Evidence of strain-induced plastic flow in the formation of phase-pure hexagonal diamond

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Diamonds are used in many industrial applications due to their extreme hardness, particularly for polishing, cutting, and pressure application. There has been an increasing interest in hexagonal diamond in recent years, largely due to its potential to be harder than diamond [1]. However, experimental hardness measurements for this technologically interesting material have yet to be reported due to the extreme temperature/pressure conditions required to form hexagonal diamond [2, 3] as well as the inability to form a phase-pure sample without cubic diamond inclusions [4]. A recent study reports low temperature formation of pure hexagonal diamond that is proposed to be due to a strain-induced plastic flow [5]. This region of pure hexagonal diamond was observed in an annular region around the central region containing a graphite-like structure. In the current study, the proposed strain-induced transformation pathway from this graphite-like structure to the phase-pure hexagonal diamond is explored using high-resolution transmission electron microscopy (TEM), electron energy loss spectroscopy (EELS), and select area diffraction pattern (SADP) to provide evidence that plastic flow has indeed occurred.

Fig. 1 shows (a) a bright field TEM image, (b) a dark field TEM image from a graphite reflection, and (c) a plot of the increasing density from the graphitic region to the hexagonal diamond region. Striations associated with plastic flow of graphitic sheets can be observed within the graphitic region. The graphitic sheets are aligned along the flow direction, with the amount of orientation within these sheets increasing with increasing strain. At regions of higher strain, these flowing graphitic sheets were observed to progressively "lock-into" hexagonal diamond within a transition region. The distribution of the hexagonal diamond is in good agreement with modelled shear-strain distributions. Density consistent with turbostratic graphite and hexagonal diamond are measured within their respective regions, with the density increasing linearly in the transition region. Graphitic inclusions within the hexagonal diamond and transition region were also found to have decreased interlayer spacing with increasing strain. The interlayer spacing of the inclusions within the hexagonal diamond region having a lower interlayer spacing than uncompressed graphite, making the transition to hexagonal diamond more energetically favourable. This is evidence for a step-wise transformation from the graphitic precursor to the hexagonal diamond structure due to a shear-induced flow mechanism.

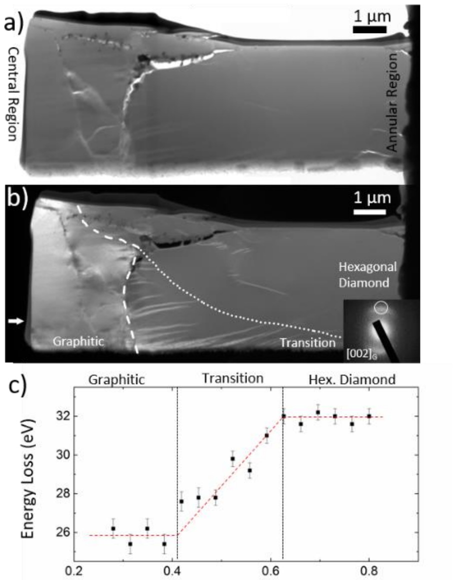

Fig. 1 *A (a) bright field TEM image and (b) a dark field TEM image taken from a graphite reflection (as indicated in inset) of the transition from a graphitic structure to hexagonal diamond with the transition region*

indicated. (c) A plot of the density at the depth indicated by an arrow in (b), showing the changing density within each region.

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