Growth of Heteroepitaxial CVD Diamond Films on Ir/YSZ/Si(001) for Detector Applications*

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In the framework of the CARAT collaboration, which executes work package 15 of the EU FP7 "HadronPhysics2" project, the diamond group at the University of Augsburg is responsible for the development and growth of heteroepitaxial diamond films, which shall be used in particular for tracking and ToF measurements of heavy ions and minimum ionising particles.

Motivation

For future particle accelerator experiments, e.g. at FAIR, we are developing novel, advanced diamond sensors grown by chemical vapour deposition (CVD), capable on one hand of replacing the commonly used silicon tracking devices and being on the other hand an advantageous alternative to polycrystalline or single-crystal diamond sensors used so far in beam diagnostics and timing applications. By using heteroepitaxial diamond films grown on Ir/YSZ/Si(001) we want to bridge the gap between polycrystalline (which exhibits inhomogeneous incomplete charge collection) and single-crystal CVD diamond (i.e. of small areas), enabling the fabrication of large-area diamond sensors of good homogeneity, high drift velocity of the charge carriers, and of almost complete collection of the particle induced charge.

Sample Preparation

The growth of heteroepitaxial diamond films on the Ir/YSZ/Si(001) multilayer system by microwave plasma enhanced CVD was established at the University of Augsburg in 2004 [1]. A layer of YSZ (yttria-stabilised zirconia) is deposited on a 4-inch Si wafer by pulsed laser deposition. In a second step a film of Ir is deposited on top of the YSZ layer by electron beam evaporation. Fig. 1 shows a schematic of the substrate's layer structure.

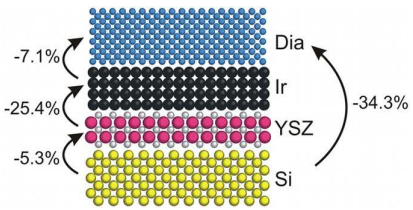

Figure 1: Structure of the Ir/YSZ/Si(001) substrate with diamond on top, numbers indicating relative lattice mismatches [1].

The diamond films are grown at present on substrates of 20×20 mm^2 lateral extension from a H_2/CH_4 plasma. This process yields material of very good crystalline quality with a FWHM of the x-ray diffraction (XRD) rocking curve of less than 0.2°, and inherits the potential of being scaled up in order to synthesise wafer-size diamond films in the future [2].

For detector applications the best material quality is needed. Therefore, thick films of diamond (ca. 1 mm) were grown in order to reduce the density of lattice defects (especially dislocations) in the final samples, which were prepared from the growth side of the film by laser cutting. Special care was also taken concerning the purity of the plasma and the reactor chamber to ensure low impurity concentrations (esp. of N, Si, and B) in the diamond films.

Results

Two samples with a thickness of ca. 300 µm were prepared for measurements of the detector performance at GSI. Photoluminescence and cathodoluminescence spectra indicated very low concentrations of N, Si, and B (see fig. 2). Raman spectra and XRD measurements showed a clear improvement over the hitherto state of the art.

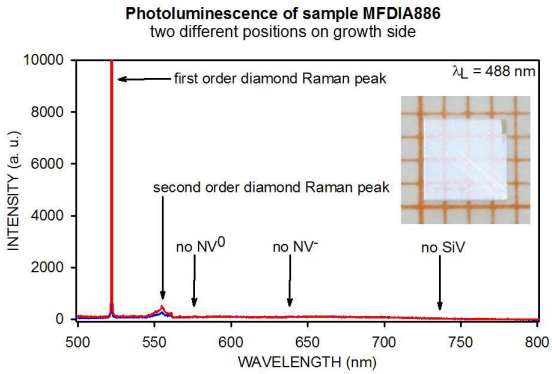

Figure 2: Raman/Photoluminescence spectrum of one sample, showing the complete absence of graphitic carbon contributions and of impurity peaks from NV and SiV centres. The inset shows a photo of the final sample.

The detailed results will be described in an extended scientific publication.

References

[1] S. Gsell, T. Bauer, J. Goldfuß, M. Schreck, and B. Stritzker, Applied Physics Letters 84 (2004) 4541.

[2] M. Fischer, S. Gsell, M. Schreck, R. Brescia, and B. Stritzker, Diamond & Related Materials 17 (2008) 1035.

* Work supported by the EU, FP7 Proj. RII3-CT-227431.

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