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Photocurrent Efficiency in Bulk and PIN SiC Photoconductive Semiconductor Switches for Pulsed Power Applications

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A comprehensive picture of the relationship between optical fluence $(30 - 30,000\ \mu J/cm^2)$, optical wavelength $(295 - 375\ nm)$, electrical bias $(8 - 64\ kV/cm)$, and photocurrent efficiency (defined as the ratio of electrons extracted to electrons generated) in SiC photoconductive semiconductor switches (PCSSs) is presented. The behavior of SiC PCSSs including high electric field stress behavior $(> 200\ kV/cm)$ captured in self consistent drift-diffusion simulations, and associated failure modes are briefly highlighted.

For a PCCS to be practical, a high photocurrent efficiency is desired. Typically, this efficiency is wavelength dependent, and in the case of the bulk PCSSs, the efficiency was observed to exhibit a broad peak over the wavelength range from 315 to 350 nm. Overall, a maximum photocurrent efficiency of at most 10 % was found, largely depending on the operating conditions. Thus, to overcome this efficiency limitation, a prototype PIN (as opposed to bulk) SiC PCSS was designed and evaluated. The PIN device was designed and optimized using TCAD Silvaco simulations along with a custom particle swarm optimization for the junction termination design. This approach yielded a 6x-10x improvement in photocurrent efficiency relative to bulk SiC PCSSs over the same parameter space with comparable voltage blocking performance.

Bearing in mind presently available pulsed UV light sources, bulk SiC PCSSs are considered to be most practical for burst high voltage or single shot pulse applications (demonstrated up to 65 MHz repetition rate), while the PIN PCSS structure lends itself to high average power, continuous pulse operation in the single digit MHz repetition rate regime.

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