§55. Correlation of Hardening and Microstructure of Tantalum Irradiated with Heavy Ions

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Tantalum is a candidate material for the divertor structural component of fusion devices because of its low long-lived radioactivity, high corrosion resistance and good fabricability. It is also considered to be used as a target material of spallation neutron sources. However, neutron irradiation studies of tantalum have been limited partly because the short-term radioactivity after neutron exposure is high. Thus charged particle irradiation studies are needed for tantalum for the purpose of deriving its fundamental radiation response. It is particularly important to develop a methodology to obtain radiation-induced property changes by means of charged particle irradiations.

In this study, the hardness of tantalum irradiated with 3 MeV Cu ions to 0.3, 3 and 20 dpa at 573K to 1546K has been evaluated by means of micro-indentation technique. The technique was developed to extract the hardness within a very thin surface area subjected to the ion irradiation damage (<500nm). Microstructures of the corresponding areas were observed by the transmission electron microscope.

The microstructures were composed of small loops, tangled dislocations and voids. Fig.1 shows the temperature dependence of dislocation density and void swelling. The swelling reaches the peak at ~1400K, while the dislocation density decreases gradually with the temperature.

The hardness measured for identical specimens is shown in Fig. 2. The hardness drastically decreases at ~900K, where no remarkable change in microstructure is observed.

Post-irradiation annealing study showed that high density of new bubbles were formed after annealing to 1273K of a specimen irradiated at 873K. Therefore, it is deduced that submicroscopic defect clusters, probably of vacancy type, enhanced the hardening at 873K. By a parameter fitting of the data at high temperatures, the contribution of the TEM-invisible defects on the hardening was quantitatively estimated. It was also shown that the effects of voids and the dislocations on the hardness is small relative to that of the loops.

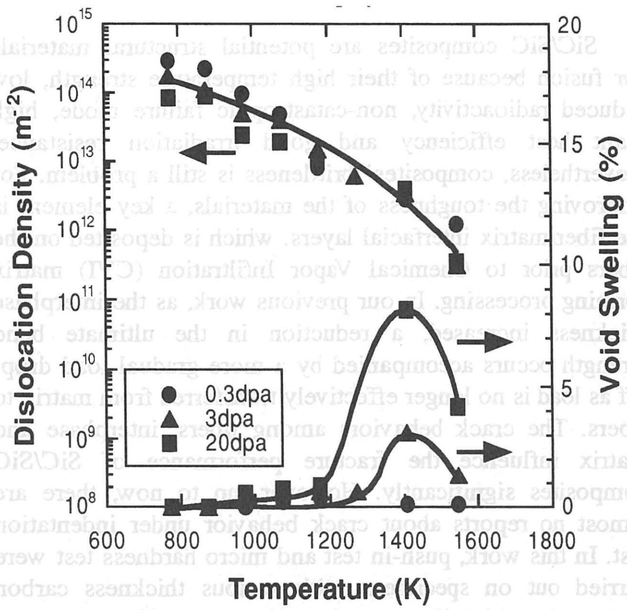

Fig.1. Temperature dependence of dislocation density and swelling.

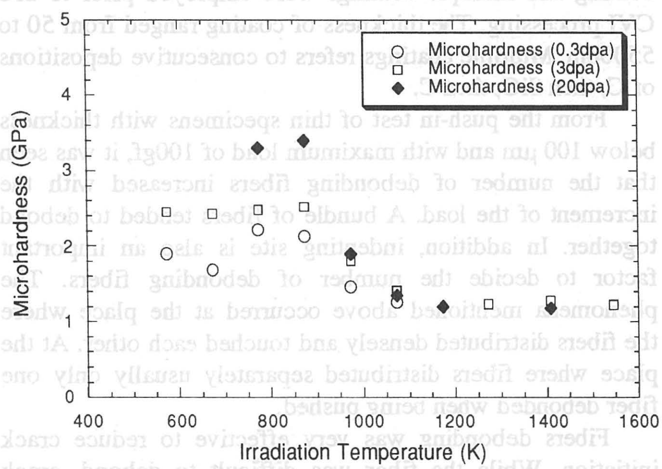

Fig.2. Temperature dependence of the hardness measured by the micro-indentation technique.