COMPARISON OF DAMAGE MICROSTRUCTURES IN NEUTRON-IRRADIATED VANADIUM AND IRON*

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It is known that bcc ferritic materials are more resistant to radiation-induced cavitational swelling than are other bcc materials. Furthermore, a recent study[1] of neutron-irradiated iron reported several unusual features of the radiation-induced microstructures. One of these was the observation that the cavity morphology, a truncated octahedron with {111} faces and {100} truncations, was the shape commonly observed in fcc materials. The morphologies commonly observed in bcc materials include truncated dodecahedrons with {110} faces and {100} truncations and cubes with {100} faces. Another interesting feature was that virtually all of the dislocation loops observed were near-edge, interstitial loops with $\underline{b} = a\langle 100\rangle$. While loops of this type are commonly found in irradiated iron and ferritic steels, interstitial loops found in many other bcc materials are oriented near-edge with $\underline{b} = a/2\langle 111\rangle$. In the present study the cavity morphology and dislocation loop geometry in bcc vanadium are compared with the previously reported observations for neutron-irradiated iron. The specimens were vanadium (V) with 100 wppm of interstitial impurities and vanadium with boron carbide additions ($V\text{-}B_4C$) which were irradiated to ~1 dpa in the same Oak Ridge Research Reactor capsules as the iron specimens. The irradiation temperatures were 623—773 K for the V specimens and 723—923 K for the $V\text{-}B_4C$ specimens. Microstructural examinations were performed in JEM 120CX and Philips EM 400T/FEG transmission electron microscopes.

Cavities were observed in all specimens. The cavities in the V specimens did not appear to have distinct facets. The cavities were faceted in the $V\text{-}B_4C$ specimens; the cavity shape indicated by tilting experiments (Fig. 1) is a truncated dodecahedron with {110} faces and {100} truncations. In the $V\text{-}B_4C$ specimens, the only dislocations observed were in the form of a coarse network. In the V specimens, the dislocation microstructures varied from clusters of small dislocation loops at 623 K to larger, homogeneously distributed loops at higher temperatures. As shown in Fig. 2a, the clusters of loops were often associated with dislocation line segments. Analyses of the geometry of the loops indicated that the Burgers vectors were a/2<111>. In general, all of the loops within individual clusters did not have the same Burgers vector. At 723 and 773 K, the dislocation loops, although larger, retained the a/2<111> Burgers vectors. Figure 2b shows the microstructures typical for these irradiation temperatures. At the same homologous temperatures, the dislocation loops in iron were near-edge, interstitial loops with a<100> Burgers vectors. Clusters of loops were also observed in the iron, however, these clusters were not associated with dislocation line segments. These results appear to contradict a recent calculation by Bullough et al.[2] of the relative probability of the formation of loops with $\underline{b} = a\langle 100\rangle$ and $\underline{b} = a/2\langle 111\rangle$ in bcc materials. The calculations showed that the relative probability of a<100> loop formation is four orders of magnitude higher for vanadium ($5.5 \times 10^{-5}$) than for iron ($5.7 \times 10^{-9}$). Also shown in Fig. 2b are irradiation-induced platelet precipitates. These precipitates lie on {012} with their long axis along <100>. This type of precipitate has been reported previously for neutron[3] and self-ion[4] irradiated vanadium. The composition of the precipitates has not been reported, although vanadium carbide and vanadium oxide have been suggested. Further analysis of these precipitates is planned.

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In conclusion, this confirmation of the expected bcc cavity morphology and dislocation loop Burgers vectors in vanadium is further evidence that the damage microstructures for ferritic materials differ from those for other bcc materials. Further investigation of radiation damage in ferritic materials is required before the mechanisms responsible for this difference can be understood.


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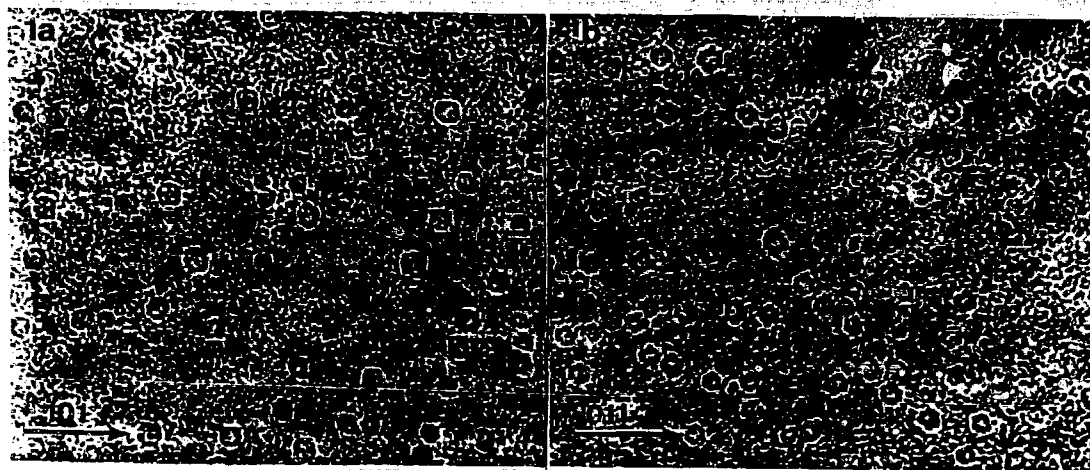

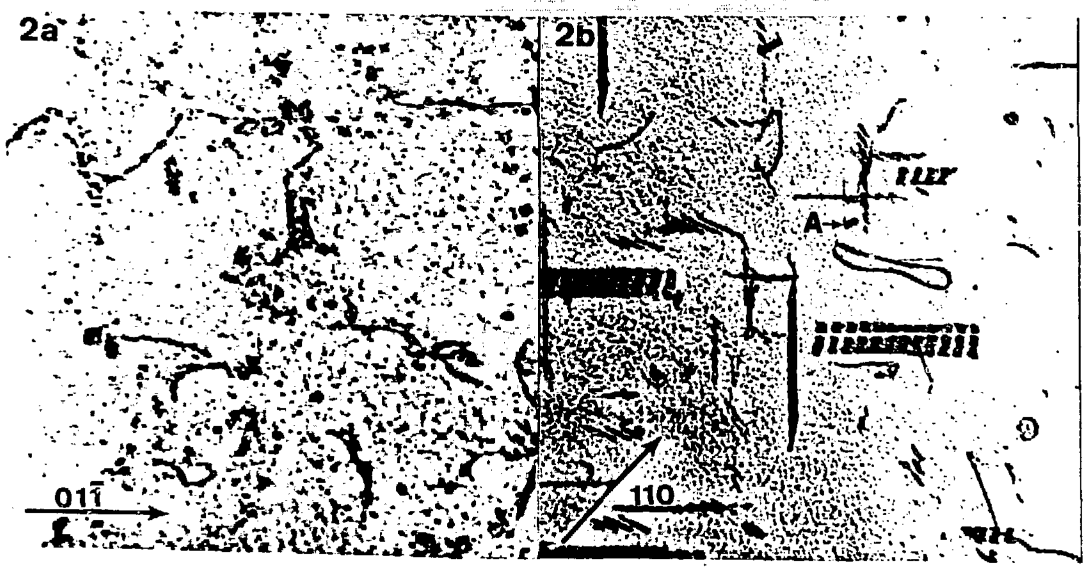


FIG. 1--Cavity morphology observed in V-$B_4C$ irradiated at 823 K for beam directions of (a) [010] and (b) [011]. Over focussed condition. Length of arrows = 50 nm.

FIG. 2--Damage microstructures observed in neutron-irradiated V for irradiation temperatures of (a) 623 K and (b) 773 K. The precipitate at "A" lies on ($\bar{1}$20) with the long axis along the beam direction [001]. Arrows indicate direction of $\underline{g}$, length of arrows = (a) 200 nm and (b) 500 nm.