§6. Development of Advanced Mechanical Test Techniques for Severe Environment Performance Evaluation of Fusion Materials

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For realization of advanced energy system like fusion reactor, material behaviors under severe environments such as 14 MeV neutron, high temperature and transmuted gas formation, are indispensable to design the reactor as a baseline data. One of critical issues of fusion material study is to establish a characteristic of mechanical property and fracture behavior under severe irradiation conditions. Charged particle irradiation makes it possible to simulate severe environmental conditions of nuclear fusion reactor. DuET facility (Institute of Advanced Energy, Kyoto Univ.) is designed to provide the most advanced and well-controlled conditions simulating fusion reactor environments, such as synergistic radiation and high temperature. In this work, near-stoichiometric and high purity SiC was used, which is promising material for reinforcement and matrix components in SiC/SiC composite. Mechanical properties of ion irradiated SiC was evaluated using nano- and micro-indentation methods with emphasis on the advancement of the evaluation technique. In addition, 3D analysis of fracture behavior was newly introduced by observing beneath indentation impression. Strength evaluation of small size specimen was conducted by nano-indentation technique. The range of displacement damage in ion irradiated SiC is limited within few micrometers (2.5 μm in this study) and non-uniformed distribution of displacement damage is formed in the thin damaged region. For effective evaluation of this thin damaged layer, the deformed area of unirradiated SiC beneath indentation was to be limited within 2.5 micrometers. Deformed area of polycrystalline SiC beneath indentation impression is shown in Fig. 1. Therefore, nano-indentation test was conducted below applied load of 16 g, which created the deformed area of 2.5 μm. Indentation tests through various applied loads can settle the problem of non-uniformed distribution of displacement damage, because it analyzes the concerned region as averaging volume.

Slight degradation of elastic modulus was seen at ion irradiated SiC, while hardness and fracture toughness increased by ion irradiation up to 1000 °C. Especially, the toughening behavior of ion irradiated SiC was clearly demonstrated by 3D analysis of crack behavior beneath indentation impression as shown in Fig. 2. 3D analysis of crack propagation in SiC after ion irradiation gave typical evidences for toughening such as crack deflecting, crack branching, and microcracking. The mechanical test technique for ion irradiated material was advanced by utilization of nano- and micro-indentation technique and 3D microstructural analysis by TEM. The mechanical property change by ion-irradiation was correlated with microstructure.

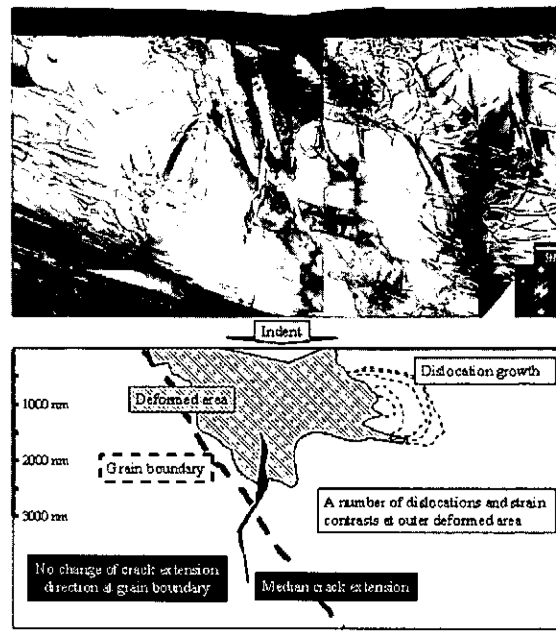

Fig. 1. Cross-sectional TEM image of SiC beneath nano-indentation imprint. Schematic explanation of TEM image is provided at the bottom side.

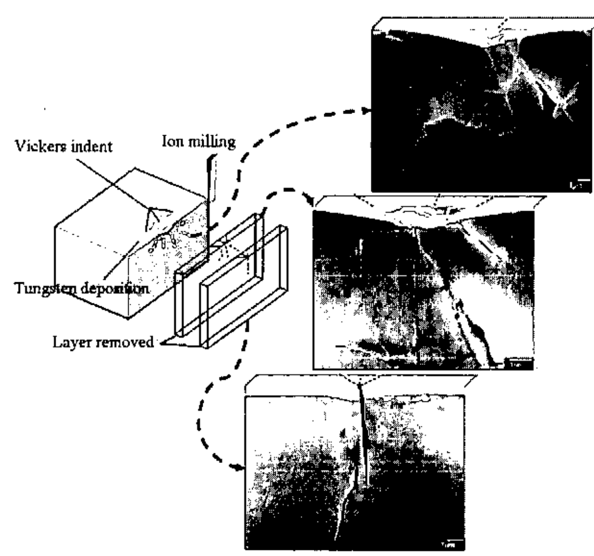

Fig. 2. Representative illustration of the sectioning process for 3D analysis of cracking behavior.

Reference

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