INVESTIGATIONS ON

NON-PUNCH-THROUGH AND PUNCH-THROUGH TYPE THYRISTORS

by

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TO MEENU

MY WIFE

CERTIFICATE

This is to certify that the dissertation entitled, "Investigations on Non-Punch-Through and Punch-Through type Thyristors", which is being submitted by Mr. Dina Nath Singh to the Indian Institute of Technology, Delhi, for the award of the degree of Doctor of Philosophy, is a record of bonafide research work carried out by him under our guidance and supervision.

In our opinion, this dissertation has reached the standard fulfilling the requirements of the regulations relating to the degree. The results contained in it have not been submitted, in part or in full, to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

There is a continuing effort to develop thyristors which can meet the present day requirements of high frequency, high current ,, and high voltage applications. Incidently in the case of thyristors, the design approaches for realising high power handling capability and high frequency performance put contradictory demands over the specifications of the starting material and the fabrication process parameters. However, there still remains the scope of improvement in the device performance by varying the process parameters carefully. For a selective control, a precise understanding of the dependence of electrical parameters on various process parameters is required. The present thesis investigates the problem of electrical parameters' variability in thyristors. Along with this, a new technique termed as 'punch-through' (PT) for selecting the parameters of the starting material has been enunciated. Furthermore, investigations on the technology of edge contour has also been carried out.

The analysis starts with the development of an appropriate analytical model for predicting the resulting changes in the electrical parameters of the device due to variations in process parameters. The two-transistor model for a p-n-p-n device with some important refinements has been employed. The refinements introduced make the model suitable enough to investigate some first order effects such as the influence of retarding and aiding built-in electric fields

in the p-base and the dynamic base-width modulation in the n-base of the thyristor on the device characteristics. The investigations lead to the conclusion that the presence of the retarding built-in field in the initial region of the p-base affects the negative resistance part of the forward blocking I-V characteristics considerably. Consequently it affects the holding current and dv/dt rating of the device. The considerations of the dynamic base-width modulation in the n-base provides some important information regarding the basic thyristor design.

In order to determine the critical diffusion parameters to be changed for the improvement in a certain electrical parameter of the device without impairing much the others, a variability analysis employing the developed analytical model is carried out. The analysis yields useful results regarding the control of considered electrical parameters. It is revealed that the maximum improvement in a certain electrical parameter of the device depends upon the extent of tolerable deterioration in the adversely impaired parameters. A trade-off relationship regarding this has been brought out.

The technology of obtaining an improved edge contour for a low-current (small area), high voltage thyristor is developed. The edge contour has been attained by chemical etching giving positively and negatively beveled surfaces at the forward and reverse blocking junctions of the device respectively.

In the newly proposed PT design technique, the blocking voltages of the thyristors are limited by punch-through mechanism instead of avalanche mechanism as in the conventional non-punch through (NPT) type design. The comparative study of the PT and NPT type thyristors provides the various advantages of the former over the latter. The PT thyristors possess higher breakover voltage, less turn-off time and higher dv/dt capability. However, in PT structures the turn-on and the on-state voltage drop have been found to be higher than those in the NPT structure. Thus, PT thyristors are found to be more suitable in cases where dv/dt rating cannot be improved by resorting to 'shorted-emitter principle', for example, in GTO and GAT thyristors. In general applications too, the PT devices may be preferred to the NPT devices on account of their improved blocking characteristics, higher dv/dt rating, less turn-off time and more flexibility in the design.

In this manner, the present thesis studies some important aspects of the non-punch-through and newly devised punch-through type thyristors. The information so obtained is utilised for improving the design of thyristors.

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