EFFECTS OF TEMPERTURE AND IRRADIATION DAMAGE ON FRACTURE AROUND NANOINDENTS

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Indentation based fracture toughness measurements remain one of the fastest and most convenient ways of measuring fracture toughness and are widely used even though there are known inaccuracies with the methodologies used. In this work we use single crystal and monocrystalline silicon carbide to study the effects of temperature and irradiation damage on crack propagation and morphologies.

SiC is being widely developed as a structural material for use in the nuclear and aerospace industries in high temperature applications such as nuclear fuel cladding and combustion chamber linings for aero engines. However its lack of ductility means in must be used in the form of a SiC SiC composite. In this work we compare fracture processes in single crystal SiC and nanocrystalline SiC around Berkovich indents from RT to 750°C. Hardness is seen to drop from 45GPa to 20GPa and reduced modulus from 300GPa to 200GPa across this temperature range, in good agreement with other studies. At room temperature the fracture occurs on the expected <$11\bar{2}0$> planes (fig 1). By 400°C this fracture has transitioned to the <$10\bar{1}0$> planes. FIB-SEM tomography shows that there is significant changes to the subsurface cracking between the two test temperatures. Whilst at room temperature the cracks run perpendicular to the surface and link up sub surface (similar to the so called half penny cracks seen around Vickers indents), at 400°C significant lateral cracking is seen with cracks running parallel to the surface. Using HR-EBSD we rationalize the change in fracture plane with a change in plastic deformation slip systems operating at high temperatures –resulting in the formation of dislocation locks leading to cracks. True fracture toughness from the known crack area are calculated to be 3MPam$^{0.5}$. This is higher than estimated form using the surface crack length alone.

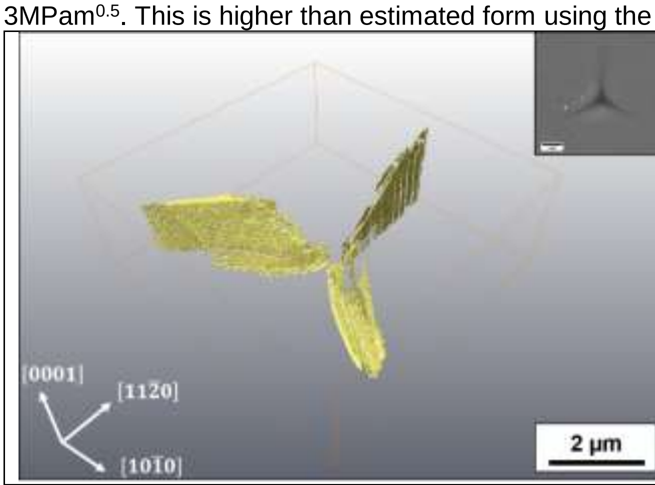

Fig 1: Cracks around nanoindents in single crystal SiC at RT. Inset shows SEM, main figures shows crack path reconstructed in from FIB-SEM tomography

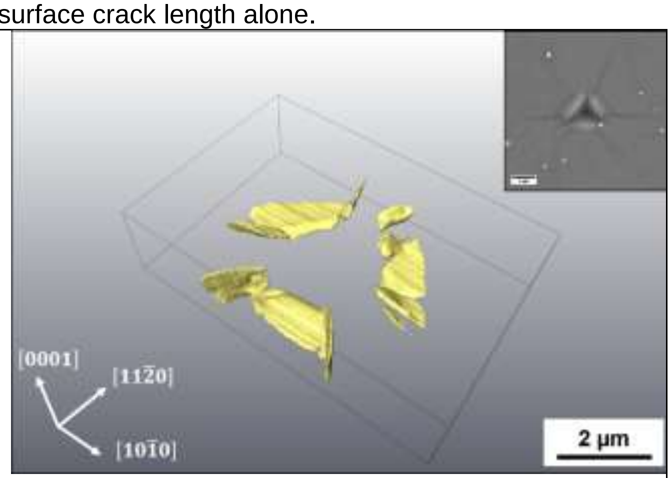

Fig 2: Cracks around nanoindents in single crystal SiC at 700°C. Inset shows SEM, main figures shows crack path reconstructed in from FIB-SEM tomography

To simulate the effect of irradiation damage on the SiC samples were implanted with Ne+ and Si+ ions at 2MeV to a damage level of 2 dpa to a depth of 1.5 µm. After irradiation all cracking is suppressed in the damaged layer but large subsurface cracks are seen below this. Using HR-EBSD and Raman spectroscopy the residual stress in this layer is estimated at ~1.2GPa due to the irradiation damage. This then acts to close prevent crack formation in the damaged layer.

This results will the discussed in the context of both the advantages of using these techniques to measure fracture toughness and the limitations that are inherent to them, and new data applying this to fracture in semi-brittle graphite will be discussed.