Growth of Heteroepitaxial CVD Diamond Films on Ir/YSZ/Si(001) for Detector Applications: Detection and Reduction of Crystal Defects*

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In the framework of the ADAMAS collaboration, which executed work package 16 of the EU FP7 HadronPhysics3 project, the diamond group at the University of Augsburg was responsible for the development and growth of heteroepitaxial diamond films, on which future tracking and timing detectors for heavy ions and minimum ionising particles shall be based. This work was a direct continuation of the activities within the former CARAT collaboration [1, 2].

Motivation

During the CARAT collaboration period, several heteroepitaxial diamond (called DoI = Diamond on Iridium, for the sake of simplicity) samples of different sizes had been grown in Augsburg and tested at GSI. During the α-particle and heavy ion beam tests, a large variation of detector performance among the samples, esp. in terms of charge collection efficiency (CCE) and polarisation effects, had been observed, leading to the need for getting a better understanding of the correlation between crystal lattice defect structure and detector performance of DoI samples. The newly gained insights are supposed to improve the growth process in order to minimise the defect density in the crystals, improving absolute detector performance and reducing relative spread among different samples. This will be crucial for the long-term targeted fabrication of DoI detector prototypes.

Detection of Dislocations

The dominating lattice defect type in DoI crystals is assumed to be the so-called threading dislocation. This one-dimensional irregularity originates from small angle grain boundaries which are formed during the earliest stages of DoI growth. The grain boundary network coarsens and finally dissolves during growth, leaving behind bands of agglomerated dislocations [3]. This process had been studied before by TEM investigations for a DoI film thickness up to ca. 34 µm. For thicker crystals in the range of several 100 µm, like the detector samples, data were not available up to now.

The newly applied method for the detection of dislocations in thick DoI crystals relies on the preferential etching of the crystal surface at defect sites, i.e. at points where dislocation lines intersect the surface. There, so-called etch-pits are formed, as shown in Fig. 1. Assuming a one-to-one correlation of dislocations and etch-pits, the areal dislocation density can be measured and the pattern of dislocation agglomerates revealed. This was done for differently thick DoI crystals in order to trace the changes during growth, as discussed in the next section.

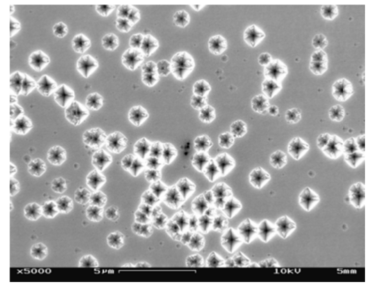

Figure 1: SEM image of etch-pits.

Reduction of Dislocation Density

The results of preliminary thickness dependent dislocation density measurements are shown in Fig. 2. The defect density is reduced with increasing crystal thickness, which quantitatively supports the previously taken route of using the upper parts of thick crystals for potential particle detectors. The dashed line indicates a $1/d$ behaviour as commonly observed for other heteroepitaxial material systems. The solid line represents a $1/\sqrt{d}$ behaviour, which seems to closer fit the experimental data. Further data are currently acquired to substantiate the behaviour and explore the mechanisms of dislocation reduction during film growth.

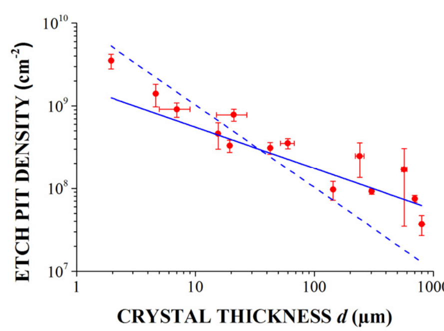

Figure 2: Areal density of etch-pits revealing dislocation density in DoI crystals of increasing thickness (The data are preliminary).

References

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[3] M.Schreck et al., Applied Physics Letters 78 (2001) 192.

* Work supported by EU, HadronPhysics3 project No. 283286.

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