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Thermal Annealing of Electron, Neutron and Proton Irradiation Effects on SiC Radiation Detectors

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Silicon carbide (SiC) is a wide bandgap semiconductor with physical properties that make it especially appropriate for radiation monitoring in radiation-harsh environments and for elevated temperature operation. In this work, the radiation effects in electron, neutron and proton irradiated 4H-SiC pn junction diodes have been investigated by means of electrical characterization in both, reverse and forward polarizations, including current-voltage characteristics measured in the temperature range from -50℃ to +200℃. It is found that the observed radiation-induced conduction resistance is exponentially dependent with the measuring temperature. The generation of acceptor-like defects is thought to be responsible for the resistivity increase of the material, eventually leading to the formation of a semi-insulating layer, with loss of diode rectification character.
The stability of the radiation-induced effects has been evaluated by applying series of thermal treatments up to 400℃. Interestingly for applications, partial recovery of diode rectification functionality is observed for electron irradiated devices, with a diode conduction recovery of more than four orders of magnitude. Furthermore, partial recovery of detectors charge collection efficiency (CCE) in alpha particle detection is registered on all cases, electron, neutron or proton irradiated devices, once subjected to the applied thermal treatments. Additionally, it is observed that the limited conduction registered under forward bias for highly irradiated SiC diodes actually allows their application as radiation detectors when operated in forward polarization. Although some lower CCE is found for SiC detectors under forward bias, better energy resolution is obtained under this operation regime, particularly at low absolute bias voltages. It is thought that filled radiation-induced traps under forward bias condition decrease charge trapping of electron-hole pairs generated upon exposure to an alpha particles source.
Briefing, some superior characteristics of SiC devices, such as those involving operation at high temperature values, may enable their use beyond the intrinsic limitations of silicon devices. Furthermore, they may help simplify some current radiation detectors experiments implemented with silicon devices, in which cooling is needed to keep functional operation after high irradiation fluences or exposure to visible light must be prevented.

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