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C-2-1 High Field and Lateral Current at Turn-on of Large Area Thyristor

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To develop the performance and di/dt capability of a large area thyristor, it is hopeful to get a high velocity of lateral spreading of the conducting regions. The plasma spreading has been attributed to the lateral diffusion of excess carriers in the base layers. However, the electric field at the boundary between the active and inactive regions should have a certain effect. In this paper, we will investigate the strength of the lateral field and its influence on the lateral current in base layers.

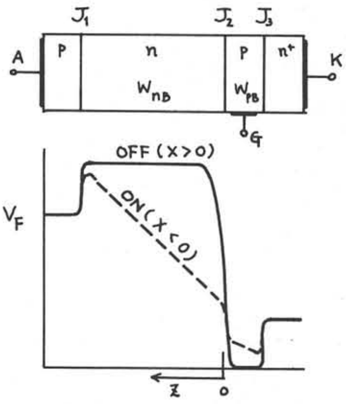

Fig.1. Schematic diagram of the electrochemical potential distributions at turn-on.

In the initial phase of turn-on, after the fall of the forward blocking voltage, the current density in the active region is so high that the voltage drop in the base layer is large. In the inactive region, however, the voltage across anode to cathode (V_F) is applied to the center p-n junction (J_2). Therefore the potential distribution may be as shown in Fig.1, and the potential difference between ON and OFF regions causes the high lateral field.

If the edge of the ON region is spreading along x-axis at a constant velocity v_s, by transforming the variables into the coordinate moving along x-axis at a velocity v_s , the minority carrier distribution Δp and electric field in n-base are given by solutions of the ambipolar equation of the form :

$$\nabla^2 \Delta p + \frac{V_s}{D_p}\cdot\frac{b+1}{2b}\cdot\frac{\partial \Delta p}{\partial X} - \frac{1}{D_p}\cdot\frac{b+1}{2b}\cdot\frac{\Delta p}{\tau_p^*} = 0$$

$$\mathbf{E}\cdot \mathrm{grad}\, \Delta p = \frac{V_s}{\mu_p}\cdot\frac{b-1}{2b}\cdot\frac{\partial \Delta p}{\partial X} - \frac{1}{\mu_p}\cdot\frac{b-1}{2b}\cdot\frac{\Delta p}{\tau_p^*}$$

where b is the mobility ratio and the space charge neutrality is assumed. By incorporating appropriate boundary conditions, lateral field E_x and lateral hole current density I_x across the YZ-plane at X=0, i.e., the boundary of the active region, are computed numerically. The results are shown in Figs.(2) and (3), where we have assumed uniform distributions of impurity atoms and neglected depletion layers. Device parameters used are listed in Table 1.

We summarize the characteristics as follows : 1) Although the field along Z-axis (E_z) is neary constant, the lateral field is negative and very high near the junction J_2 , and the strength can be larger than 10^4 V/cm. 2) The lateral flow of minority carrier into the OFF region is reduced by lateral field, and is negative near J_2 .

Since turn-on of the device is performed by the build-up of the minority carrier near the center junction J_2, the electric field in the bulk should prevent the spreading of the active region. Thus the di/dt capability and effective area of thyristor are reduced. Another effect of the lateral field is the possibility of the breakdown in the base layers. For 1200V and 200A thyristor with FI gate, for example, the voltage drop V_F is larger than 100V. Then E_z is as high as 10^3 V/cm, but E_x can be larger than 10^5 V/cm. Thus the device will be led to failure by the lateral field rather than by the forward conducting drops.

Table 1. Numerical values

W_{nB} = 200 μm	W_{pB} = 20 μm
μ_p = 300 $cm^2/V\cdot s$	D_p = 10 cm^2/s
τ_p^* = 5μsec	v_s = 10^5 cm/s
b = μ_n/μ_p = D_n/D_p = 2	

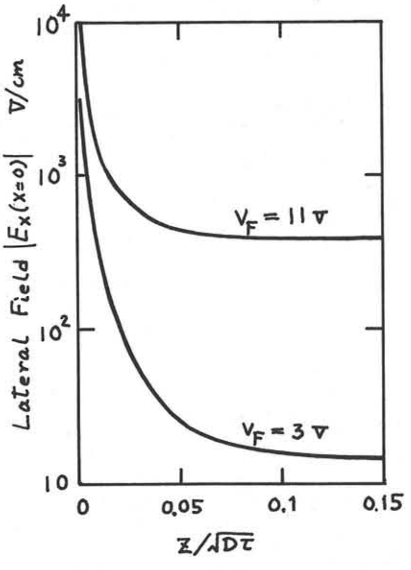

Fig.2. Lateral electric field at the boundary of the active region.

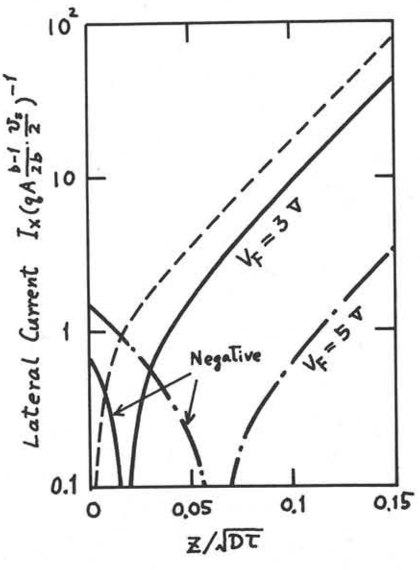

Fig.3. Lateral current density across the boundary of the active region. Broken line is for the case of zero field.