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Hybrid diamond pixel detectors for the upgrade of ATLAS

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Chemical Vapour Deposition (CVD) diamond has a number of properties that make it an attractive alternative for high energy physics detector applications like tracking detectors, luminosity monitors and beam monitors. Its large band-gap (5.5 eV) and large displacement energy (42 eV/atom) make it a material that is inherently radiation tolerant with very low leakage currents and high thermal conductivity. CVD diamond is being investigated by the RD42 Collaboration for use very close to LHC interaction regions, where the most extreme radiation conditions are found and thus hybrid pixel detectors are used. A process of building pixel modules with CVD diamond detectors has been developed together with the Fraunhofer IZM, the bump vendor of ATLAS IBL. As readout chip FE-I4, the new ATLAS pixel chip is used. FE-I4 features 80x336 pixel on a 20x16.8 mm^2 active area and 25 ns time resolution which can be operated at thresholds below 1500e-. Results show that the low threshold of FE-I4 together with the low noise of the diamond is the key feature for their operation. Recently the FE-I4 diamond pixel modules have been chosen for the ATLAS Diamond Beam Monitor project (DBM), an upgrade of the ATLAS luminosity measurements system. In this presentation the production process of diamond pixel detectors is explained and the results of FE-I4 based pixel modules in test beam and lab measurement are presented. The usage of diamond pixel detectors in the upgrade projects of ATLAS is discussed.

Optional extended abstract

Tracking detectors, luminosity monitors and beam monitors of the experiments at the Large Hadron Collider and their upgrades must be able to operate in radiation environments several orders of magnitude harsher than those of any current detector. Chemical Vapour Deposition (CVD) diamond has a number of properties that make it an attractive alternative for high energy physics detector applications. Its large band-gap (5.5 eV) and large displacement energy (42 eV/atom) make it a material that is inherently radiation tolerant with very low leakage currents and high thermal conductivity. CVD diamond is being investigated by the RD42 Collaboration for use very close to LHC interaction regions, where the most extreme radiation conditions are found. State of the art for the usage as innermost tracking detector of LHC experiments are hybrid pixel detectors. A hybrid pixel detector consists of a highly segmented sensor layer which is bump bonded pixel by pixel to a readout chip. Each pixel features an amplification of the input signal and an individual adjustable threshold. Afterwards the data are stored until a trigger signal is received and send to the off detector readout stage. This approach combines high spatial resolution and fast, zero suppressed readout in an environment with high track density as required by LHC. The usage of CVD diamond sensors instead of standard silicon sensors is an attractive option for upgrades of pixel detector at LHC. For the upgrade of the ATLAS pixel detector, the Insertable B-Layer (IBL), a new pixel readout chip called FE-I4 has been developed. FE-I4 is a chip with 80 x 336 pixel on a 20 x 16.8 mm^2 active area and 25 ns time resolution which can be operated at low thresholds below 1500e-.A process of building pixel modules with CVD diamond detectors has been developed together with the Fraunhofer IZM, Berlin which is the prime bump bonding vendor of the ATLAS IBL. The entire metallization of the diamond and bump bonding is handled by IZM so a high quality hybrid pixel detector can be built. Several pCVD and scCVD diamond pixel detectors have been successfully built at IZM with the FE-I4 and its predecessor FE-I3. Results of the FE-I4 diamond modules show that the low

threshold of FE-I4 together with the low noise of the diamond sensor is the key feature of the operation a highly segmented diamond sensor. The relative low input charge of the diamond can be compensated by the low threshold of the FE-I4 so that still a good signal over noise needed for a high efficient particle detection can be achieved. Recently the FE-I4 diamond pixel modules have been chosen for the ATLAS Diamond Beam Monitor project (DBM), an upgrade of the ATLAS luminosity measurements system. In this presentation the production process of diamond pixel detectors is explained and the results of FE-I4 based pixel modules in test beam and lab measurement are presented. The usage of the diamond pixel detectors in the upgrade projects of ATLAS is discussed.

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