A light-triggered thyristor intended for high-voltage power conversion application such as high voltage direct current (HVDC) transmission, has been receiving 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, or with an auxiliary thyristor whose rated junction temperature is reduced for better design trade-off. There have been no attempts 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 (\( V_{BRH}=4kV \)) 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 \( \Phi \) 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...
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 \( R_{\text{q}/f} = 0 \).

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 \( X_{\text{off}} \) on quantum efficiency \( \eta \), are illustrated in Fig. 5. The quantum efficiency is measured with a rather unique method proposed by the authors. Rapid increase in \( \eta \) 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 \( \Phi^* \) and dv/dt capability at \( T_j = 125^\circ \text{C} \) and at \( V_{\text{r}} = \) 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 \( \Phi^* = 2.5 \text{mW} \) under worst case condition, more than 250A/\( \mu \text{s} \) di/dt capability at 2kV, and 1.5kV/\( \mu \text{s} \) dv/dt capability at 5kV, both at \( T_j = 125^\circ \text{C} \). 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 \( \times 30 \mu \text{s} \) 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.

![Figure 4](image1.png)

![Figure 5](image2.png)

![Figure 6](image3.png)

References