Transactions of the Korean Nuclear Society Autumn Meeting
Changwon, Korea, October 24-25, 2024

Irradiation induced creep behavior of dilute Al alloys

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Keywords : heavy ion irradiation, Al alloys, irradiation induced creep

1. Introduction

A newer trend in irradiation damage research is to employ ion irradiations in combination with newly developed micromechanical testing on miniaturized specimens[1-3]. To have a better knowledge on irradiation damage in nanocrystalline materials, irradiation induced creep measurements on nanocrystalline metals were performed. This work is aimed to help fill this gap in knowledge by performing irradiation induced creep measurements using thin-film bulge tests.

2. Methods and Results

2.1 Experimental

The thin film bulge test samples, membrane size 2.75 x 0.5 mm2, were prepared using a modification of conventional micro-fabrication and photolithography methods [4]. Nanocrystalline Al alloys are grown using an AJA DC magnetron sputtering system.

The experimental setup was placed at the end of High Voltage Engineering Van de Graaff accelerator, which was used for ion irradiation. Mechanical analysis of the thin film bulge test can be found in ref. [5]. The strain can be expressed as,

$$\varepsilon_x = \varepsilon_0 + \frac{2h^2}{3a^2} arcsin \ \ \frac{2ah}{(a^2+h^2)} - 1$$

where ε_0 represents residual strain.

Microstructural characterization of the specimen was conducted using TEM and STEM methods. For High Resolution Transmission Electron Microscopy (HRTEM) imaging, especially, JEOL 2010F EF-FEG was employed using high angle annular dark field (HAADF)-STEM.

2.2 Characterization

STEM_HAADF micrographs showing the final microstructure of AlSc1.1 after irradiation induced creep (IIC) are presented. No precipitates were observed after IIC in the as-deposited samples. The grain size of pre-annealed $AlSc_{1.1}$ did not change after RT irradiation and precipitation is not observed.

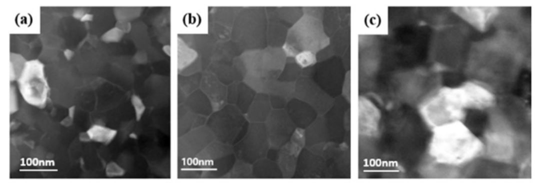

Fig. 1. HAADF-STEM images of $AlSc_{1.1}$ after IIC (a) at room temperature: as grown, (b) at 75 ºC: as grown (c) at room temperature (25 ºC): pre-annealed at 250 ºC,

2.3 Irradiation induced creep

Regarding $AlSc_{1.1}$ as-grown IIC, IIC results show a dependence on temperature. At room temperature B_0 ~ 1.1 E- 4 MPa-1·dpa-1 and at 75 °C, B_0 ~ 2.2 E- 4 MPa-1·dpa-1. The third set of creep data refers to a pre-annealed sample (at 250 ºC) irradiated at RT. The data for this sample are intriguing, as the strain rates and values of B_0 are initially very small, but they slowly increase with dose and approach the value for B_0 for the as-grown sample irradiated at RT.

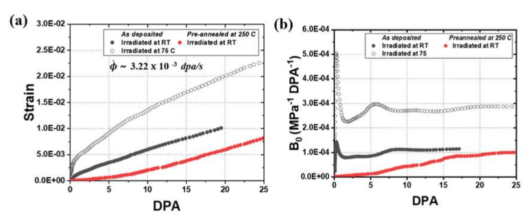

Fig. 2. IIC response of AlSc1.1 (a) DPA vs strain (b) DPA vs creep compliance

The measured steady state creep compliances are reported in Table 1. $AlSc_{1.1}$ binary alloy exhibits better creep resistance than pure Al as indicated in Table 1. $AlSc_{1.1}$ binary alloy exhibits better creep resistance than pure Al as indicated in Table 1.

Table I: Creep compliance (B_0)

	Condition	Temp. (°C)	B_0 ($MPa^{-1}DPA^{-1}$)
$AlSc_{1.1}$	As grown	RT	~ 1.0 E^{-4}
		75	~ 2.2 E^{-4}
	Pre-annealed at 250°C	RT	~ 1.0 E^{-4}
Al	As grown	100	~ 4.5 E^{-4}

3. Conclusions

This study demonstrated a reliable method for measuring based on the bulge test during heavy ion irradiation. The results reveal, moreover, that irradiation induced creep occurs in Al at temperatures as low as room temperature, which is reasonable as vacancies are already highly mobile in Al at this temperature. The experiments also showed that pre-existing Al_3Sc precipitates in Al appear to reduce the irradiation induced creep compliance.

REFERENCES

[1] S. Özerinç, R.S. Averback, W.P. King, In situ Measurements of Irradiation-Induced Creep of Nanocrystalline Copper at Elevated Temperatures, Jom 68(11), p.2737-2741, 2016.

[2] S. Özerinç, R.S. Averback, W.P. King, In situ creep measurements on micropillar samples during heavy ion irradiation, Journal of Nuclear Materials 451(1-3), p.104-11, 2014

[3] G.S. Jawaharram, P.M. Price, C.M. Barr, K. Hattar, R.S. Averback, S.J. Dillon, High temperature irradiation induced creep in Ag nanopillars measured via in situ transmission electron microscopy, Scripta Materialia 148, p.1-4, 2018.

[4] Y. Xiang, X. Chen, J.J. Vlassak, Plane-strain bulge test for thin films, Journal of materials research 20(09), p. 2360-2370, 2005

[5] F. H. Ruddy, A. R Dulloo, J. G Seidel, J.W.Palmour, and R. Singh, The Charged Particle Response of Silicon Carbide Semiconductor Radiation Detector, Nuclear Instruments and Methods In Physics Research, Vol.505, p.159, 2003.