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TENSILE PROPERTIES AND MICROSTRUCTURE OF HELIUM-INJECTED AND REACTOR-IRRADIATED V-20 Ti*

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- DISCLAIMER

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The objective of this work was to determine the effect of preinjected helium followed by neutron irradiation on the mechanical properties and microstructure of V-20% Ti. These results will be used for the evaluation of the potential use of V-20% Ti in fusion reactor service.

The details of helium preinjection, neutron irradiation, and of postirradiation testing were reported previously.^{1,2} Sheet specimens of V-20% Ti were preinjected to helium contents of 90 and 200 at. ppm. The chemical composition of the V-20% Ti used in this study was: Ti-19.7%, C-150 wt ppm, O-830 wt ppm, and N-830 wt ppm. After the injection, the tensile specimens were irradiated in row-7 of EBR-II to a neutron fluence of about 3×10^{26} n/m² (>0.1 MeV), corresponding to about 17 dpa, at temperatures of about 400, 575, and 700°C, either in static sodium or in helium. After neutron irradiation the microstructures were characterized by transmission electron microscopy; tensile tests were conducted at the respective irradiation temperatures and fracture surfaces were examined by scanning electron microscopy.

Tensile results on control, helium-preinjected, and neutron-irradiated specimens are shown graphically in Figures 1-9.

Stress-strain curves for the control, 90 and 200 at. ppm helium preinjected specimen tested at 400 and 700°C are plotted in Figures 1 and 2. The yield stress, ultimate stress, and total elongation of the specimens before neutron irradiation are shown in Figures 3-5 as a function of test temperature. The helium preinjection has increased the yield stress, ultimate stress, and total elongation of the specimen for the test temperature of 525°C and lower. The increase in strength and elongation was dependent on the amount of preinjected helium. Above 575°C the preinjected helium did not greatly affect the strength properties, but did affect the elongation. The reduction of the total elongation depended on

the amounts of preinjected helium. The higher the test temperature, the larger the reduction of elongation. The value of elongation at 700°C was 13.3 and 8.7% in the 90 and 200 at. ppm injected specimen. These values are 69 and 45% of the elongation of the control specimen as shown in Figure 5. The fractured surfaces of the control, 90, and 200 at. ppm helium preinjected specimen, tested at 700°C, are shown in Figure 6. With no preinjected helium the failure mode was clearly ductile, with no evidence of grain boundary failure. With preinjected helium the failures became mixed ductile and grain boundary separation. Grain boundary facets are visible on the fracture surface and grain boundary cracks are visible on the specimen surface. The fraction of the grain boundary fracture increased as the helium content increased from 90 to 200 at. ppm. Stress-strain curves after neutron irradiation of the control, 90, and 200 at. ppm helium preinjected specimen tested at 400 and 700°C are plotted in Figures 7 and 8. The yield stress, ultimate stress, and total elongation of the specimens after neutron irradiation are shown in Figures 9 and 10 as a function of test temperature. The test temperature for the specimens after neutron irradiation was chosen near the neutron irradiation temperature. Neutron irradiation at 400°C has increased the yield stress and ultimate stress of the specimen, especially for the specimen containing no preinjected helium. On the other hand, neutron irradiation above 575°C did not increase the yield stress and ultimate stress. No appreciable effect of preinjected helium on the strength properties following neutron irradiation could be detected. As for the ductility, the total elongation of the irradiated specimen was decreased at all test temperatures. With no preinjected helium the elongation increased as the irradiation and test temperature increased. At 700°C test temperature no detectable effect of neutron irradiation on the elongation was observed. The preinjected specimens, however, showed

significant decreases of total elongation above 575°C. At the 700°C test temperature, the total elongations of the 90 and 200 at. ppm helium injected specimen were 6.2 and 3.2%, which were 29 and 16% of the helium free specimen.

The fractured surface of the 0, 90, and 200 at. ppm helium preinjected specimen following neutron irradiation to 17 dpa, and tensile testing at 700°C, are shown in Figure 11. With no preinjected helium the fracture remained ductile. With preinjected helium grain boundary separation becomes evident. The amount of grain boundary separation increases with helium content and was much greater after neutron irradiated than was observed for samples containing preinjected helium but not neutron irradiated (Figure 6). The fracture surface of the 200 at. ppm helium-injected specimen shows complete grain boundary separation (Figure 11c).

REFERENCES

1. J. A. Horak, "Helium Implantation in Potential CTR Structural Materials," Controlled Thermonuclear Material Technology Program Annu. Prog. Rep. June 30, 1975, ORNL-5082, pp. 40-42.
2. M. P. Tanaka, J. A. Horak, and E. E. Bloom, "Tensile Properties of Helium-Injected and Reactor-Irradiated V-20 Ti," ADIP Quarterly Prog. Rep. June 30, 1980, DOE/ER-0045/3, pp. 138-145.

Figure 1. Effect of Injected Helium on the Stress-Strain Behavior of Annealed V-20 Ti at 400°C Test Temperature.

Figure 2. Effect of Injected Helium on the Stress-Strain Behavior of Annealed V-20 Ti at 700°C Test Temperature.

Figure 3. Effect of Injected Helium on the Yield and Ultimate Stress of V-20 Ti as Function of Temperature.

Figure 4. Effect of Injected Helium on the Total Elongation of V-20 Ti as Function of Temperature.

Figure 5. Percentage Change in Total Elongation as Function of Test Temperature.

V-20 Ti (EBR-II, X-287)

NO dpa
T_s 700°C

NO He

90 He

200 He

Figure 6. Effect of Helium on Fracture Mode at 700°C.

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Figure 7. Stress-Strain Behavior of Helium Injected Samples at 400°C Following Neutron Irradiation at 400°C.

Figure 8. Stress-Strain Behavior of Helium Injected Samples at 700°C Following Neutron Irradiation at 700°C.

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Figure 9. Effect of Neutron Irradiation on Yield and Ultimate Tensile Strength.

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Figure 10. Effect of Neutron Irradiation on Total Elongation.

V-20Ti (EBR-II, X-287)

20 dpa
IN He

T_i 700°C

NO He

90 He

200 He

Figure 11. Fracture Mode of He Injected V-20 Ti Following Neutron Irradiation.