Microsc. Microanal. 26 (Suppl 1), 2020

doi:10.1017/S1431927620000380

Characterization of Microstructure and Irradiation Hardening of Zr -1% Nb and Zr-2.5% Nb During Low Dose Neutron Irradiation

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Zirconium-niobium alloys are structural materials in nuclear power plants. During operation, the working environment of these components is a combination of temperature, irradiation, oxidation and hydrogen pick-up. Morphology, orientation, distribution and crystallographic aspects of hydrides and second phase particles play important roles.

In this work, the interaction between hydrides, second phase particles and radiation damage at 25 ºC y 300 ºC in Zr-1%Nb and Zr-2.5%Nb will be analyzed. A group of samples of each material was hydrided and irradiated in the CNEA-RA3 nuclear reactor. They were placed in a capsule located in one of the reactor irradiation channels. The neutron fluence was $3.5x10^{23}$n m^{-2} after an irradiation of 30 days. Both alloys were analyzed by transmission electron microscopy.

TEM micrographs show hydrides in the α-Zr matrix. These hydrides have been characterized as needle-shape type ξ (zeta), with HCP structure, lattice parameters a = 0.33 nm and c = 1.029 nm, corresponding to a trigonal crystal with spatial group P3m1[1]. As well, small spherical precipitates were found. Their crystal structure was characterized as hexagonal closed-packet, knowing as $Zr(Nb,Fe)_2$Laves phase. This phase was characterized as such by diffraction and not by composition due to its small size. The superposition of the matrix accentuates the uncertainty of the data that give higher values than those corresponding to a Laves phase [2]. Due to the small size of the Fe particles it is common to confuse them with ⟨a⟩ loops [3]. The presence of these precipitates was observed surrounding the ξ hydrides at the dose worked. In Zr-1%Nb samples ω phase was also found

Neutron irradiation in nuclear reactors creates point defects, such as vacancies and interstitials. Eventually interstitials migrate and nucleate giving rise to loops. Type ⟨a⟩ loops are the first to nucleate at low doses (5×10^{25} n m^{-2}) and low temperatures. These loops can be of vacancies or interstitials, varying from 5 to 20 nm in size, depending on the irradiation temperature [4].

In the present study, it has not been possible to characterize them. Cockeram et al. [5] reported that after irradiation fluences lower than 0.058×10^{24} n m^2, neither $\langle a \rangle$ nor $\langle c \rangle$ type dislocations loops or point defect clusters are observed.

The tensile test of the material irradiated with ξ hydrides showed a high hardening and a significant decrease of the ductility. Therefore, it can be inferred that the damage by irradiation influences more in the mechanical properties. Irradiation loops or clusters of point defects are presents. Their size is below the size detection limits for TEM.

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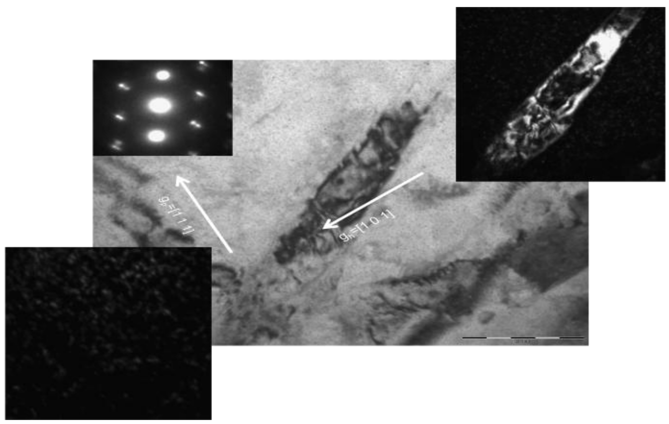

Figure 1. TEM bright field image of ξ hydrides and Fe precipitates in the α-Zr matrix, SAD pattern and dark fields in Zr-1%Nb. Tensile test was performed at 300 ºC

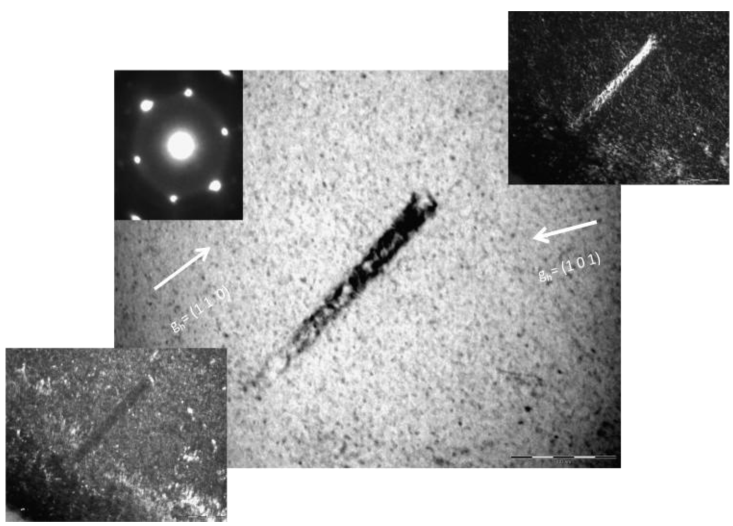

Figure 2. **T**EM bright field image of ξ hydrides and Fe precipitates in the α-Zr matrix, SAD pattern and dark fields in Zr-2.5%Nb Tensile test was performed at 300 ºC.

https://doi.org/10.1017/S1431927620000380 Published online by Cambridge University Press