Accepted Manuscript

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PII: S0022-3115(18)30143-0

DOI: 10.1016/j.jnucmat.2018.05.068

Reference: NUMA 50998

To appear in: *Journal of Nuclear Materials*

Received Date: 30 January 2018

Revised Date: 3 May 2018

Accepted Date: 28 May 2018

Please cite this article as: A. Renault-Laborne, J. Hure, J. Malaplate, P. Gavoille, F. Sefta, B. Tanguy, Tensile properties and deformation microstructure of highly neutron-irradiated 316 stainless steels at low and fast strain rate, *Journal of Nuclear Materials* (2018), doi: 10.1016/j.jnucmat.2018.05.068.

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Tensile properties and deformation microstructure of highly neutron-irradiated 316 stainless steels at low and fast strain rate

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Keywords: Austenitic stainless steel, tensile properties, dislocation channeling, twinning, phase transformation, strain rate

Abstract: Post-irradiation deformation behavior of solution-annealed (SA) and cold-worked (CW) 316 austenitic stainless steel irradiated to doses from 9 to 39 dpa is examined as a function of strain rate and irradiation conditions (neutron spectrum, temperature). Tensile properties are found to be significantly higher for lower irradiation temperature and for CW material, for similar irradiation levels. The effect of strain rate on tensile properties is shown to be weak in the range [$10^{-8}s^{-1}$; $10^{-4}s^{-1}$]. TEM investigations after deformation for levels of plastic strain of about 1% show on SA 316 the presence of deformation bands corresponding to one or even a mixture of twins, extended stacking faults, α'-martensite islands and ε-martensite nanobands. Bundles of crisscrossing bands, found to be a composite of overlapping stacking faults, nanotwins and ε-martensite nanolayers, are observed at TEM foils edges near the grain boundaries with α'-martensite islands decorating these edges. Except observation of a slight decrease of the number of deformation bands in the specimen deformed at slower strain rate, no qualitative microstructural differences appear between specimens tested at slow and fast strain rates.

1. Introduction

Austenitic (γ) stainless steels are widely used as core structural components in Light Water Reactors (LWRs), owing to their good mechanical properties and corrosion resistance in primary water. However, they are exposed to intense neutron flux and suffer radiation-induced changes of mechanical properties such as hardening, loss of strain hardening capacity, toughness reduction. Mechanical property changes originate from microstructural evolution such as formation of Frank loops, cavities, precipitates (see e.g., [1]). In addition, a degradation mechanism is observed, called Irradiation-Assisted Stress Corrosion Cracking (IASCC), leading to baffle-to-former bolts failures (for a recent review, see [2]) under applied stress. IASCC can have a significant influence on maintenance cost and time, and hence is an issue of concern for in-core components. IASCC is a complex degradation phenomenon, and various contributors have been proposed, such as Radiation-Induced Segregation (RIS) at grain boundaries, radiation hardening, and initial microchemistry / microstructure [3].

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