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REIRRADIATION OF HFIR SPECIMENS IN FFTF

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1.0 Objective

The object of this effort is to determine whether large levels of helium substantially alter the development of neutron-induced swelling in austenitic alloys.

2.0 Summary

A series of AISI 316 and PCA specimens previously irradiated in HFIR to doses ranging from 10 to 44 dpa have been measured to determine their density and then included in the MOTA irradiation experiment for continued irradiation in FFTF. These specimens were divided into two subsets to be discharged after 30 and 60 dpa.

3.0 Program

Title: Irradiation Effects Analysis (AKJ)
Principal Investigator: D. G. Doran
Affiliation: Hanford Engineering Development Laboratory

4.0 Relevant Program Plan Task/Subtask

Subtask II.C. Effects of Helium on Microstructure

5.0 Accomplishments and Status

5.1 Introduction

Two alternative interpretations of a unique but limited set of data have been advanced in an attempt to predict the influence of large levels of helium on the swelling of AISI 316[1,2]. Whether or not large amounts of helium can preclude the development of the ∿1%/dpa swelling rate typical of the Fe-Ni-Cr austenitic system[3] has not yet been demonstrated to everyones satisfaction. It has also been proposed that interactions between helium bubbles and TiC precipitates in titanium-modified steels can substantially alter the swelling behavior[4]. In the absence of large helium levels Ti-modified steels have been shown to swell like 316 in the post-transient regime[5,6].

In an attempt to test the various predictions a series of specimens irradiated in the HFIR reactor have been incorporated into the MOTA experiment to accumulate large displacement levels (30 and 60 dpa) without adding significantly to the large helium levels (500-3600 appm) already attained in HFIR. The specimens are in the form of TEM disks and were irradiated to doses of 10.5, 22 and 44 dpa at nominal temperatures of 400, 500 and 600°C. The alloys included in the experiment are the N-lot heat of AISI 316 and PCA, both in the annealed and cold-worked conditions.

Duplicate specimens were examined by transmission electron microscopy at Oak Ridge National Laboratory and were chosen to provide a large variety of starting microstructures. A description of these microstructures is given in Table I.

5.2 Status of Experiment

Density measurements have been made at Westinghouse Hanford Company on all specimens. The specimens were then subdivided into eleven groups. Each group consists of one alloy (316 or PCA) to be irradiated at one irradiation temperature (400, 500 and 600°C) to one dose level (either 30 or 60 dpa). Due to specimen limitations there are no 316 specimens at 400°C and 30 dpa, although there are 316 specimens at 400°C and 60 dpa. All eleven groups of specimens are now being irradiated in FFTF.

6.0 REFERENCES

1. H. R. Brager and F. A. Garner, J. Nucl. Mater., 117 (1983) 159-176.

2. G. R. Odette, P. J. Maziasz and J. A. Spitznagel, J. Nucl. Mater., 103-104 (1981) 1289.

3. F. A. Garner, J. Nucl. Mater., 122 & 123 (1984) 459.

4. P. J. Maziasz, J. Maziasz, J. Nucl. Mater., 122 & 123 (1984) 472.

5. F. A. Garner, Swelling Behavior of Titanium-Modified AISI 316 Alloys, DAFS Quarterly Progress Report DOE/ER-0046/17, May 1984, p. 102.

6. F. A. Garner and H. R. Brager, "Influence of Titanium on the Neutron-Induced Swelling of Austenitic Alloys," this report.

7.0 Future Work

This effort will resume upon discharge of the MOTA-1C and MOTA-1D experiments.

8.0 Publications

None

TABLE I: Specimen Irradiation Conditions and Microstructure

Alloy/ Condition	Specimen Identification	HFIR Irradiation Conditions: Temperature (°C)	dpa	Helium (at. ppm)	Microstructural Conditions: Cavity Size (d, nm)	Concentration (m-3)	Total cvf Swelling (%)	Dislocation Structure	Precipitate Microstructure
PCA, SA	(6) ED-65, -98, -70, -80, -69, -94		None				None	Solution annealed	Some medium-sized MC particles from fabrication
	(1) ED-76	400	$\sim$10.5	$\sim$520	None detectable	(n.d)	(n.d)	High concentration of Frank loops	n.d.
	(1) ED-19	400	$\sim$22	$\sim$1700 (bimodal)	2.5 6.9	1.5×10^{23} 3×10^{21}	0.2	Some network and many Frank loops	Coarser MC, some γ', and possibly some G phase
	(1) ED-90	400	$\sim$44	$\sim$3600	5.9	8.2×10^{22}	0.94	Some network and and many Frank loops	Coarser MC and some γ'
	(2) ED-15, -18	500	$\sim$22	$\sim$1700 (bimodal)	2.2 10.1	7.8×10^{22} 9.7×10^{21}	0.84	Network and Frank loops	Coarser γ', a little MC, possibly some G
	(1) ED-01	600	$\sim$22	1750 bubbles, matrix voids, ppt. voids	6.1 21.9 53	1.3×10^{22} 1.3×10^{21} 3.3×10^{19}	1.7	Network and larger Frank loops	Coarse G phase, some fine MC, and γ'
	(1) ED-72	600	$\sim$44	$\sim$3600 bubbles, matrix voids, ppt. voids	4.9 28 41	2.1×10^{22} 1.1×10^{21} 1.13×10^{21}	6.9	Network and some small Frank loops	Coarse G phase, little or no MC and γ'
PCA, 25% CW	(2) EC-99, -68	None			None		None	Cold worked network	None
PCA, 25% CW	(1) EC-04	400	$\sim$22	$\sim$1700	2.3	2.1×10^{23}	0.13	Network plus many Frank loops	Tremendous concentration of fine MC
	(1) EC-92	400	$\sim$44	$\sim$3600	3.0	2.4×10^{23}	0.37	Network plus many Frank loops	Fine and coarser MC
N-lot 316, 20% CW	(1) AD-04	400	$\sim$22	$\sim$1475 (bimodal)	3.2 5.4	7.4×10^{22} 1.6×10^{21}	0.14	Network plus many Frank loops	Some coarser MC (VC?), Very little γ'
	(2) AD-19 -34	500	$\sim$22	$\sim$1475 (bimodal)	4.0 9.8	3.7×10^{22} 1.7×10^{21}	0.25 0.25	Network plus Frank loops	Many medium-sized M_6C particles
	(1) AD-20	500	$\sim$44	$\sim$3000 bubbles, matrix voids, ppt. voids	5.8 13.3 60	7.2×10^{22} 9.9×10^{21} 1.7×10^{19}	3.6	Network plus Frank loops	Tremendous density of medium and coarse M_6C
	(1) AD-53 -56	600	$\sim$22	$\sim$1475 bubbles, matrix voids	4.5 11.8	2.2×10^{22} 3×10^{21}	0.52	Network plus Frank loops	Some γ' in matrix, coarse M_6C on faulted bands
	(2) AD-?	600	$\sim$44	$\sim$3000 bubbles, matrix voids, ppt. voids	9.3 29.3 86	2.5×10^{21} 2.7×10^{21} 1.86×10^{19}	5.9	Loose network	A tremendous amount of coarser M_6C
N-lot 316, SA	(2) AG-3, -6	500	$\sim$22	$\sim$1475	Not measured (n.m.)			n.m.	n.m.
	(2) AG-5, -9	600	$\sim$22	$\sim$1475	(n.m.)			n.m.	n.m.