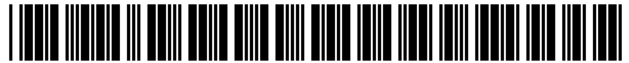

US006649287B2

(12) **United States Patent**
Weeks, Jr. et al.

(10) **Patent No.: US 6,649,287 B2**
(45) **Date of Patent: Nov. 18, 2003**

(54) **GALLIUM NITRIDE MATERIALS AND METHODS**

(75) Inventors: **T. Warren Weeks, Jr.**, Raleigh, NC (US); **Edwin L. Piner**, Cary, NC (US); **Thomas Gehrke**, Apex, NC (US); **Kevin J. Linthicum**, Angier, NC (US)

(73) Assignee: **Nitronex Corporation**, Raleigh, NC (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/736,972**

(22) Filed: **Dec. 14, 2000**

(65) **Prior Publication Data**

US 2002/0074552 A1 Jun. 20, 2002

(51) **Int. Cl.**[7] **B32B 9/00**; B32B 18/00; H01L 21/335

(52) **U.S. Cl.** **428/698**; 428/336; 428/446; 428/689; 428/697; 438/142

(58) **Field of Search** 428/446, 688, 428/689, 677, 698; 438/142

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,192,987 A	3/1993	Khan et al.
5,239,188 A	8/1993	Takeuchi et al.
5,290,393 A	3/1994	Nakamura
5,296,395 A	3/1994	Khan et al.
5,389,571 A	2/1995	Takeuchi et al.
5,393,993 A	2/1995	Edmond et al.
5,442,205 A	8/1995	Brasen et al.

(List continued on next page.)

FOREIGN PATENT DOCUMENTS

EP	0514018	11/1992
EP	0 852 416 A1	7/1998
EP	0 942 459 A1	9/1999
EP	0 951 055 A2	10/1999
JP	11040847	2/1999
JP	1115514	5/1999
WO	WO 9641906	12/1996
WO	WO 00/33365 A1	6/2000
WO	WO 01/27980 A1	4/2001
WO	WO 01/37327 A1	5/2001
WO	WO 01/43174 A2	6/2001
WO	WO 01/47002 A2	6/2001
WO	WO 01/59819 A1	8/2001

OTHER PUBLICATIONS

Pearsall, Thomas P. Volume Editor, "Strained–Layer Superlattices: Materials Science & Technology," Semiconductors and Semimetals, vol. 33, pp. 242–243, Department of Electrical Engineering, University of Washington, Seattle, Washington, Academic Press, Inc. 1991 No month.

Hirosawa et al., "Growth of Single Crystal $A1_xGa_{1-x}N$ Films on Si Substrates by Metalorganic Vapor Phase Epitaxy," Jpn. J. Appl. Phys. vol. 32 (1993) pp 1039–1042 No month.

Primary Examiner—Deborah Jones
Assistant Examiner—G. A. Blackwell-Rudasill
(74) *Attorney, Agent, or Firm*—Wolf, Greenfield & Sacks, P.C.

(57) **ABSTRACT**

The invention provides semiconductor materials including a gallium nitride material layer formed on a silicon substrate and methods to form the semiconductor materials. The semiconductor materials include a transition layer formed between the silicon substrate and the gallium nitride material layer. The transition layer is compositionally-graded to lower stresses in the gallium nitride material layer which can result from differences in thermal expansion rates between the gallium nitride material and the substrate. The lowering of stresses in the gallium nitride material layer reduces the tendency of cracks to form. Thus, the invention enables the production of semiconductor materials including gallium nitride material layers having few or no cracks. The semiconductor materials may be used in a number of microelectronic and optical applications.

70 Claims, 11 Drawing Sheets