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RADIATION EFFECTS ON THE N-CHANNEL IGBT

Abstract

The IGBT (Insulated Gate Bipolar Transistor) combines the advantages of a power MOSFET (Metal-Oxide Semiconductor Field-Effect Transistor) and a bi-polar power transistor. The input has a MOS gate structure, and the output is a wide base PNP transistor. The base drive current for the PNP transistor is fed through the MOSFET at the gate. The change of electrical characteristics for irradiated IGBT is mainly coming from the change of characteristics of MOSFET at the input gate and the PNP transistors at the output. MOS devices are among the most sensitive of all semiconductor to radiation, in particular ionizing radiation, showing much change ever after a relatively low dose. The gate oxide structure gives the main influence on the changes in the electrical characteristics affected by irradiation. A change of the I-V characteristic towards more negative values of gate voltage is brought by charge trapping at the gate oxide. In conduction mode, the epitaxial region is conductivity modulated (by excess holes and electrons) thereby eliminating a major component of the on-resistance. The relationship between threshold voltage VT and charge Qtot in SiO2 is given by

ΔVT=-ΔQ/Cox

where COX is fixed for each different kind of MOSFET, and the change of charge, Qtot, depends on the dose. The change of threshold voltage, VT, is proportional to Qtot. In this paper, the IGBT macro-model incorporating irradiation is implemented and analyzed the electrical characteristics of VT on exposure to various gamma radiation doses (0 (pre-irradiation), 5, 10, 20, 30 (krad)) under the positive gate biases of 0, 2.5, 5, and 10 V, by SPICE simulation and experiments, respectively. In addition, the collector current characteristics as a function of gate emitter voltage (VGE) are compared with the model considering the radiation damage of different doses and the gate biases. It is shown that the change of VT is more rapidly decreasing, as the gate biases voltage is increased, since the depletion region under the gate oxide is expanded. The subthreshold current increases for the surface leakage under higher dose level. It is evaluated that VT shift is the major contribution of current increase, but for more than some total dose, the current is increased because of the current gain degradation occurred in the vertical PNP at the output of the IGBT's.