Multi-scale approach applied to the macro/micro-mechanical characterization of chromium-coated Zr-based nuclear fuel claddings

Yanis TaÏbi*[1,2], Sergio Sao-Joao[2], Szilvia Kalacska[2], Guillaume Kermouche[2], Paul Saby[2], Ali Charbal[1], and Jean-Christophe Brachet[1]

[1]CEA - DES ISAS DRMP SRMA – CEA - DES ISAS DRMP SRMA – France
[2]Mines Saint-Etienne – Centre SMS – France

Abstract

Micromechanical testing such as micro-pillar compression or micro-cantilever bending, have been significantly developed in the field of material science. These methods can provide good evaluation of mechanical properties at microstructural scales, offering insights into material behavior that traditional macroscale testing cannot provide. Small samples subjected to controlled loading conditions, allow studying deformation mechanisms, fracture behavior, and properties such as elasticity, yield strength, and plasticity at the microscale. These methods are well suited for the investigation of deposited chromium coatings recently applied to Enhanced Accident Tolerent Fuel (EATF) Zirconium based claddings. The generated coating microstructure (columnar near the outer surface and equiaxed near the substrate) and residual stresses induced by the fabrication process (HiPIMS-PVD) may provide specific mechanical properties of the thin chromium coating compared to pure (bulk) chromium materials. It is in this context that micromechanical testing are used to help understanding microstructure-mechanical properties relationships of chromium coated cladding tubes. To that end, micromechanical tests have been recently adapted and used on 15μm thick chromium coatings deposited on a Zr-based nuclear fuel cladding. In this poster, different micromechanical behavior characterization methods are illustrated and applied to the chromium coatings of interest. Firstly, bending test on pre-notched microcantilever coupled with EBSD is illustrated to assess the coating's toughness by tracking the crack propagation modes. Secondly, the elastoplastic behavior of the coating is assessed using micro-compression test. This micromechanical approach provides a good evaluation of the yield strength for instance. Finally, two methods to determine the residual stresses states are assessed: (1) traditional X-ray diffraction using the "$\sin^2(\Psi)$ method" and (2) by combination of Focused Ion Beam (FIB) machining and Digital Image Correlation (DIC), (so called FIB-DIC method).

*Speaker