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Assessing the Role of Non-Local Trap-to-Band Impact Ionization in 4H-SiC Photoconductive Switches Containing Deep Defects Aimed at Enhanced Hold-off Voltages

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The importance of non-local effects in impact ionization has been long recognized, particularly in connection with breakdown in gases, where Crooke's dark space and glow striations provide classic examples. The main point is that impact ionization is the consequence of electrons drifting down a potential gradient (i.e., in the presence of a spatial electric field) pick up energy E and can impact ionize only when this energy exceeds the ionization threshold. Ionization rates, therefore, should not depend on the local electric fields, as has routinely been used in analysis, but on the path integral.

4H-SiC is a promising material for high-power photoconductive switches given its resistance to chemical attack and radiation, stability at high temperatures, higher saturation electron drift velocity over Si and GaAs, larger thermal conductivity, and high breakdown fields in the 3-4 MV/cm range. For the same breakdown voltage, the on-state resistance of a SiC device is expected to be lower by two orders of magnitude than that for Si because smaller layer thicknesses and/or higher doping levels can be used. Such SiC material for photoconductive switches usually uses deep traps/defects to attain the desired high hold-off voltage strengths required for pulsed power applications.

Here we provide numerical studies to probe effects of non-local trap-to-band impact ionization for SiC photoconductors. We show that the non-local nature of the ionization can substantially alter the local fields, result in a pile-up of free electrons, and possibly lead to prolonged cathode injection and space-charge striations. Our modeling is based on a one-dimensional, time-dependent drift-diffusion approach, and includes multiple traps, trapping/detrapping dynamics, field-dependence of various processes, and possible hole injection. The role of trap energy level and concentration on the conduction characteristics will also be analyzed.

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