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doi:10.1017/S1431927618009315
Microsc. Microanal. 24 (Suppl 1), 2018

Defect Analysis of Single Crystal Synthetic Diamond

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Diamond films and crystals have attracted a lot of attention recently due to their applications in semiconductor devices. Diamond has unique semiconductor properties including high breakdown field, high carrier velocity, and the highest thermal conductivity [1]. These properties are due to its unique atomic structure (Fd-3m). Therefore, diamond is very promising for high-frequency devices that comprise transistors, interconnects, and transparent electrodes [2]. It is also used as a substrate in silicon- and graphene-based devices. Processing and fabrication of diamond films is normally carried out at high temperature and high pressure, where defects are unavoidable. In order to obtain the best properties of diamond, its structure should be nearly perfect, with no defects at the nanoscale. Hence, high resolution characterization techniques are needed to provide information about the atomic structure. This will allow structure-property correlations of the synthesized diamond.

Synthetic diamond powder used in this investigation was synthesized by a high pressure/high temperature method. SEM analysis showed that the diamond powder (45-μm particle size) was composed of single crystals, with well-defined cubo-octahedral faceting, Figure 1(a). On the other hand, XRD analysis displayed a single-crystal pattern with a high degree of peak broadening, as well as a broad low-angle peak, Figure 1(b), clearly indicating the presence of lattice defects in the crystalline material. Electron Energy Loss Spectroscopy (EELS) analysis confirmed that the powder was composed of high purity carbon. A small sample of the diamond powder was crushed and ground into much finer particles, such that a few tapered edges were suitable for high resolution TEM. Dark-field imaging of the non-crystalline regions indicated the presence of a second phase or lattice disorder. No dislocations are observed in the lattice-fringe patterns, Figure 2(a) Selected Area Electron Diffraction (SAED) analysis confirmed the XRD results, indicating areas of well-defined crystallinity associated with regions of no resolved crystallinity. A typical SAED pattern showed crystalline spots superimposed on broad diffraction rings, Figure 2(b). The measured lattice constants verified a diamond-cubic structure. This presentation will describe defect analysis at the micro- and nano-size levels. EELS data will also be compared for various carbon-based structures. Stress analysis at the atomic scale will be evaluated for imaged areas.

To summarize, single-crystal synthetic diamond is analyzed using microscopic and spectroscopic techniques. Crystallinity and defect structures are observed using HRTEM, SAED, and EELS. The EELS spectra correspond to a defective structure in the diamond. Combination of HRTEM and EELS is a powerful method to observe defects in crystalline crystals.

Reference:

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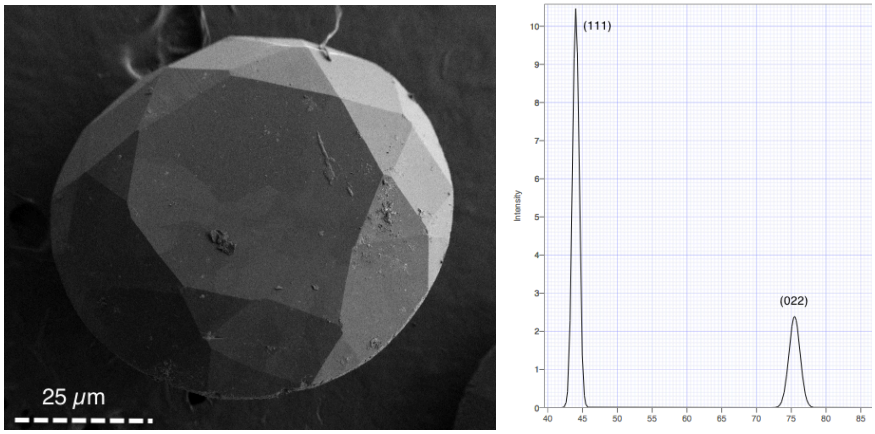
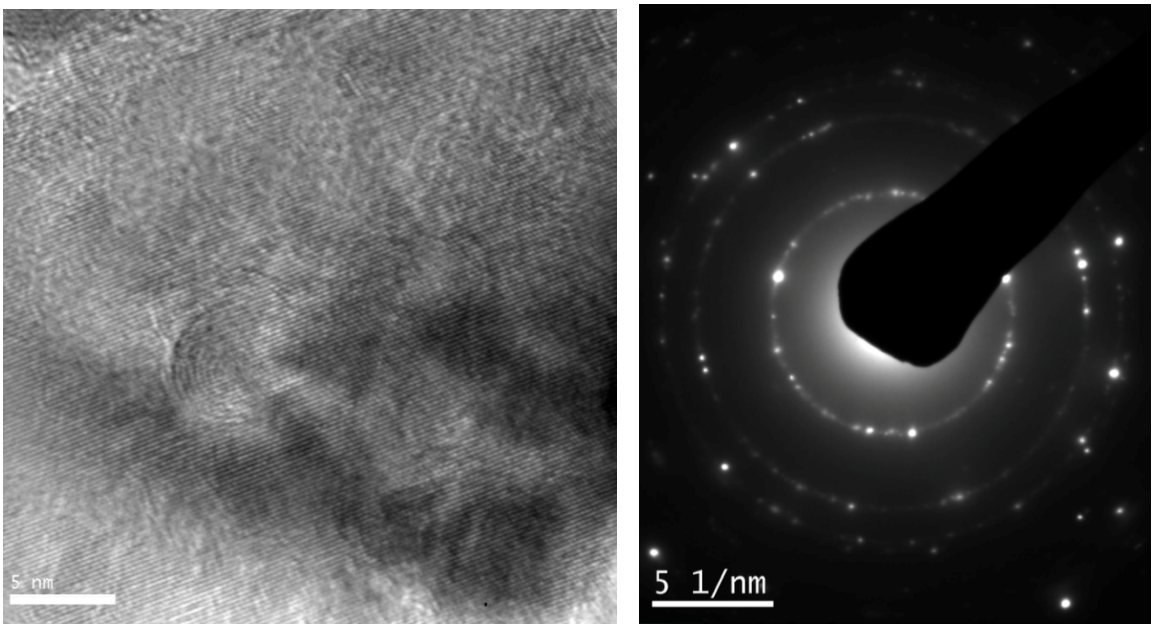


(a) **(b)**

Figure 1. (a) Low magnification SEM micrograph of diamond faceted particle, and (b) corresponding x-ray diffraction of the diamond powder.



(a) **(b)**

Figure 2. (a) High Resolution Transmission Electron Micrograph of the as synthesized diamond powder, and (b) corresponding selected area electron diffraction of the imaged area.

https://doi.org/10.1017/S1431927618009315 Published online by Cambridge University Press