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FFTF/MOTA IRRADIATION OF REFRACTORY ALLOYS UNDER CONSIDERATION AS PLASMA FACING COMPONENTS

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FFTF/MOTA IRRADIATION OF REFRACTORY ALLOYS UNDER CONSIDERATION AS PLASMA FACING COMPONENTS - F. A. Garner, Pacific Northwest Laboratory[a]

OBJECTIVE

The objective of this effort is to provide data on the radiation response of refractory alloys being considered for short-term applications such as the ITER project and also for long-term fusion goals.

SUMMARY

A refractory alloy irradiation series involving four discharges of the Materials Open Test Assembly (MOTA-1B through MOTA-1E) has been completed. This experiment contains pure Mo, Mo-41Re, TZM and Nb-1Zr. Irradiation temperatures in this experiment ranged from 404 to 730°C with neutron exposures yielding 8.7 to 110.8 dpa. Measurement of density changes and disk bend testing are planned to begin shortly.

PROGRESS AND STATUS

Introduction

Dispersion-strengthened copper and several refractory alloys are now under consideration as possible candidates for applications as plasma facing structural components for the ITER project. The refractory alloys are Mo-(5-10)Re, Mo-(41-50)Re, and Nb-1Zr. For ITER applications, the fluences currently envisioned are fairly low (~3 dpa) at temperatures of 50-700°C. Long-term applications might require much higher exposure levels, depending on the level of emphasis placed on low activation. Neither Nb, Mo, or Cu currently qualify as low activation materials.

A refractory alloy irradiation sequence involving four discharges from MOTA-1B, 1C, 1D, and 1E has been completed. It contains pure Mo, Mo-41Re and Nb-1Zr, each in two different heat treatments (see Table 1). All specimens are in the form of TEM disks. There are two specimens of each alloy in each packet. In most cases there are two identical packets for each set of irradiation conditions. Thus in most cases there are four specimens for each set of alloy and irradiation condition. The refractory alloy TZM was also included in a small subset of packages. Only one dose level at each irradiation temperature is available for TZM. The dose levels for TZM range from 52.6 to 61.5 dpa, with the exception of the 431°C series, which reached 110.8 dpa.

Table 1
Specimen Identity

Identification Code	Group Designation[a]	Alloy	Heat Treatment[b]
AN	A	Pure Molybdenum	HTB
AM	B	Pure Molybdenum	HTA
AO	B	Mo-41Re	HTA
AP	B	Mo-41Re	HTB
AT	A	Nb-1Zr	HTB
AR	B	Nb-1Zr	HTA
AK	C	TZM	HTA

(a) All alloys except TZM were irradiated in packets containing subsets of specimens designated either group A or B. Group C (TZM) was irradiated along with some subsets of group B. See Table 2, column 2 for details.
(b) HTA = solution annealed
HTB = 20% cold worked.

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The irradiations, with one exception in MOTA-1D, were conducted with active temperature control to ±5°C. (An overtemperature event of approximatly 1-h duration occurred in MOTA-1D, with varying impact on the packet temperature, depending on the target temperature of each specimen packet.) The irradiation and specimen matrix are shown in Table 2.

Those specimens retrieved from the MOTA-1B discharge received doses ranging from 8.7 to 15.0 dpa and will provide a conservative estimate of the behavior required for the ~3 dpa ITER application. Data at higher dpa levels can be used not only for long-term fusion goals, but also to extrapolate back to fluence levels below the 8.7 to 15.0 dpa range, i.e., those relevant to the ITER project.

Table 2
Irradiation Conditions for Refractory Alloy Experiment in FFTF-MOTA

Packet	Contents[a]	MOTA-1B		MOTA-1C		MOTA-1D		MOTA-1E		Total dpa
		Temperature, °C	dpa[b]	Temperature, °C	dpa	Temperature, °C	dpa	Temperature, °C	dpa	
MAEZ	A	431	15.0	--	--	--	--	--	--	15.0
NAEZ	A	431	15.0	420	35.3	--	--	--	--	50.3
N6EZ	B	431	14.1	420	33.1	--	--	--	--	47.2
P6EZ	B	431	13.8	420	32.2	404	24.0	--	--	70.0
R6EZ	B	431	13.8	420	32.2	404	23.3	414	32.8	102.1
M6EZ	B,C	431	14.5	420	33.9	404	24.5	414	32.8	105.7
PAEZ	A	431	15.0	420	35.3	404	25.5	414	35.0	110.8
RAEZ	A	431	15.0	420	35.3	404	25.5	414	35.0	110.8
MAE1	A	471	11.4	--	--	--	--	--	--	11.4
NAE1	A	471	11.4	470	26.8	--	--	--	--	38.2
N6E1	B	471	9.6	470	22.6	--	--	--	--	32.2
P6E1	B	471	8.7	470	20.3	470	14.7	--	--	43.7
R6E1	B	471	8.7	470	20.3	470	14.7	--	--	43.7
M6E1	B,C	471	10.4	470	24.5	470	17.7	--	--	52.6
PAE1	A	471	11.4	470	26.8	470	19.4	--	--	57.6
RAE1	A	471	11.4	470	26.8	470	19.4	--	--	57.6
MAE7	A	569	11.5	--	--	--	--	--	--	11.5
NAE7	A	569	11.5	550	27.0	--	--	--	--	38.5
N6E7	B	569	12.2	550	28.6	--	--	--	--	40.8
P6E7	B	569	12.7	550	29.7	549	21.5	--	--	63.9
R6E7	B	569	13.1	550	30.8	549	22.3	--	--	66.2
M6E7	B,C	569	12.2	550	28.6	549	20.7	--	--	61.5
PAE7	A	569	11.5	550	27.0	549	19.6	--	--	58.1
RAE7	A	569	11.5	550	27.0	549	19.6	--	--	58.1
MAE5	A	645	11.5	--	--	--	--	--	--	11.5
NAE5	A	645	11.5	652	27.0	--	--	--	--	38.5
N6E5	B	645	12.2	652	28.6	--	--	--	--	40.8
P6E5	B	645	12.7	652	29.7	650	21.5	--	--	63.9
R6E5	B	645	12.7	652	30.8	650	22.3	--	--	65.8
M6E5	B,C	645	12.2	652	28.6	650	20.7	--	--	61.5
PAE5	A	645	11.5	652	27.0	650	19.6	--	--	58.1
RAE5	A	645	11.5	652	27.0	650	19.6	--	--	58.1
MAE6	A	722	11.5	--	--	--	--	--	--	11.5
NAE6	A	722	11.5	730	27.0	--	--	--	--	38.5
N6E6	B	722	12.2	730	28.6	--	--	--	--	40.8
P6E6	B	722	12.7	730	29.7	730	21.5	--	--	63.9
R6E6	B	722	13.1	730	30.8	730	22.3	--	--	66.2
M6E6	B,C	722	12.2	730	28.6	730	20.7	--	--	61.5
PAE6	A	722	11.5	730	27.0	730	19.6	--	--	58.1
RAE6	A	722	11.5	730	27.0	730	19.6	--	--	58.1

(a) Group A contains Mo (HTB) and Nb-1Zr (HTB). Group B contains Mo-41Re (both HTA and HTB) and Mo (HTA) and Nb-1Zr (HTA). Group C contains only TZM (HTA).
(b) dpa values calculated for stainless steel.

Post-Irradiation Examination

Specimen packets from MOTA-1B, -1C, and -1E are currently available in the fusion hot cell for removal and sorting of specimens. Specimen packets from MOTA-1D have been requested for transfer from long-term storage to the fusion hot cell. Density change measurements have been scheduled, with priority placed on the lower fluence ITER-relevant specimens. Disk bend tests are also under consideration to examine the possibility of radiation-induced embrittlement.

FUTURE WORK

This effort will continue focusing on post-irradiation examination of existing specimens and on the possibility of including minitensile specimens in MOTA during cycle 12 of FFTF.

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