



US006933541B1

(12) **United States Patent**  
**Huang**

(10) **Patent No.:** **US 6,933,541 B1**

(45) **Date of Patent:** **Aug. 23, 2005**

(54) **EMITTER TURN-OFF THYRISTORS (ETO)**

(75) Inventor: **Alex Q. Huang**, Blacksburg, VA (US)

(73) Assignee: **Virginia Tech Intellectual Properties, Inc.**, Blacksburg, VA (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.: **09/486,779**

(22) PCT Filed: **Sep. 30, 1998**

(86) PCT No.: **PCT/US98/20594**

§ 371 (c)(1),  
(2), (4) Date: **Mar. 2, 2000**

(87) PCT Pub. No.: **WO99/17374**

PCT Pub. Date: **Apr. 8, 1999**

**Related U.S. Application Data**

(60) Provisional application No. 60/060,557, filed on Sep. 30, 1997.

(51) **Int. Cl.**<sup>7</sup> ..... **H01L 29/74; H01L 31/111**

(52) **U.S. Cl.** ..... **257/177; 257/133; 257/138; 257/147; 257/150; 257/180; 257/181**

(58) **Field of Search** ..... **257/119, 177, 133, 257/135, 138, 139, 140, 146, 147, 163, 150, 257/180, 181**

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

4,768,075 A \* 8/1988 Broich et al. .... 257/181  
5,856,683 A \* 1/1999 Schlangenotto ..... 257/140

\* cited by examiner

*Primary Examiner*—Steven Loke

(74) *Attorney, Agent, or Firm*—Whitham, Curtis & Christofferson, P.C.

(57) **ABSTRACT**

A family of emitter controlled thyristors employ plurality of control schemes for turning the thyristor an and off. In a first embodiment of the present invention a family of thyristors are disclosed all of which comprise a pair of MOS transistors, the first of which is connected in series with the thyristor and a second which provides a negative feedback to the thyristor gate. A negative voltage applied to the gate of the first MOS transistor causes the thyristor to turn on to conduct high currents. A zero to positive voltage applied to the first MOS gate causes the thyristor to turn off. The negative feedback insures that the thyristor only operates at its breakover boundaries of the latching condition with the NPN transistor portion of the thyristor operating in the active region. Under this condition, the anode voltage  $V_A$  continues to increase without significant anode current increase. Emitter turn-off (ETO) thyristor fabrication packages are also disclosed having packaged semiconductor devices controlling the thyristor.

**17 Claims, 24 Drawing Sheets**

