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EFFECT OF HELIUM ON VOID SWELLING IN VANADIUM

by J. L. Brimhall and E. P. Simonen

MASTER

Battelle
Pacific Northwest Laboratories
Richland, Washington 99352

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J. L. Brimhall and E. P. Simonen
Pacific Northwest Laboratory
Battelle Memorial Institute
Richland, Washington 99352

Large amounts of helium will be generated in the first wall of a fusion reactor. In the simulation of radiation damage by heavy ion bombardment, the helium is generally injected prior to the ion bombardment. It is expected that the effect of helium will depend on whether it is injected simultaneously with the heavy ions or injected prior to the heavy ion bombardment. In this work, vanadium was bombarded with Ni ions under conditions of simultaneous helium injection and prior helium injection. The void formation and resultant swelling were then compared.

Commercially pure vanadium, annealed at 1100°C in a vacuum of 1×10^{-7} torr, was used in the experiment. Some material was pre-injected with 3 appm helium and subsequently bombarded (in the VEC at Harwell) with 46 MeV Ni^{6+} ions at 750°C. Material with no helium was also bombarded with the nickel ions. For the simultaneous irradiation experiment, specimens were bombarded at 750°C with 5 MeV Ni^{++} ions in the accelerator at High Voltage Engineering. A 200 KeV helium beam was magnetically merged with the nickel beam near the target so that the helium beam was concurrent with the nickel beam. The helium injection rate was 0.07 appM/sec at the point of maximum concentration. Specimens with no helium were also bombarded in the same experiment.

The results of the electron microscopic analysis of the void microstructure are summarized in Table 1. The results reported for 5 MeV Ni^{++} ions represent the spread in values from two different specimens.

The results show that helium injected prior to bombardment can be effective in promoting void formation. At 750°C and at the relatively low dose rate, voids could not be generated in the specimen without helium. At the higher dose rate, voids were generated in specimens with no helium. There was little difference between these specimens and those in which helium was injected simultaneously with the nickel.

TABLE 1. VOID PARAMETERS FOR DIFFERENT CONDITIONS OF HELIUM AND NICKEL BOMBARDMENT

Irradiation Condition	Dose Rate (dpa/sec)	Dose (dpa)	Void Diameter (Å)	Void Density (cm^{-3})	Void Volume Fraction (%)
46 MeV Ni^{6+}, 3 appM He pre-injected	8×10^{-4}	16	350	1.7×10^{14}	0.73
46 MeV Ni^{6+}, No He	8×10^{-4}	16	None	-	-
5 MeV Ni^{++}, 100-300 appM He applied simultaneously	1.2×10^{-2}	50-60	116-120	$5\text{-}10 \times 10^{15}$	0.6 - 1.4
5 MeV Ni^{++}, No He	1.2×10^{-2}	50-60	140-145	$3\text{-}5 \times 10^{15}$	0.52 - 0.96

These results can be shown to be consistent with the experimental results of Santhanam, et. al.[1] and the nucleation theory of Wiedersich and Katz[2]. The nucleation rate is a strong function of the vacancy supersaturation which is dependent on the defect generation rate. Only at lower supersaturation values, i.e., low dose rate, is helium effective in increasing the nucleation rate. The relative values of the predicted nucleation rates, with and without helium, agree with the experimental observations. The calculated rates, however, are critically dependent on such factors as the vacancy formation energy, which is not well known.

In summary, little difference in void microstructural swelling of vanadium is noted when helium is injected simultaneously with a nickel beam as compared to no helium injection, at least at high dose rates. At lower dose rates, a strong helium effect is seen when the helium is injected prior to heavy ion bombardment. The effect of the helium is shown to be a strong function of the overall displacement damage rate.

REFERENCES

1. A. T. Santhanam, A. Taylor, and S. D. Harkness, "Defects and Defect Clusters in B.C.C. Metals and Their Alloys," Nuclear Metallurgy, Vol. 18, R. J. Arsenault, ed., p. 302 (1973).

2. H. Wiedersich and J. L. Katz, ibid., p. 530.