MODELING OF IONIZATION PHENOMENA IN SiC DIODES

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We have applied our drift-diffusion simulation to a 6H-SiC We have first looked at the influence of temperature on device performance, in particular concerning the degree of ionization of the deep levels present in the semiconductor. We have detected large variations in the ionization rate by going when the temperature goes from 300 to 800 K. The different behavior of acceptors and donors causes the diode depletion region to grow more rapidly on the n side than on the p one. The peak field increases with temperature, due to the higher level of fixed charge at the junction. In the examined structures, tunneling times out of shallow are in the femtosecond range for sufficiently high fields. Thus tunneling is the dominant ionization mechanism under high bias conditions. We have studied the diode response to a pulsed voltage, findind a significant influence of tunneling processes. None of the effects founds for SiC shows up in Si diodes. There, in fact, donors and acceptors are much shallower, and they result completely ionized under any standard operating condition.

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Scientific work done during the reporting period

The work has continued along the lines indicated in the two previous reports. The Drift-Diffusion simulator has been used to study the dynamical behaviour of 6-H SiC diodes subject to a reverse bias pulse of picosecond duration.

In a Silicon diode, such condition creates a temporary current spike related to the dynamical rearrangement of carriers to the evolving potential. The spike rapidly decays away well before the end of the pulse, reaching the stationary condition typical of reverse bias, that is a current almost equal to zero.

In a 6H SiC diode, a quite peculiar situation is found. At sufficiently high bias (but lower than the breakdown voltage), after a very fast transient that leads to a spike similar to that of Si diodes, the current reaches a steady value different from zero, which values as high as 100 A/m^2. The current increases with reverse bias, leading to a knee in the reserve diode characteristics that are characterized by a very soft onset of breakdown. The phenomenon seems to be associated to the development of a dipole at the $N\text{-}P^+$ interface, caused by the combined effect of field-assisted ionization and subsequent production of holes by impact ionization processes near that interface. When one of the two processes of field assisted ionization and impact ionization is selectively turned off in the simulation, a Silicon-like behaviour is found. This clearly indicates that the observed effect is due to the combined action of the two phenomena mentioned above. We are performing additional checks to better understand the physical nature of the effect, and the possible presence of numerical artifacts.

We have also developed a simple temperature model that allows us to account for the internal heating of the device. The temperature increase during device operation (present of course when some reverse current is present) affect both the trasport (through the temperature dependence of donor and acceptor ionization levels and mobility) and the breakdown characteristics (via the variation with temperature of ionization rates and band gap energy). The temperatures reached by the device can be of the order of several hundreds Kelvin degrees. Such temperature raise leads in general to a reduction of the diode current.

Research plans for the remainder of the contract period

The research will continue along the following lines :

1. Comparison of the drift diffusion simulation for SiC diodes with available experiments, and identification of the mechanisms determining the device behavior at breakdown

Administrative actions during the reported period

The interaction with Dr. Fazi from ARL has continued via e-mail, since no visits have occured. Scientific discussions have also started with Dr. Zanoni of the University of Padova, who is going to characterize some of the SiC diodes in collaboration with Dr. Fazi.

Other information

As mentioned in the 1st report, a delay exists between the actual delivery date of invoice and reports and what reported in the contract