Digest of Tech. Papers The 13th Conf. on Solid State Devices. Tokyo

A −2 −9 Novel Gate Structure for High Voltage Light-Triggered Thyristor

H. Ohashi, T. Tsukakoshi, T. Ogura and Y. Yamaguchi

Toshiba Research and Development Center

1, Komukai Toshiba-cho, Saiwai-ku, Kawasaki 210, Japan

A light-triggered thyristor intended for high-voltage power conversion application such as high voltage direct current (HVDC) transmission, has been recieving much attention as a new switching device. Specifically indispensable to HVDC applications are sufficiently high di/dt and dv/dt capabilities, which should be realized consistently with high light-triggering sensitivity. Previous authors have tried to solve these problems either using high power light source,[(1)∼(4)] or with a auxiliary thyristor[(5)∼(7)] whose rated junction temperature is reduced for better design trade-off. There have been no atempts to fire a high power thyristor directly with a commercially available light emitting diode (LED). The subject of this paper is a novel gate structure for high power directly light-triggered thyristor, which is easily fired with a light-triggering system consisting of commercially available LED and optical fibers.

High-voltage light sensitive pilot thyristor (V_{DRM}=4kV) with multi-stage amplifying gate were examined to satisfy the above mentioned requirements. The pilot thyristor shown in Fig.1 (Category-A) is one of the conventional light-triggered thyristor, where p-base surface is illuminated by the light signal. The structures shown in Fig.2 (Category-B) and Fig.3 (Category-C) are of newly developed high-voltage light sensitive pilot thyristors. The Category-B is intended to greatly improve light sensitivity, satisfying sufficiently high dv/dt capability for high-voltage application requirements. The Category-C structure was developed in order to improve di/dt capability of the Category-B structure.

The key features of the Category-C structure are its light-sensitive area surface, consisting of a central p-base portion, and its surrounding stepwise deep diffused n-emitter. Figure 4 shows minimum light-triggering power Φ^* vs. the ratio of the central p-base portion to light-signal flux radius R_2/r. As is evident from the figure, rather long initial turn-on length can be obtained by making R_2/r ratio around the

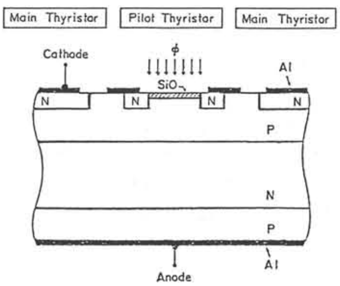

Fig.1 Category-A

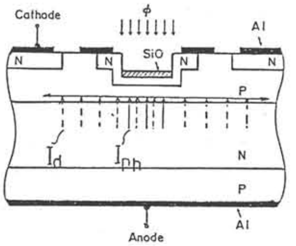

Fig.2 Category-B

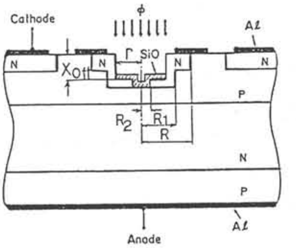

Fig.3 Category-C

value from 0.5 to 0.6, providing high di/dt capability and keeping almost the same high light sensitivity as the Category-B unit ($R_2/r = 0$).

Another important factor contributing to good trade-off solution between dv/dt capability and light sensitivity, is optimization of anti-reflection film (SiO) width and removed silicon depth of light-sensitive area. The effects of removed silicon depth X_{off} on quantum efficiency η , are illustrated in Fig.5. The quantum efficiency is measured with a rather unique method proposed by the authors. Rapid increase in η with removed n-emitter depth is explained by introducing a free-carrier absorption effect, in addition to intrinsic absorption of silicon. As a result of the above mentioned precise investigations, more than 70% to 75% quantum efficiency is achieved.

Figure 6 shows experimental and calculated results between Φ^* and dv/dt capability at T_j=125°C and at V_D= Rated blocking voltage (4kV) for each structure Category. As shown in the figure, Category-C light sensitivity is more than 3 times larger than that of Category-A under the same dv/dt capability condition.

A 4kV-1.5kA directly light-triggered thyristor was developed using Category-C as a first pilot thyristor for a newly developed multi-stage amplifying gate. The above mentioned improvement resulted in excellent overall characteristics of Φ^*=2.5mW under worst case condition, more than 250A/μs di/dt capability at 2kV, and 1.5kV/μs dv/dt capability at 3kV, both at T_j=125°C. Besides, it should be emphasized that this unit was safely light-triggered from 4kV full blocking voltage, by triggering device consisting of a commercially available single LED, fed with lamp.X 30μs current pulse, and a 7-meter long, 3mm diameter bundle light guide.

All of these results encourage near future application of this unit to HVDC.

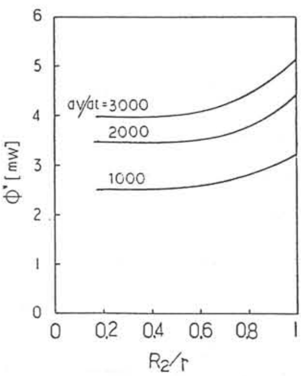

Fig.4 R_2/r vs. Φ^*

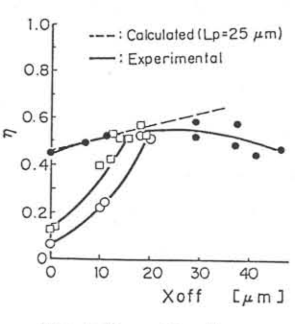

Fig.5 X_{off} vs. η
● : P type
○ : N⁺type (Xj1=26μm)
□ : N⁺type (Xj2=23μm)

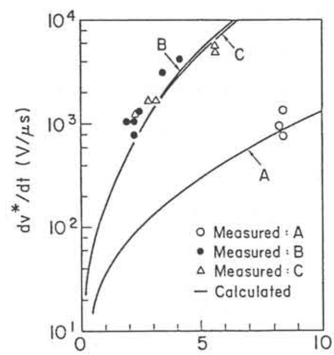

Fig.6 Φ^* vs. dv*/dt

References (1)E.S.Shlegel, et al., Tech.Digest, IEDM, 483(1976); (2)V.Temple, et al., IEEE Trans., ED-27, 583(1980); (3) Nakagawa, et al., Tech.Digest, Solid State Conf., 49(1980); (4) N.Konishi, et al., Tech.Digest, IEDM 642(1980); (5)D.Silber, et al., Tech.Digest, IEDM, 575 (1978); (6)A.A.Jacklin, et al., Tech.Digest, IEDM, 254(1979); (7) Hashimoto, et al., Tech. Digest of Electron Device Meeting, EDD-78-73, IEE of Japan