



US006653653B2

(12) **United States Patent**  
**Brousseau, III**

(10) **Patent No.:** **US 6,653,653 B2**  
(45) **Date of Patent:** **Nov. 25, 2003**

(54) **SINGLE-ELECTRON TRANSISTORS AND FABRICATION METHODS IN WHICH A PROJECTING FEATURE DEFINES SPACING BETWEEN ELECTRODES**

**FOREIGN PATENT DOCUMENTS**

EP	0 884 768 A2	12/1998
WO	WO 93/08464	4/1993
WO	WO 99/61911	12/1999
WO	WO 01/13432	2/2001

(75) Inventor: **Louis C. Brousseau, III**, Raleigh, NC (US)

**OTHER PUBLICATIONS**

(73) Assignee: **Quantum Logic Devices, Inc.**, Austin, TX (US)

International Search Report, PCT/US/22747, Dec. 21, 2000.  
Lenigk et al., *Surface Characterization of a Silicon-Chip-Based DNA Microarray*, Langmuir, 2001, pp. 2497–2501.  
Letsinger et al., *Use of a Steroid Cyclic Disulfide Anchor in Constructing Gold Nanoparticle–Oligonucleotide Conjugates*, Bioconjugate Chem., 2000, vol. 11, pp. 289–291.  
Taylor et al., *Probing Specific Sequences on Single DNA Molecules With Bioconjugated Fluorescent Nanoparticles*, Analytical Chemistry, vol. 72, No. 9, May 1, 2000, pp. 1979–1986.

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 100 days.

(21) Appl. No.: **09/905,471**

(22) Filed: **Jul. 13, 2001**

(65) **Prior Publication Data**

US 2003/0012930 A1 Jan. 16, 2003

(51) **Int. Cl.**<sup>7</sup> ..... **H01L 29/06**

(52) **U.S. Cl.** ..... **257/39; 257/24; 257/30; 257/253; 257/414; 257/624; 438/49; 438/962**

(58) **Field of Search** ..... **257/24, 25, 30, 257/37, 38, 39, 253, 414, 622–624; 438/49, 962**

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

4,777,019 A	10/1988	Dandekar	422/68
4,778,769 A	10/1988	Forrest et al.	436/501
4,877,582 A	10/1989	Oda et al.	422/68
4,894,339 A	1/1990	Hanazato et al.	435/182
5,039,390 A	8/1991	Hampp et al.	204/412
5,219,577 A	6/1993	Kossovsky et al.	424/494
5,408,106 A *	4/1995	Seabaugh	257/17
5,420,746 A	5/1995	Smith	361/311
5,543,351 A	8/1996	Hirai et al.	
5,571,376 A *	11/1996	Bestwick et al.	156/647.1
5,576,563 A	11/1996	Chung	257/253
5,646,420 A	7/1997	Yamashita	257/17
5,653,939 A	8/1997	Hollis et al.	422/50
5,747,839 A	5/1998	Hammond et al.	257/253

(List continued on next page.)

(List continued on next page.)

*Primary Examiner*—Bradley W. Baumeister

(74) *Attorney, Agent, or Firm*—Myers Bigel Sibley & Sajovec

(57) **ABSTRACT**

A single-electron transistor includes a projecting feature, such as a pyramid, that projects from a face of a substrate. A first electrode is provided on the substrate face that extends onto the projecting feature. A second electrode is provided on the substrate face that extends onto the projecting feature and that is spaced apart from the first electrode. At least one nanoparticle is provided on the projecting feature between the first and second electrodes. Accordingly, the geometric configuration of the projecting feature can define the spacing between the first and second electrodes. The single-electron transistors may be fabricated by forming a projecting feature on a substrate that projects from a face thereof, forming a first electrode on the substrate face that extends onto the projecting feature, forming a second electrode on the substrate face that extends onto the projecting feature and that is spaced apart from the first electrode, and placing at least one nanoparticle on the projecting feature between the first and second electrodes.

**56 Claims, 10 Drawing Sheets**

