

3D diamond detectors for particle tracking and dosimetry

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Introduction

Advances in the laser processing technologies has enabled the production of a new type of particle detector - 3D diamond (Figure 1). Compared to conventional planar technologies, previous work with Silicon has proven that the 3D geometry improves radiation tolerance of detectors. First tests of single-crystal and polycrystalline CVD diamond 3D detectors in various particle beams demonstrate the viability of this concept.

The Idea/Concept

The idea is to produce electrodes inside the bulk of a radiation hard detector material. By combining the 3D concept with diamond a new class of radiation tolerant detectors has been developed.

Recent improvement in the fabrication method¹ by using a spatial light modulator (SLM) improved the quality of conductive wires, allowing the fabrication of devices in both single-crystal and polycrystalline CVD diamond with lower resistivity of the wires (0.2 Ωcm vs 2.5 Ωcm without this technology). The performance test of these devices show promising results (see Figures 2 and 3). The SLM technique provides a small focal spot with a higher energy density, and opens up the possibility of arbitrary wire geometries with a diameter below 1 μm enabling new electrode configurations.

The challenges are to increase the production speed, reliability and uniformity of the process in order to scale from prove-of-concept studies to production readiness for applications in eg. particle tracking and medical dosimetry.

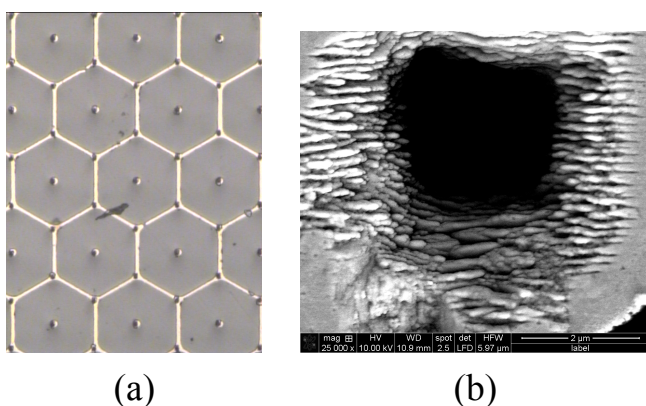


Figure 1: Front view of a 3D diamond detector with hexagonal cell, structure size 100 μm (a) and SEM of an graphitic electrode (b).

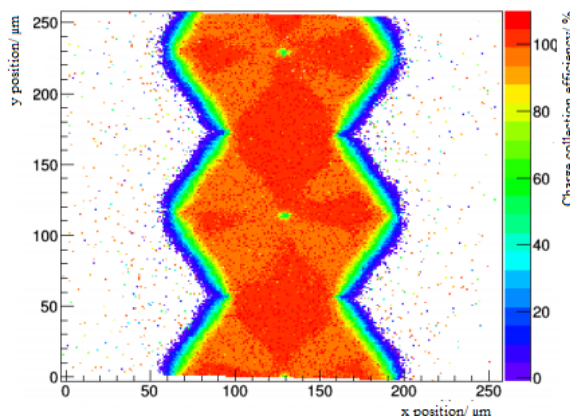


Figure 2: Response of a strip of 3D hexagonal cells in scCVD diamond to a 4.5 MeV proton microbeam.

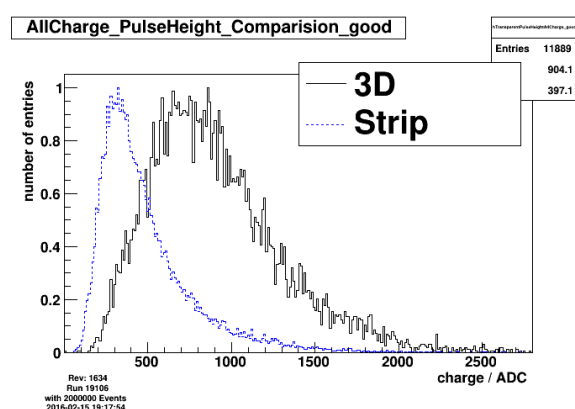


Figure 3: Comparing planar strip and 3D pCVD diamond detectors response to 120 GeV protons (MIP).

Potential Impact

This technology has the potential to provide ultra radiation hard particle detectors for tracking applications for the next generation of particle colliders (HL-LHC, FAIR). The flexibility to create arbitrarily shaped wires in the diamond bulk can be exploited in other areas, e.g. micro dosimetry in medical applications or manipulation of N-V centres in diamond used for quantum computing.

1: T. V. Kononeko et al., Appl. Phys. A 90, 645-651 (2008)

2: B. Sun et al., APL 105, 231105 (2014)