Plasma Torch Method for Silicon Carbide (SiC) Dopant Implantation

V. R. N. Veltmeyer*[1,2]; R. M. Beraldo[1,2]; J. Pissolato Filho[3];J. A. Diniz[1,2] ; M. V. Puydinger dos Santos[1,2]
[*]E-mail: v225209@dac.unicamp.br
School of Electrical and Computer Engineering (FEEC-UNICAMP)
[1]Department of Electronics and Biomedical Engineering (DEEB)
[2]Center for Semiconductor Components and Nanotechnologies (CCSNano)
[3]High Voltage Laboratory (LAT) - Department of Systems and Energy (DSE)
UNICAMP, 13083-970, P.O. Box. 6061, CAMPINAS, SP, Brazil.

ABSTRACT

Silicon Carbide (SiC) has been shown to be a capable semiconductor for power electronics applications, as it supports high forward currents whilst blocking high reverse voltages, while switching up to MHz frequencies. Those properties are enabled by an exceptionally durable crystalline lattice that allows it to withstand remarkably high temperatures, enabling it to sustain transient power regimes that would otherwise destroy standard silicon semiconductors.

This exceptional crystal lattice, however, also represents the main challenge in fabricating large SiC power electronics, as it is extremely difficult to dope (or alter in general) with standard fabrication techniques, whether it be thermal diffusion or ionic implantation. The former requires heating the substrate to temperatures as high as 2100 K for several minutes, while the latter requires 100-300 keV per µm of implant depth for aluminum, the standard p-dopant for SiC, while also requiring substrate heating up to temperatures between 500-1100 K during the entire process.

Our study aims to evaluate a novel method of dopant implantation, adapting an innovative plasma torch device to perform both thermal diffusion and ionic implantation concurrently by using accelerated ions within a thermal plasma discharge. The main source of ion energy are Lorentz electromagnetic forces, which also increase the plasma plume’s temperature via magnetic self-confinement, a process which has been experimentally shown to reach temperatures to extremes of 4000 K in the original device.

This plasma torch, which originally operated at atmospheric pressure, was fitted with a fused-quartz high-vacuum (10^{-5} Torr) chamber to reduce the beam’s temperature while also boosting ion energies by increasing their mean free path. A silicon carbide wafer coated on one side with aluminum will be placed perpendicularly to the plasma flight path, where nitrogen ions (n-type SiC dopant) will bombard the wafer, simultaneously heating it while pushing accelerated dopants into the crystal lattice, a novel hybrid method which combines the best aspects of the two existing alternatives, conceivably doping the uncoated side to an n-type semiconductor while the coated to a p-type, creating a standard diode junction, which will be tested to determine the quality of this new processing method.

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