603	1847.43	18.11205882
24.4619	3004.86	29.45941176	36.9792	1526.01	14.96088235	31.3483	3718.23	36.45323529	44.529	1852.21	18.15892157
24.4557	3008.11	29.49127451	37.0331	1525.27	14.95362745	31.4468	3723	36.5	44.6309	1856.24	18.19843137
24.5453	3016.19	29.5704902	37.0998	1529.75	14.99754902	31.4851	3729.76	36.56627451	44.6457	1862.28	18.25764706
24.5619	3021.91	29.62656863	37.1764	1531.87	15.01833333	31.553	3735.6	36.62352941	44.6863	1868.95	18.32303922
24.6254	3029.6	29.70196078	37.253	1532.49	15.02441176	31.5786	3743.44	36.70039216	44.784	1874.49	18.37735294
24.7094	3033.38	29.73901961	37.3551	1533.12	15.03058824	31.6553	3748.35	36.74852941	44.8349	1877.14	18.40333333
24.7897	3036.77	29.7722549	37.4062	1535.49	15.05382353	31.7456	3755.93	36.82284314	45.6362	1912.06	18.74568627
24.8515	3044.72	29.85019608	37.5083	1537.86	15.07705882	31.7816	3760.31	36.86578431	45.7048	1915.72	18.78156863
24.9296	3052.28	29.92431373	37.576	1541.1	15.10882353	31.8092	3767.36	36.93490196	45.7511	1917.23	18.79637255
24.9993	3057.49	29.97539216	37.6249	1541.6	15.11372549	31.937	3774.54	37.00529412	45.8583	1915.59	18.78029412
25.0983	3063.74	30.03666667	37.6946	1543.22	15.12960784	31.9626	3780.8	37.06666667	45.955	1917.35	18.79754902
25.1589	3068.04	30.07882353	37.7856	1545.84	15.15529412	32.0137	3786.39	37.12147059	46.0213	1920.63	18.82970588
25.2077	3075.47	30.15166667	37.8441	1551.2	15.20784314	32.1159	3792.52	37.18156863	46.0755	1919.62	18.81980392
25.2207	3080.81	30.20401961	37.9462	1553.2	15.22745098	32.2182	3795.98	37.2154902	46.141	1923.15	18.85441176
25.289	3085.76	30.25254902	37.9972	1555.58	15.25078431	32.2343	3803.37	37.28794118	46.1903	1926.8	18.89019608
25.324	3093.85	30.33186275	38.0738	1559.19	15.28617647	32.3066	3806.56	37.31921569	46.2924	1930.46	18.92607843
25.3867	3098.68	30.37921569	38.1504	1560.06	15.29470588	32.3463	3814.81	37.40009804	46.3435	1932.85	18.9495098
25.4984	3104.29	30.43421569	38.2015	1560.31	15.29715686	32.4483	3819.86	37.44960784	46.4456	1935.5	18.9754902
25.5356	3109.51	30.48539216	38.2898	1566.79	15.36068627	32.525	3822.79	37.47833333	46.5064	1938.53	19.00519608
25.5748	3116.44	30.55333333	38.337	1568.41	15.37656863	32.5761	3828.78	37.53705882	46.5358	1942.19	19.04107843
25.637	3122.05	30.60833333	38.4099	1569.9	15.39117647	32.6229	3834.64	37.5945098	46.6139	1941.94	19.03862745
25.7397	3127.54	30.66215686	38.4862	1570.03	15.39245098	32.7169	3839.97	37.64676471	46.6757	1947.61	19.09421569
25.8166	3134.01	30.72558824	38.5548	1573.27	15.42421569	32.7607	3844.77	37.69382353	46.7522	1949.76	19.11529412
25.8221	3140.28	30.78705882	38.6487	1576.51	15.45598039	32.8363	3845.43	37.70029412	46.8288	1953.04	19.14745098
25.8792	3145.5	30.83823529	38.6981	1577.13	15.46205882	32.8319	3851.83	37.76303922	46.8799	1956.32	19.17960784
25.9772	3152.28	30.90470588	38.7652	1580.87	15.49872549	32.9597	3857.16	37.81529412	47.0075	1958.72	19.20313725
26.0144	3159.47	30.97519608	38.8408	1581.24	15.50235294	33.0108	3862.23	37.865	47.0585	1961.38	19.22921569
26.1011	3165.61	31.03539216	38.9083	1584.86	15.53784314	33.1067	3868.77	37.92911765	47.1096	1964.79	19.26264706
26.1872	3171.49	31.09303922	39.0107	1584.74	15.53666667	33.1546	3871.17	37.95264706	47.2116	1967.06	19.28490196
26.1934	3175.41	31.13147059	39.0545	1587.61	15.56480392	33.1973	3877.45	38.01421569	47.2615	1970.09	19.31460784
26.3235	3183.26	31.20843137	39.1513	1589.73	15.58558824	33.2694	3880.92	38.04823529	47.3253	1975.23	19.365
26.3618	3191.37	31.28794118	39.2169	1593.97	15.62715686	33.336	3887.46	38.11235294	47.3934	1978.64	19.39843137
26.4267	3197.26	31.34568627	39.2683	1593.84	15.62588235	33.3777	3893.19	38.16852941	47.4383	1981.42	19.42568627
26.4552	3204.07	31.41245098	39.3155	1595.34	15.64058824	33.4732	3899.32	38.22862745	47.536	1983.56	19.44666667
26.5141	3209.44	31.46509804	39.3777	1600.83	15.69441176	33.5601	3903.33	38.26794118	47.5785	1987.85	19.48872549
26.6112	3217.04	31.53960784	39.4436	1604.71	15.73245098	33.5997	3908.8	38.32156863	47.649	1990.88	19.51843137
26.6368	3222.66	31.59470588	39.5121	1607.58	15.76058824	33.7159	3914.27	38.37519608	47.7195	1993.02	19.53941176
26.7137	3228.94	31.65627451	39.5831	1609.58	15.78019608	33.7918	3920.94	38.44058824	47.7494	1997.19	19.58029412
26.7649	3235.49	31.7204902	39.6527	1612.33	15.80715686	33.8567	3923.75	38.46813725	47.8067	2000.98	19.61745098
26.8135	3240.07	31.76539216	39.6968	1615.2	15.83529412	33.8988	3925.88	38.48901961	47.9013	2003	19.6372549
26.8757	3248.32	31.84627451	39.7665	1618.07	15.86343137	33.9475	3932.56	38.5545098	47.9778	2007.67	19.68303922
26.9446	3252.77	31.88990196	39.8364	1620.82	15.89039216	34.059	3939.25	38.62009804	48.0288	2011.21	19.7177451
26.998	3258.67	31.9477451	39.9294	1624.7	15.92843137	34.059	3945.26	38.67901961	48.1228	2015.13	19.75617647
26.9927	3267.72	32.03647059	39.9708	1628.82	15.96882353	34.1612	3949.94	38.72490196	48.1649	2017.53	19.77970588
27.0358	3272.96	32.08784314	40.0151	1631.7	15.99705882	34.2378	3952.48	38.74980392	48.2294	2020.81	19.81186275
27.1288	3279.13	32.14833333	40.0534	1636.83	16.04735294	34.3091	3959.04	38.81411765	48.2492	2022.33	19.82676471
27.1835	3284.38	32.19980392	40.1188	1641.25	16.09068627	34.3554	3963.32	38.85607843	48.357	2028.15	19.88382353
27.2627	3292.65	32.28088235	40.1563	1646.49	16.14205882	34.4236	3970.75	38.92892157	48.3998	2031.31	19.91480392
27.3483	3300.14	32.35431373	40.2364	1645.12	16.12862745	34.4979	3978.24	39.00235294	48.4908	2035.61	19.95696078
27.3892	3305.7	32.40882353	40.3326	1647.37	16.15068627	34.5897	3983.18	39.05078431	48.5395	2037.64	19.97686275
27.4313	3310.55	32.45637255	40.3718	1654.24	16.21803922	34.6281	3987.32	39.09137255	48.5905	2040.04	20.00039216
27.4825	3317.25	32.52205882	40.4229	1657.24	16.24745098	34.715	3990.67	39.12421569	48.667	2043.59	20.03519608
27.5593	3323.28	32.58117647	40.5249	1660.24	16.27686275	34.7903	3996.82	39.1845098	48.7946	2048.02	20.07862745
27.6255	3330.5	32.65196078	40.6269	1661.86	16.2927451	34.8489	4003.91	39.25401961	48.8173	2051.57	20.11343137
27.6649	3337.59	32.72147059	40.6683	1665.36	16.32705882	34.9116	4009.4	39.30784314	48.89	2053.34	20.13078431
27.704	3344.95	32.79362745	40.6977	1670.36	16.37607843	34.9985	4015.16	39.36431373	48.9814	2058.29	20.17931373
27.7945	3352.18	32.8645098	40.7336	1673.87	16.4104902	35.0358	4019.98	39.41156863	49.0294	2059.68	20.19294118
27.8413	3357.96	32.92117647	40.834	1674.24	16.41411765	35.0697	4026.01	39.47068627	49.1008	2065.75	20.25245098
27.9181	3365.72	32.9972549	40.8678	1679.87	16.46931373	35.1578	4033.65	39.54558824	49.1519	2069.8	20.29215686
27.9693	3372.43	33.06303922	40.9597	1683.38	16.50372549	35.2344	4039.95	39.60735294	49.1974	2075.11	20.34421569
27.9949	3380.73	33.14441176	41.0099	1684.88	16.51843137	35.2854	4046.12	39.66784314	49.2687	2078.02	20.3727451
28.0563	3385.72	33.19333333	41.0864	1687.26	16.54176471	35.3365	4050.28	39.70862745	49.3426	2079.54	20.38764706
28.0872	3391.9	33.25392157	41.1374	1692.64	16.5945098	35.4386	4056.32	39.76784314	49.4117	2083.72	20.42862745
28.178	3398.47	33.31833333	41.1834	1695.39	16.62147059	35.5408	4063.55	39.83872549	49.5048	2087.26	20.46333333
28.1937	3407.41	33.40598039	41.2779	1699.03	16.65715686	35.5889	4070.79	39.90970588	49.5627	2091.31	20.50303922
28.3023	3413.6	33.46666667	41.3243	1701.28	16.67921569	35.6824	4077.49	39.97539216	49.6015	2093.97	20.52911765
28.3535	3421.1	33.54019608	41.3908	1706.04	16.72588235	35.6989	4084.6	40.04509804	49.6369	2099.17	20.58009804
28.4513	3428.34	33.61117647	41.4312	1710.43	16.76892157	35.7718	4087.42	40.0727451	49.7134	2103.73	20.62480392
28.5414	3436.11	33.68735294	41.5023	1712.69	16.79107843	35.8124	4095.87	40.15558824	49.7899	2106.9	20.65588235
28.5551	3443.36	33.75843137	41.5993	1716.7	16.83039216	35.9061	4102.71	40.22264706	49.8555	2110.19	20.68813725
28.6226	3448.64	33.81019608	41.6569	1718.96	16.85254902	35.9266	4110.64	40.30039216	49.8838	2115.01	20.73539216
28.6909	3453.39	33.85676471	41.7171	1722.09	16.88323529	35.9593	4116.42	40.35705882	49.9714	2118.06	20.76529412
28.7378	3461.04	33.93176471	41.7987	1723.81	16.90009804	36.0675	4121.25	40.40441176	49.9942	2121.48	20.79882353
28.789	3468.61	34.00598039	41.8639	1727.31	16.93441176	36.151	4126.76	40.45843137	50.0962	2126.68	20.84980392
28.8784	3478.36	34.10156863	41.8432	1731.82	16.97862745	36.1888	4135.1	40.54019608	50.1726	2130.36	20.88588235
28.9405	3484.95	34.16617647	41.9283	1736.7	17.02647059	36.2288	4139.35	40.58186275	50.2151	2136.46	20.94568627
29.0224	3490.1	34.21666667	42.0303	1737.2	17.03137255	36.3073	4150.22	40.68843137	50.2858	2139.51	20.97558824
29.0633	3496.69	34.28127451	42.0813	1738.46	17.04372549	36.339	4156.4	40.74901961	50.3538	2144	21.01960784
29.0965	3500.38	34.31745098	42.1578	1744.09	17.09892157	36.4158	4164.2	40.8254902	50.4022	2148.82	21.06686275
29.1221	3508.83	34.40029412	42.2147	1749.23	17.14931373	36.4926	4172.13	40.90323529	50.4532	2153	21.10784314
29.1988	3515.96	34.47019608	42.2793	1751.74	17.17392157	36.595	4180.2	40.98235294	50.5552	2157.44	21.15137255
29.2756	3519.39	34.50382353	42.3564	1751.61	17.17264706	36.6206	4186.93	41.04833333	50.6257	2160.36	21.18
29.3012	3527.45	34.58284314	42.3875	1756	17.21568627	36.69	4192.45	41.10245098	50.6577	2164.93	21.22480392
29.4035	3532.08	34.62823529	42.464	1760.27	17.25754902	36.7738	4199.18	41.16843137	50.713	2170	21.2745098
29.5314	3538.69	34.69303922	42.5659	1762.65	17.28088235	36.7513	4207.4	41.24901961	50.8103	2172.03	21.29441176
29.557	3544.51	34.75009804	42.5914	1766.29	17.31656863	36.8258	4216.69	41.34009804	50.8868	2177.37	21.34676471
29.5674	3548.34	34.78764706	42.6679	1768.92	17.34235294	36.9026	4222.51	41.39715686	50.9123	2181.18	21.38411765
29.6365	3555.87	34.86147059	42.7444	1772.31	17.37558824	37.0049	4228.43	41.45519608	50.9844	2185.37	21.42519608
29.7109	3561.68	34.91843137	42.8208	1775.07	17.40264706	37.0236	4236.37	41.53303922	51.0561	2187.91	21.45009804
29.7877	3568.94	34.98960784	42.861	1778.08	17.43215686	37.1155	4246.2	41.62941176	51.0974	2192.99	21.49990196
29.8418	3574.89	35.04794118	42.9133	1783.99	17.49009804	37.1885	4249.71	41.66382353	51.136	2199.73	21.56598039
29.9279	3580.97	35.10754902	42.9774	1787	17.51960784	37.2047	4257.79	41.74303922	51.1769	2205.32	21.62078431
30.0125	3586.13	35.15813725	43.0799	1786.88	17.51843137	37.245	4266.56	41.82901961	51.2982	2208.76	21.6545098
30.0396	3590.36	35.19960784	43.0714	1789.89	17.54794118	37.2892	4272.22	41.8845098	51.3715	2211.56	21.68196078
30.0954	3595.79	35.25284314	43.1659	1793.28	17.58117647	37.3599	4277.21	41.93343137	51.3715	2215.38	21.71941176
30.146	3604.66	35.33980392	43.2576	1797.93	17.62676471	37.428	4284.5	42.00490196	51.4989	2217.67	21.74186275
30.2228	3610.75	35.3995098	43.3054	1800.32	17.65019608	37.4952	4292.6	42.08431373	51.5455	2223.27	21.79676471
30.2483	3616.71	35.45794118	43.3819	1802.71	17.67362745	37.543	4300.17	42.15852941	51.5865	2227.95	21.84264706
30.3251	3621.22	35.50215686	43.4583	1803.59	17.6822549	37.6198	4306.21	42.2177451	51.6543	2232.02	21.88254902
30.3762	3628.24	35.57098039	43.5348	1807.87	17.72421569	37.6425	4315.38	42.30764706	51.743	2235.96	21.92117647
30.4529	3634.61	35.63343137	43.6279	1810	17.74509804	37.7349	4323.48	42.38705882	51.8097	2238.5	21.94607843
30.5041	3641.15	35.69754902	43.6425	1812.13	17.76598039	37.7765	4331.17	42.46245098	51.8417	2243.46	21.99470588
30.6064	3645.78	35.74294118	43.708	1814.27	17.78696078	37.8503	4339.14	42.54058824	51.9312	2247.02	22.02960784
30.6419	3653.73	35.82088235	43.79	1818.11	17.82509804	37.9015	4346.98	42.61745098	52.0286	2249.43	22.05323529
30.7273	3659.29	35.87539216	43.8403	1818.41	17.82754902	37.9776	4354.69	42.69303922	51.9949	2253.76	22.09568627
30.8145	3667.11	35.95205882	43.9105	1821.17	17.85460784	38.0206	4361.99	42.76460784	52.0879	2258.47	22.14186275
30.8125	3671.62	35.99627451	43.9753	1826.32	17.90509804	38.0619	4370.78	42.85078431	52.1849	2261.01	22.16676471
30.8583	3678.39	36.06264706	44.0703	1830.71	17.94813725	38.1288	4379.31	42.93441176	52.2532	2265.22	22.20803922
30.926	3683.56	36.11333333	44.1212	1831.59	17.95676471	38.198	4385.54	42.9954902	52.3208	2269.8	22.25294118
30.9668	3689.4	36.17058824	44.1977	1834.99	17.99009804	38.2379	4394.78	43.08607843	52.3715	2269.93	22.25421569
31.0517	3696.04	36.23568627	44.2741	1837.12	18.01098039	38.2856	4400.46	43.14176471	52.4932	2275.4	22.30784314
31.138	3701.35	36.2877451	44.3443	1842.91	18.0677451	38.3624	4406.27	43.19872549	52.5442	2279.35	22.34656863

2min He./Air Plasma		
38.4135	4416.29	43.29696078
38.4819	4424.81	43.3804902
38.5467	4433.21	43.46284314
38.5897	4439.58	43.52529412
38.6348	4445	43.57843137
38.7033	4452.46	43.65156863
38.7976	4461.01	43.73539216
38.8232	4466.17	43.78598039
38.8743	4475.24	43.87490196
38.951	4483.37	43.95460784
39.0278	4490.01	44.01970588
39.0533	4497.2	44.09019608
39.1237	4506.29	44.17931373
39.19	4515.25	44.26715686
39.232	4523.13	44.34441176
39.3246	4531.28	44.42431373
39.3662	4539.44	44.50431373
39.4676	4548	44.58823529
39.4782	4556.91	44.67558824
39.5592	4560.57	44.71147059
39.6854	4572.12	44.82470588
39.7027	4579.46	44.89666667
39.7698	4589.39	44.99401961
39.8465	4598.64	45.08470588
39.8465	4604.9	45.14607843
39.9235	4613.35	45.22892157
39.951	4618.93	45.28362745
39.9716	4626.15	45.35441176
39.9752	4636.79	45.45872549
40.0519	4646.46	45.55352941
40.103	4653.54	45.62294118
40.1541	4661.17	45.6977451
40.282	4670.31	45.78735294
40.3179	4679.17	45.87421569
40.3553	4685.31	45.93441176
40.4118	4694.31	46.02264706
40.4273	4702.1	46.09901961
40.4926	4711.52	46.19137255
40.5586	4720.68	46.28117647
40.6253	4729.5	46.36764706
40.6678	4737.14	46.44254902
40.6989	4744.79	46.51754902
40.7853	4753.4	46.60196078
40.8696	4761.59	46.6822549
40.9078	4771.3	46.77745098
40.9989	4779.65	46.85931373
41.0149	4788.27	46.94382353
41.0589	4794.7	47.00686275
41.1532	4801.83	47.07676471
41.194	4811.3	47.16960784
41.1855	4819.1	47.24607843
41.3056	4827.99	47.33323529
41.3823	4836.35	47.41519608
41.4078	4844.15	47.49166667
41.51	4850.46	47.55352941
41.5356	4857.86	47.62607843
41.6378	4867.6	47.72156863
41.6484	4876.51	47.80892157
41.7391	4881.18	47.85470588
41.7916	4893.51	47.97558824
41.8171	4901.19	48.05088235
41.8938	4910.24	48.13960784
41.9389	4918.75	48.22303922
41.9796	4927.53	48.30911765
42.0196	4936.6	48.39803922
42.0849	4944.15	48.47205882
42.1217	4953.09	48.55970588
42.1785	4962.3	48.65
42.2135	4969.73	48.72284314
42.2533	4976.4	48.78823529
42.3659	4985.46	48.87705882
42.4003	4993.16	48.95254902
42.4749	5004.03	49.05911765
42.5679	5012.42	49.14137255
42.586	5019.31	49.20892157
42.6098	5028.53	49.29931373
42.6609	5035.97	49.3722549

Control		
52.6206	2282.79	22.38029412
52.6951	2285.6	22.40784314
52.748	2283.94	22.39156863
52.8723	2286.24	22.41411765
52.8904	2290.32	22.45411765
53.013	2292.99	22.48029412
53.0837	2296.18	22.51156863
53.1775	2300.39	22.55284314
53.1738	2302.18	22.57039216
53.2679	2305.88	22.60666667
53.3607	2311.26	22.65941176
53.4257	2317.25	22.71813725
53.4868	2321.58	22.76058824
53.5632	2327.7	22.82058824
53.6396	2330.25	22.84558824
53.7138	2335.86	22.90058824
53.741	2342.62	22.96686275
53.7931	2349.51	23.03441176
53.8862	2354.11	23.0795098
53.9059	2357.17	23.1095098
53.9456	2363.18	23.16843137
54.0041	2371.74	23.25235294
54.0686	2377.23	23.30617647
54.1293	2384.01	23.37264706
54.1707	2388.1	23.4127451
54.2542	2395.72	23.48745098
54.2619	2402.75	23.55637255
54.3776	2410.54	23.6327451
54.4288	2423.71	23.76186275
54.4706	2428.82	23.81196078
54.5392	2433.17	23.85460784
55.1432	2519.66	24.70254902
55.1854	2529.02	24.79431373
55.2753	2534.93	24.8522549
55.2717	2536.73	24.86990196
55.347	2542.76	24.92901961
55.4234	2547.9	24.97941176
55.4743	2555.1	25.05
55.525	2563.12	25.12862745
55.5596	2570.69	25.20284314
55.627	2579.04	25.28470588
55.7288	2584.3	25.33627451
55.7196	2590.85	25.4004902
55.804	2598.95	25.47990196
55.8404	2606.8	25.55686275
55.8978	2615.29	25.64009804
55.9073	2623.01	25.71578431
55.9328	2632.29	25.80676471
56.0236	2639.76	25.88
56.0601	2650.16	25.98196078
56.1365	2655.44	26.03372549
56.1757	2665.74	26.13470588
56.2129	2672.82	26.20411765
56.2892	2680.03	26.27480392
56.328	2688.93	26.36205882
56.3842	2698.73	26.45813725
56.3657	2708.28	26.55176471
56.442	2714.48	26.61254902
56.5184	2723.39	26.69990196
56.5947	2731.94	26.78372549
56.6047	2740.45	26.86715686
56.6369	2749.74	26.95823529
56.6728	2757.75	27.03676471
56.773	2766.14	27.11901961
56.7635	2775.97	27.21539216
56.824	2783.59	27.29009804
56.9003	2792.26	27.37509804
56.9174	2800.54	27.45627451
56.948	2811.38	27.56254902
57.0131	2817.71	27.62460784
57.0532	2827.15	27.71715686
57.1235	2839.83	27.84147059
57.1073	2849.42	27.9354902
57.155	2857.83	28.01794118
57.2567	2866.65	28.10441176
57.2999	2877.15	28.20735294
57.3066	2886.5	28.29901961
57.3654	2897.02	28.40215686
57.4095	2907.78	28.50764706
57.4604	2916.08	28.58901961
57.5112	2925.94	28.68568627
57.5356	2935.67	28.78107843
57.5968	2945.54	28.87784314
57.6385	2956.59	28.98617647
57.7148	2967.77	29.09578431
57.7772	2975.71	29.17362745
57.7658	2986.44	29.27882353
57.8155	2995.02	29.36294118

CONTROL

EXTENSION (In)	TIME (Sec)	LOAD (Lb)	Stress (PSI)	Adj Strain (mm/mm)
0	0	0.018266	0.146128	0
0.028875	0.174	0.109596	0.87677	0.028875
0.079	0.429	0.694109	5.552876	0.079
0.112625	0.599	1.406485	11.25188	0.112625
0.17725	0.928	2.575512	20.604093	0.17725
0.227625	1.183	2.81297	22.50376	0.227625
0.261	1.353	2.831236	22.64989	0.261
0.311375	1.608	3.214823	25.718584	0.311375
0.3615	1.863	3.379217	27.033739	0.3615
0.395125	2.033	3.452281	27.618253	0.395125
0.445125	2.287	3.488813	27.910508	0.445125
0.4955	2.543	3.726272	29.810176	0.4955
0.528875	2.713	3.799336	30.39469	0.528875
0.579375	2.969	4.109859	32.878871	0.579375
0.629375	3.223	4.000263	32.002102	0.629375
0.663125	3.394	3.835868	30.686947	0.663125
0.713375	3.649	3.653208	29.225663	0.713375
0.76375	3.904	3.762804	30.102433	0.76375
0.79725	4.075	3.981996	31.855973	0.79725
0.8475	4.33	4.109859	32.878871	0.8475
0.89775	4.585	3.927198	31.417588	0.89775
0.93125	4.755	4.018528	32.148229	0.93125
0.9815	5.01	4.109859	32.878871	0.9815
1.015	5.18	4.000263	32.002102	1.015
1.068375	5.451	4.164657	33.317257	1.068375
1.11875	5.707	4.292519	34.340155	1.11875
1.15225	5.877	4.000263	32.002102	1.15225
1.202375	6.131	4.182923	33.463384	1.202375
1.25275	6.386	3.981996	31.855973	1.25275
1.286125	6.556	3.817602	30.540818	1.286125
1.336375	6.811	3.671474	29.371792	1.336375
1.3865	7.066	3.744538	29.956306	1.3865
1.420125	7.237	3.817602	30.540818	1.420125
1.470375	7.491	3.835868	30.686947	1.470375
1.520625	7.747	3.415749	27.325996	1.520625
1.554	7.917	3.561877	28.495021	1.554
1.60425	8.172	3.634942	29.079535	1.60425
1.6545	8.427	3.452281	27.618253	1.6545
1.688125	8.597	3.488813	27.910508	1.688125
1.738375	8.852	3.634942	29.079535	1.738375
1.788625	9.107	3.360951	26.887609	1.788625
1.822	9.277	3.397483	27.179866	1.822
1.87225	9.531	3.287887	26.303098	1.87225
1.905625	9.701	3.360951	26.887609	1.905625
1.956	9.956	3.634942	29.079535	1.956
2.00625	10.211	3.671474	29.371792	2.00625
2.039625	10.381	3.561877	28.495021	2.039625
2.08975	10.635	3.616676	28.933408	2.08975
2.14225	10.902	3.525345	28.202764	2.14225
2.175875	11.072	3.525345	28.202764	2.175875
2.226125	11.327	3.835868	30.686947	2.226125
2.2765	11.582	4.201189	33.609514	2.2765
2.309875	11.752	4.402115	35.216924	2.309875
2.360125	12.007	4.365583	34.924667	2.360125
2.4105	12.263	4.201189	33.609514	2.4105
2.444	12.433	4.201189	33.609514	2.444
2.494375	12.688	4.182923	33.463384	2.494375
2.544375	12.943	4.420381	35.363053	2.544375
2.59925	13.221	4.511712	36.093694	2.59925
2.649375	13.476	4.310785	34.486283	2.649375
2.683	13.646	4.56651	36.532081	2.683
2.73325	13.901	4.56651	36.532081	2.73325
2.7835	14.156	4.639574	37.11659	2.7835
2.816875	14.326	4.438647	35.509181	2.816875
2.86725	14.581	4.146391	33.171128	2.86725
2.917625	14.837	4.47518	35.80144	2.917625
2.951125	15.006	4.456913	35.655308	2.951125
3.001375	15.261	4.420381	35.363053	3.001375
3.0515	15.517	4.8405	38.724004	3.0515
3.085125	15.687	4.968362	39.7469	3.085125
3.1355	15.942	4.438647	35.509181	3.1355
3.185625	16.197001	4.785702	38.285618	3.185625
3.21925	16.368	4.548243	36.385949	3.21925
3.269375	16.622	4.65784	37.262722	3.269375
3.319625	16.877001	4.822234	38.577877	3.319625
3.35325	17.047001	4.74917	37.993363	3.35325
3.403375	17.302	5.059693	40.477546	3.403375
3.453625	17.556999	5.041427	40.331414	3.453625
3.48725	17.726999	4.694372	37.554977	3.48725
3.5375	17.983	4.803968	38.431745	3.5375
3.570875	18.152	4.548243	36.385949	3.570875
3.621125	18.407	4.548243	36.385949	3.621125
3.6715	18.663	4.694372	37.554977	3.6715
3.704875	18.832001	4.676106	37.408849	3.704875
3.75525	19.087999	4.109859	32.878871	3.75525
3.8055	19.343	4.109859	32.878871	3.8055
3.839	19.513	4.255987	34.047898	3.839
3.88925	19.767	4.000263	32.002102	3.88925
3.939625	20.023001	4.073327	32.586614	3.939625
3.973125	20.193001	4.310785	34.486283	3.973125
4.02325	20.448	4.018528	32.148229	4.02325
4.073375	20.702	4.000263	32.002102	4.073375
4.107	20.872999	3.817602	30.540818	4.107
4.15725	21.128	3.488813	27.910508	4.15725
4.207375	21.382999	3.671474	29.371792	4.207375
4.245	21.573999	3.68974	29.517919	4.245
4.29525	21.829	3.525345	28.202764	4.29525
4.3455	22.084	4.000263	32.002102	4.3455

2MIN HE/AIR PLASMA TREATED

EXTENSION (In)	TIME (Sec)	LOAD (Lb)	Stress (PSI)	Adj Strain (mm/mm)
0	0.001	0.018266	0.146128	0
0.028625	0.172	0.273991	2.191925	0.028625
0.078875	0.428	1.022898	8.183186	0.078875
0.12925	0.683	2.301521	18.412168	0.12925
0.1795	0.938	3.507079	28.056637	0.1795
0.229875	1.194	4.164657	33.317257	0.229875
0.29625	1.531	5.425014	43.400111	0.29625
0.3465	1.786	5.662472	45.299779	0.3465
0.39675	2.041	5.370215	42.961724	0.39675
0.43025	2.211	5.699004	45.592034	0.43025
0.480375	2.466	6.210453	49.683627	0.480375
0.530625	2.721	6.922829	55.382633	0.530625
0.581	2.976	6.575774	52.606196	0.581
0.63125	3.232	6.539242	52.313937	0.63125
0.681625	3.487	6.393113	51.144909	0.681625
0.73175	3.742	6.447912	51.583295	0.73175
0.782125	3.997	6.466178	51.729423	0.782125
0.8155	4.167	6.630572	53.044578	0.8155
0.86575	4.421	6.667104	53.336837	0.86575
0.916	4.677	6.137389	49.099113	0.916
0.966375	4.932	6.466178	51.729423	0.966375
1.016625	5.187	7.032425	56.259401	1.016625
1.07	5.459	6.959361	55.674888	1.07
1.12025	5.714	7.087223	56.697788	1.12025
1.170375	5.968	7.215085	57.720684	1.170375
1.203875	6.139	7.47081	59.76648	1.203875
1.254125	6.393	7.233352	57.866815	1.254125
1.30475	6.65	7.269883	58.15907	1.30475
1.355	6.906	7.087223	56.697788	1.355
1.40525	7.161	7.744801	61.958408	1.40525
1.4555	7.416	7.397745	59.181966	1.4555
1.505625	7.671	7.087223	56.697788	1.505625
1.55575	7.926	7.105489	56.843915	1.55575
1.589375	8.096	7.269883	58.15907	1.589375
1.6395	8.352	7.269883	58.15907	1.6395
1.68975	8.606	6.922829	55.382633	1.68975
1.74	8.862	6.941095	55.52876	1.74
1.79025	9.117	7.123755	56.990043	1.79025
1.840375	9.372	6.886296	55.090374	1.840375
1.8905	9.627	6.977627	55.821015	1.8905
1.94075	9.881	6.703636	53.629092	1.94075
1.974375	10.052	6.667104	53.336837	1.974375
2.0245	10.307	6.86803	54.944246	2.0245
2.074625	10.562	6.429646	51.437168	2.074625
2.127125	10.828	6.758434	54.067478	2.127125
2.177375	11.083	6.648838	53.190709	2.177375
2.227625	11.338	6.137389	49.099113	2.227625
2.27775	11.593	6.064325	48.514603	2.27775
2.327875	11.848	5.680738	45.445907	2.327875
2.361375	12.018	5.735536	45.884293	2.361375
2.411625	12.273	5.918197	47.345576	2.411625
2.46175	12.527	5.845132	46.761062	2.46175
2.511875	12.782	6.046059	48.368472	2.511875
2.562125	13.038	6.137389	49.099113	2.562125
2.612375	13.293	6.283517	50.26814	2.612375
2.6625	13.547	6.173921	49.391372	2.6625
2.71275	13.803	6.027793	48.222344	2.71275
2.746375	13.973	6.301783	50.414268	2.746375
2.7965	14.228	6.520976	52.167809	2.7965
2.84675	14.483	6.721902	53.775219	2.84675
2.897	14.738	6.758434	54.067478	2.897
2.947375	14.994	6.557508	52.460064	2.947375
2.997625	15.249	6.612306	52.89845	2.997625
3.04775	15.504	6.922829	55.382633	3.04775
3.098125	15.76	6.886296	55.090374	3.098125
3.131625	15.93	6.886296	55.090374	3.131625
3.181625	16.184	6.703636	53.629092	3.181625
3.231875	16.438999	6.703636	53.629092	3.231875
3.282125	16.695	7.160287	57.282302	3.282125
3.33225	16.948999	6.849765	54.798119	3.33225
3.3825	17.205	7.160287	57.282302	3.3825
3.43275	17.459	7.251617	58.012943	3.43275
3.482875	17.715	7.142021	57.13617	3.482875
3.516375	17.885	7.379479	59.035839	3.516375
3.566625	18.139999	7.324682	58.597457	3.566625
3.616875	18.395	6.922829	55.382633	3.616875
3.667	18.65	7.47081	59.76648	3.667
3.717375	18.906	8.000525	64.004204	3.717375
3.767625	19.160999	7.050691	56.405529	3.767625
3.81775	19.416	7.616938	60.935508	3.81775
3.868	19.67	8.62157	68.972565	3.868
3.9015	19.841	8.658103	69.264824	3.9015
3.95175	20.096001	8.402378	67.219028	3.95175
4.002	20.351	8.420644	67.365155	4.002
4.052125	20.606001	8.548506	68.388051	4.052125
4.102375	20.861	8.658103	69.264824	4.102375
4.15275	21.117001	8.767699	70.141593	4.15275
4.202875	21.372	8.840763	70.726106	4.202875
4.257375	21.648001	8.420644	67.365155	4.257375
4.291	21.819	8.62157	68.972565	4.291
4.341125	22.073999	9.22435	73.794803	4.341125
4.39125	22.327999	9.005157	72.041257	4.39125
4.4415	22.583	8.840763	70.726106	4.4415
4.491625	22.837999	8.384112	67.072896	4.491625
4.542	23.094	8.164919	65.319359	4.542
4.591875	23.347	8.731166	69.849334	4.591875
4.64225	23.603001	8.000525	64.004204	4.64225
4.67575	23.774	7.963993	63.711945	4.67575

4.379	22.254	3.908932	31.271461	4.379	4.726125	24.028999	8.402378	67.219028	4.726125
4.42925	22.509001	3.744538	29.956306	4.42925	4.77625	24.283001	8.237984	65.903873	4.77625
4.462625	22.677999	4.109859	32.878871	4.462625	4.8265	24.539	8.146653	65.173227	4.8265
4.513	22.934	3.981996	31.855973	4.513	4.876875	24.794001	8.183185	65.465486	4.876875
4.563125	23.188999	3.981996	31.855973	4.563125	4.927	25.049	8.53024	68.241924	4.927
4.596625	23.358999	4.292519	34.340155	4.596625	4.9775	25.304001	9.187817	73.50254	4.9775
4.646875	23.614	4.274253	34.194026	4.646875	5.02775	25.559999	8.639836	69.118692	5.02775
4.69725	23.868999	4.493446	35.947567	4.69725	5.06125	25.73	8.292781	66.342255	5.06125
4.73075	24.039	4.56651	36.532081	4.73075	5.11125	25.983999	8.055323	64.442586	5.11125
4.781	24.294001	4.310785	34.486283	4.781	5.161625	26.239	8.037057	64.296459	5.161625
4.83125	24.549	4.255987	34.047898	4.83125	5.211875	26.493999	7.452544	59.620353	5.211875
4.864625	24.719	3.835868	30.686947	4.864625	5.262125	26.749001	7.489076	59.912612	5.262125
4.914875	24.974001	4.073327	32.586614	4.914875	5.312375	27.004	8.402378	67.219028	5.312375
4.965125	25.229	4.091593	32.732743	4.965125	5.362625	27.26	8.80423	70.433847	5.362625
4.99875	25.4	3.78107	30.248561	4.99875	5.412875	27.514999	8.365846	66.926769	5.412875
5.048875	25.653999	4.018528	32.148229	5.048875	5.446375	27.684999	8.292781	66.342255	5.446375
5.099375	25.91	4.274253	34.194026	5.099375	5.496625	27.940001	7.817865	62.542922	5.496625
5.13275	26.08	4.055061	32.440486	5.13275	5.546875	28.195	7.708268	61.666149	5.546875
5.183125	26.336	3.945464	31.563716	5.183125	5.59725	28.451	7.708268	61.666149	5.59725
5.23325	26.59	4.000263	32.002102	5.23325	5.64725	28.705	7.817865	62.542922	5.64725
5.266875	26.761	3.744538	29.956306	5.266875	5.697625	28.959999	8.146653	65.173227	5.697625
5.317	27.016001	3.908932	31.271461	5.317	5.747875	29.216	7.763067	62.104535	5.747875
5.350375	27.184999	3.835868	30.686947	5.350375	5.798125	29.471001	7.726534	61.812276	5.798125
5.400875	27.441	3.507079	28.056637	5.400875	5.831625	29.641001	7.580406	60.643253	5.831625
5.451125	27.695999	3.671474	29.371792	5.451125	5.882125	29.896999	7.744801	61.958408	5.882125
5.484625	27.865999	3.525345	28.202764	5.484625	5.954625	30.264999	7.507342	60.058739	5.954625
5.534875	28.121	3.561877	28.495021	5.534875	6.005	30.521	7.434278	59.474225	6.005
5.585	28.375999	3.634942	29.079535	5.585	6.055	30.775	7.836131	62.689049	6.055
5.6185	28.546	3.744538	29.956306	5.6185	6.10525	31.030001	7.909195	63.273563	6.10525
5.66875	28.801001	3.616676	28.933408	5.66875	6.155625	31.285999	7.671736	61.373894	6.155625
5.719	29.055	4.018528	32.148229	5.719	6.205875	31.541	7.671736	61.373894	6.205875
5.7525	29.225	3.945464	31.563716	5.7525	6.23925	31.709999	7.690002	61.520021	6.23925
5.80275	29.481001	3.799336	30.39469	5.80275	6.2895	31.966	7.744801	61.958408	6.2895
5.853	29.736	4.383849	35.070796	5.853	6.33975	32.221001	8.055323	64.442586	6.33975
5.886625	29.907	4.219455	33.755641	5.886625	6.39	32.476002	8.201451	65.611614	6.39
5.936875	30.160999	4.219455	33.755641	5.936875	6.44025	32.73	8.585038	68.68031	6.44025
5.98725	30.417	4.146391	33.171128	5.98725	6.4905	32.986	8.676368	69.410951	6.4905
6.020625	30.587	3.945464	31.563716	6.020625	6.5405	33.240002	8.877295	71.018361	6.5405
6.070875	30.841999	4.292519	34.340155	6.070875	6.59075	33.495998	8.785965	70.28772	6.59075
6.121125	31.096001	4.347317	34.778539	6.121125	6.62425	33.665001	8.493708	67.949669	6.62425
6.154625	31.267	4.47518	35.80144	6.154625	6.6745	33.919998	8.365846	66.926769	6.6745
6.204875	31.521	4.676106	37.408849	6.204875	6.72475	34.174999	8.402378	67.219028	6.72475
6.2385	31.691999	4.47518	35.80144	6.2385	6.775	34.431	8.329314	66.634514	6.775
6.288625	31.947001	4.438647	35.509181	6.288625	6.825125	34.686001	8.365846	66.926769	6.825125
6.339	32.202	4.65784	37.262722	6.339	6.8755	34.941002	8.274516	66.196128	6.8755
6.372375	32.372002	4.511712	36.093694	6.372375	6.925625	35.195999	7.963993	63.711945	6.925625
6.422625	32.626999	4.858766	38.870132	6.422625	6.976	35.452	8.055323	64.442586	6.976
6.472875	32.882	5.114491	40.915928	6.472875	7.009375	35.622002	7.872663	62.981304	7.009375
6.5065	33.051998	5.041427	40.331414	6.5065	7.059625	35.876999	8.037057	64.296459	7.059625
6.55675	33.307999	4.8405	38.724004	6.55675	7.109875	36.132	7.799598	62.39679	7.109875
6.607	33.562	5.004895	40.039159	6.607	7.160125	36.387001	8.219717	65.757741	7.160125
6.6405	33.733002	4.8405	38.724004	6.6405	7.21025	36.641998	7.744801	61.958408	7.21025
6.690875	33.987999	4.529977	36.239822	6.690875	7.2605	36.896999	7.288149	58.305198	7.2605
6.741125	34.243	4.511712	36.093694	6.741125	7.31075	37.152	8.237984	65.903873	7.31075
6.774625	34.412998	4.730904	37.847236	6.774625	7.361	37.407001	7.854397	62.835176	7.361
6.824875	34.667999	4.8405	38.724004	6.824875	7.3945	37.577	7.763067	62.104535	7.3945
6.875	34.923	5.096225	40.769801	6.875	7.444875	37.833	8.877295	71.018361	7.444875
6.908625	35.092999	5.571142	44.569138	6.908625	7.495	38.088001	8.603304	68.826438	7.495
6.958875	35.348999	5.260619	42.084956	6.958875	7.545125	38.341999	9.626202	77.009622	7.545125
7.009125	35.603001	5.53461	44.276879	7.009125	7.595375	38.597	9.827129	78.617036	7.595375
7.0425	35.772999	5.662472	45.299779	7.0425	7.645625	38.852001	10.009789	80.078319	7.645625
7.09275	36.028	4.694372	37.554977	7.09275	7.695625	39.106998	9.388744	75.109954	7.695625
7.126375	36.198002	4.456913	35.655308	7.126375	7.746	39.362	9.352212	74.817699	7.746
7.176625	36.453999	4.109859	32.878871	7.176625	7.779375	39.532001	9.808863	78.470905	7.779375
7.22675	36.708	4.584776	36.678208	7.22675	7.829625	39.786999	9.58967	76.717368	7.829625
7.260375	36.879002	4.292519	34.340155	7.260375	7.87975	40.041	8.932093	71.456748	7.87975
7.310625	37.133999	4.237721	33.901769	7.310625	7.95525	40.424999	9.443542	75.54834	7.95525
7.360875	37.389	4.639574	37.11659	7.360875	8.0055	40.68	9.754064	78.032518	8.0055
7.394625	37.560001	4.56651	36.532081	7.394625	8.0555	40.933998	10.502972	84.02378	8.0555
7.444875	37.814999	4.347317	34.778539	7.444875	8.10575	41.188999	10.028055	80.224442	8.10575
7.49525	38.07	5.132757	41.062055	7.49525	8.15575	41.443001	10.028055	80.224442	8.15575
7.528625	38.240002	4.730904	37.847236	7.528625	8.18925	41.613998	9.754064	78.032518	8.18925
7.579	38.494999	4.694372	37.554977	7.579	8.239375	41.868	9.534872	76.278981	8.239375
7.629125	38.75	4.968362	39.7469	7.629125	8.289625	42.123001	9.754064	78.032518	8.289625
7.662625	38.919998	4.65784	37.262722	7.662625	8.339625	42.375999	9.790597	78.324782	8.339625
7.712875	39.174999	5.059693	40.477546	7.712875	8.389875	42.632	10.064588	80.516705	8.389875
7.763125	39.43	4.877032	39.016259	7.763125	8.44	42.887001	9.754064	78.032518	8.440001
7.796625	39.599998	4.548243	36.385949	7.796625	8.498625	43.183998	9.206083	73.648671	8.498625
7.847	39.855	5.370215	42.961724	7.847	8.54875	43.438999	10.228981	81.831856	8.54875
7.89725	40.110001	4.694372	37.554977	7.89725	8.58225	43.609001	10.393376	83.147015	8.58225
7.93075	40.279999	4.730904	37.847236	7.93075	8.63225	43.862999	10.174183	81.39347	8.63225
7.98125	40.535999	5.297151	42.37721	7.98125	8.682375	44.118	10.55777	84.462166	8.682375
8.014625	40.706001	4.93183	39.454646	8.014625	8.732625	44.372002	10.302046	82.416374	8.732625
8.065	40.960999	4.968362	39.7469	8.065	8.782625	44.625999	11.160549	89.2844	8.782625
8.115375	41.216	5.498078	43.984624	8.115375	8.852125	44.98	10.28378	82.270242	8.852125
8.14875	41.386002	5.205821	41.646569	8.14875	8.902375	45.234001	10.959624	87.676994	8.902375
8.199	41.640999	5.151023	41.208187	8.198999	8.952625	45.490002	10.667367	85.338939	8.952624
8.24925	41.896	5.333683	42.669469	8.249249	8.986125	45.66	10.046321	80.370574	8.986125
8.282875	42.066002	5.114491	40.915928	8.282875	9.036125	45.914001	11.34321	90.745682	9.036125
8.333125	42.320999	5.370215	42.961724	8.333125	9.086125	46.167999	11.032687	88.261504	9.086125
8.38325	42.576	5.516344	44.130752	8.38325	9.13625	46.423	10.612568	84.900552	9.13625
8.416875	42.745998	5.205821	41.646569	8.416875	9.1865	46.678001	10.941357	87.530862	9.1865
8.4755	43.043999	5.479812	43.838497	8.4755	9.236625	46.931999	10.082853	80.662828	9.236625
8.525625	43.298	5.242353	41.938828	8.525625	9.28675	47.187	10.74043	85.923448	9.28675
8.55925	43.469002	5.169289	41.354314	8.55925	9.336875	47.442001	10.904825	87.238608	9.336875
8.609375	43.723999	5.351949	42.815597	8.609375	9.37025	47.611	10.265513	82.124111	9.37025
8.65975	43.979	5.351949	42.815597	8.65975	9.4205	47.866001	8.913827	71.310616	9.4205
8.69325	44.148998	5.406748	43.253983	8.69325	9.47075	48.120998	3.434015	27.472123	9.47075
8.743625	44.404999	5.041427	40.331414	8.743625	9.521	48.376999	2.538979	20.311837	9.521
8.793875	44.659	4.712638	37.701104	8.793875	9.571125	48.632	3.086961	24.695686	9.571125
8.827375	44.828999	5.242353	41.938828	8.827375	9.6215	48.887001	1.315155	10.521239	9.6215
8.887125	45.132	5.735536	45.884293	8.887125	9.688375	49.226002	0.566247	4.529978	9.688375