Electrical and Photo Conductivities in Heteroepitaxial Quasi Single-Crystal CVD-Diamond Detectors*

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The properties of CVD Diamond (CVDD) detectors such as high mobility of charge carriers, radiation hardness, and low dark conductivity provide a detector material, which is suggested to be applied in high intensity heavy-ion beam environments where classical detector devices cannot be operated [1]. In the future FAIR experiments radiation-hard materials with large area will be required for a variety of detection applications. Heteroepitaxial 'quasi' single crystal CVD diamond grown on wafer-scale Ir/YSZ/Si(001) substrates was investigated as an alternative to small-area homoepitaxial single crystal CVDD (scCVDD). Recent samples D1 and D2 of thicknesses d_{D1} = 290µm and d_{D2} = 320µm, respectively, showed interesting results in terms of structural homogeneity, charge collection efficiency, and dark conductivity.

We investigated the conduction mechanisms (both dark and photo conductivities) of several DoI films by measuring the dark currents at various temperatures (room temperature to 673K) up to biasing voltages of ± 1000V. The photo conductivity was tested with contacts consisting of different metals (e.g. Ti/Pt/Au, Al) by irradiating the samples with UV-vis-light from a Xenon source.

Dark conductivities

The dark current vs the electric field E_D (*I-E*$_D$ characteristics) was measured for various DoI samples of different thicknesses and for scCVDD films at room temperatures using Keithley 6517A electrometers and a metallically shielded dark box under nitrogen flow, as shown in Fig.1. The dark current of all DoI samples (Fig.1a) is by one order of magnitude lower than the current observed with the scCVDD film; similar results have been reported in [1, 2]

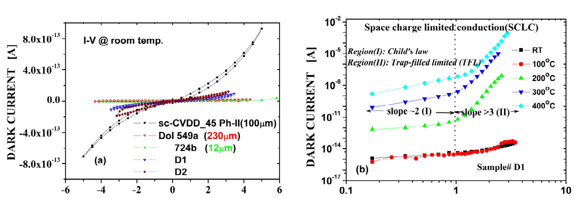

Figure 1: (a) The electric field dependence of the dark current (I-E_D characteristics) of various DoI films at room temperature compared to scCVDD (black). At ± 2V/µm, the dark current of the DoI samples is $I_{DoI} < 0.05$pA whereas $I_{sc} \approx 0.2$pA, (b) Same as in (a) for DoI sensor D2. A space charge limited conduction mechanism is indicated (see text).

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After studying all possible conduction mechanisms, the appropriate electron transport mechanism for the DoI material was found to be the space charge limited conduction (SCLC), that is, a defect dominated conduction mechanism. The SCLC theory describes the dark currents as follows:

$$I_{Child} = 9/8\,\mu\kappa_D (V^2/d^3), \qquad I_{TFL} = 9/8\,\mu\kappa_D \theta (V^2/d^3),$$

where μ is the electron mobility, κ_D is the dielectric constant, V the applied bias, d is the detector thickness, and θ the ratio of the free to the trapped charge carriers. In Fig. 1(b), the curves *I-E*$_D$ (473 to 673K) show two distinct regions: one where Child's law holds (slope ~ 2) and a second one with slope > 3, which indicates a trap-filled-limited (TFL) conduction. This suggests that a huge amount of traps are present in the bulk. Optical cross polarizer imaging of the tested samples also showed homogeneously distributed dislocations in the volume [1]. The activation energy of the traps in the new samples was determined to E^{ac}= (1.026 - 1.318) ± 0.074 eV, which is similar to the value E^{ac} = 1.4eV reported previously [2].

Photo conductivities

In order to investigate the photoconductivity of D1 and D2, the current induced by UV light injection was measured as a function of the photon energy and plotted in Fig. 2 in arbitrary units. According to the measured photocurrents D2 is less defective compared to sample D1. The E^{ac} is attributed to shallow traps. It is worth mentioning that we varied type of different metal contacts on DoI films but almost no difference in the behaviour of the dark current could be observed.

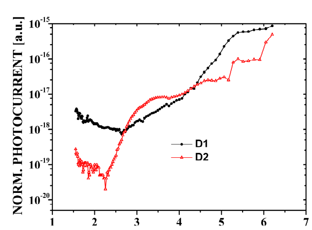

Figure 2: The photoelectric characteristics of D1 and D2.

References

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[2] A. Stolz, *et al.* Diam. Rel. Mater., 15 (2006), 807.