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Diamond Particle Detectors for High Energy Physics

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On behalf of the RD42 Collaboration – see Appendix A

Abstract

Diamond devices have now become ubiquitous in the LHC experiments, finding applications in beam background monitoring and luminosity measuring systems. This sensor material is now maturing to the point that the large pads in existing diamond detectors are being replaced by highly granular tracking devices, in both pixel and strip configurations, for detector systems that will be used in Run II at the LHC and beyond. The RD42 collaboration has continued to seek out additional diamond manufacturers and quantify the limits of the radiation tolerance of this material. The ATLAS experiment has recently installed, and is now commissioning a fully-fledged pixel tracking detector system based on diamond sensors. Finally, RD42 has recently demonstrated the viability of 3D biased diamond sensors that can be operated at very low voltages with full charge collection. These proceedings describe all of these advances.

Keywords: Particle detectors, radiation tolerance, precision tracking, high energy physics

1. CVD Diamond Material

Diamond has a number of properties that make it an attractive alternative to silicon as a sensor material for solid state particle detection applications. Its large band-gap and consequent small leakage current have allowed the production of position sensitive devices by simply patterning electrodes on the surface, as opposed to implanting diode junctions in silicon. Furthermore the large band-gap and strong atomic bonds make diamond material much less susceptible to the radiation doses typically found in modern high energy collider physics experiments. Its low dielectric constant means that for a given sensor area, the load capacitance on a readout amplifier will be half that of a similar shaped silicon detection element. Finally the high band-gap allows the saturation the drift field producing prompt signals, with rise-times below one nanosecond. The fast signals in diamond detectors have already been exploited to provide single turn feedback on beam conditions near experimental interaction regions and to make bunch-by-bunch measurements of the collider luminosity. All four LHC experiments have diamond beam monitors, based on single large pad electrodes, currently in operation and their focus is now turning to the use of diamond sensors with segmented readout geometry for use in charged particle tracking applications.

The RD42 collaboration [1] has been developing particle detector prototypes based on Chemical Vapour Deposited (CVD) diamond sensor material for two decades. Over the last few years our main focus has been building particle detector prototypes and promoting their transition to fully-fledged detector systems in the LHC experiments. It is now possible to routinely grow polycrystalline CVD diamond wafers 12-15 cm in diameter that produce most-probable signals approaching 10000 electrons from the passage of a minimum ionising particle. This is the result of a 10-year collaborative development effort between RD42 and Element6 [2] and a more recent two year, accelerated development cycle with II-VI Incorporated [3]. Figure 1 shows one of three wafers that have been produced by

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