IRRADIATION EFFECTS ON THE OXIDATION FIRST STAGES of a 316L austenitic stainless steel in simulated primary environment

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Achieving a better understanding of the Irradiation Assisted Stress Corrosion Cracking (IASCC) resistance is one of the issues to improve the durability of Pressurized Water Reactors. To do so, assessing the interaction of irradiation defects with oxidation of internal vessel bolts, made up of 316L alloy, is crucial. Indeed, some recent studies [1-2] seem to indicate that irradiation modifies the kinetics and the nature of the oxides formed. The properties of oxide films formed, including morphology, thickness, structure and chemical compositions are thought to play a crucial role in the oxidation process, especially at the initial stages and at crack tips. To study at best the IASCC mechanisms, one should focus on the investigation of the oxidation occurring at the crack tips. As cracks will further propagate, they will present at crack tips oxidized areas analogous to the oxidation first stages. Hence, to emulate the oxidation at the cracks tips, short times oxidations were carried out in simulated PWR environment. They allowed to investigate the oxidation first stages on surface oxides and especially the oxides formation and growth.

First, the characterization of the oxide layers formed on unirradiated 316L stainless steel in simulated primary environment will be presented. Their nature, structure and morphology both on the surface and at grain boundaries were investigated. Indeed, since the main bolt cracks appears to be intergranular ones, attention was drawn on grain boundaries oxidations. The effect of crystallographic orientation of the underlying metal grain on the oxide scales and oxidation kinetic was thoroughly studied and will be presented.

Second, the irradiation effect on the oxidation kinetics of the austenitic 316L exposed to primary water have been studied. Synthetic proton pre-irradiations were chosen to emulate the neutron irradiation and still induced similar changes in the materials (dislocation loops, Radiation Induced Segregation (RIS), cavities). The oxide morphology, thickness and composition both on the surface and at grain boundaries have been characterized from macroscopic investigations techniques (optical microscopy, Gazing Incidence X-Ray diffraction (GIXRD), Raman spectroscopy) to microscopic ones (SEM-EBSD, TEM, STEM-EDX-EELS). Then, results on the Irradiation Assisted Corrosion (IAC) experiment of a sample oxidized under proton flux will be presented.

[1] S. Perrin, L. Marchetti, C. Duhamel, M. Sennour, F. Jomard. 'Influence of irradiation on the oxide film formed on 316L stainless steel in PWR Primary Water, Oxidation of metals, Vol.80, no 5-6, pp.623-633, 2013.

[2] J. Gupta, J. Hure, B. Tanguy, L. Laffont, M.-C. Lafont, E. Andrieu, ,Characterization of ion irradiation effects on the microstructure, hardness, deformation and crack initiation behavior of austenitic stainless steel: heavy ions vs protons' Journal of nuclear materials, 501, 45-58, 2018