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Novel 3D micro-structuring of diamond for radiation detector applications: enhanced performances evaluated under particles and photons beams.

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In order to push forward the state-of-the art of device radiation hardness, we propose to use so called 3D electrode geometry: where the collecting electrodes are implemented within the bulk of the diamond and separated by a few tens of microns (limited by the processing techniques). The reduced distance between the buried electrodes enables higher electric fields to be applied, thus faster drift velocities, shorter drift path of charge carriers, and a reduced probability of trapping in the detector. Such an approach has been successfully tested for silicon detectors where significant improvement in radiation hardness (comparable to planar diamond detectors) has been obtained.

Here we applied the approach to diamond devices, processing 3D geometries to demonstrate the gain it brings to the performances of CVD diamond detectors. The prototypes used buried conductive graphitic micro-channels, fabricated within the diamond bulk using an UV laser (337 nm). A 5x5 matrix with 200µm spacing between electrodes was processed on a mono-crystalline sample. The electronic properties of the 3D diamond prototype were carefully evaluated, including namely current-voltage, transient-current, and charge collection efficiency characteristics under ionizing particles and X-ray micro-beam.

The results demonstrate the improvements provided by the 3D diamond detectors and open up new possibilities for radiation detectors for extreme applications.

Optional extended abstract

Due to its remarkable physical properties: wide band gap, high charge carrier mobility, and high radiation hardness, diamond exhibits superior interests for the fabrication of radiation detection devices. Conventional diamond detectors rely on planar geometry, i.e. where the minimum distance between collecting electrodes, i.e. the charge carrier drift distance, is thus limited by the sample thickness. Although planar diamond devices showed superior radiation hardness to silicon analogues, a major degradation of the detection properties could be observed under prolonged irradiations.

In order to push forward the state-of-the art of device radiation hardness, we propose to use so called 3D electrode geometry: where the collecting electrodes are implemented within the bulk of the diamond and separated by a few tens of microns (limited by the processing techniques). The reduced distance between the buried electrodes enables higher electric fields to be applied, thus faster drift velocities, shorter drift path of charge carriers, and a reduced probability of trapping in the detector. Such an approach has been successfully tested for silicon detectors where significant improvement in radiation hardness (comparable to planar diamond detectors) has been obtained.

Here we applied the approach to diamond devices, processing 3D geometries to demonstrate the gain it brings to the performances of CVD diamond detectors. The prototypes used buried conductive graphitic micro-channels, fabricated within the diamond bulk using an UV laser (337 nm). A 5x5 matrix with 200µm spacing between electrodes was processed on a mono-crystalline sample. The electronic properties of the 3D diamond prototype were carefully evaluated, including namely current-voltage, transient-current, and charge collection efficiency characteristics under ionizing particles and X-ray micro-beam.

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