Understanding the mechanisms of environmental degradation by high-resolution microscopy

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In order to develop better materials for nuclear reactors, we need a more fundamental understanding of the mechanisms that control their performance and, more importantly, their degradation while in service. Recent developments in instrumentation and data analysis have finally allowed for a more direct observation of key features such as crack tips, nanoprecipitates or radiation-induced changes [1]. Information on the microstructure or chemical composition with sub-nm resolution is now achievable. In addition, through correlative microscopy, the same region/feature can be successfully probed with various techniques, overcoming their individual limitations. We have combined transmission electron microscopy, atom-probe tomography and NanoSIMS to provide an unprecedented multi-scale description. This approach is proving very successful to understand the key material properties [2,3]. We will illustrate this approach by showing how the mechanisms controlling a complex problem such as stress corrosion cracking (SCC) in pressurized water reactors (PWRs) can be quantified, allowing for predictive model validations. The effect of factors such as applied stress, working temperature, irradiation or environment chemistry can now be better understood with the use of dedicated in-situ experiments.

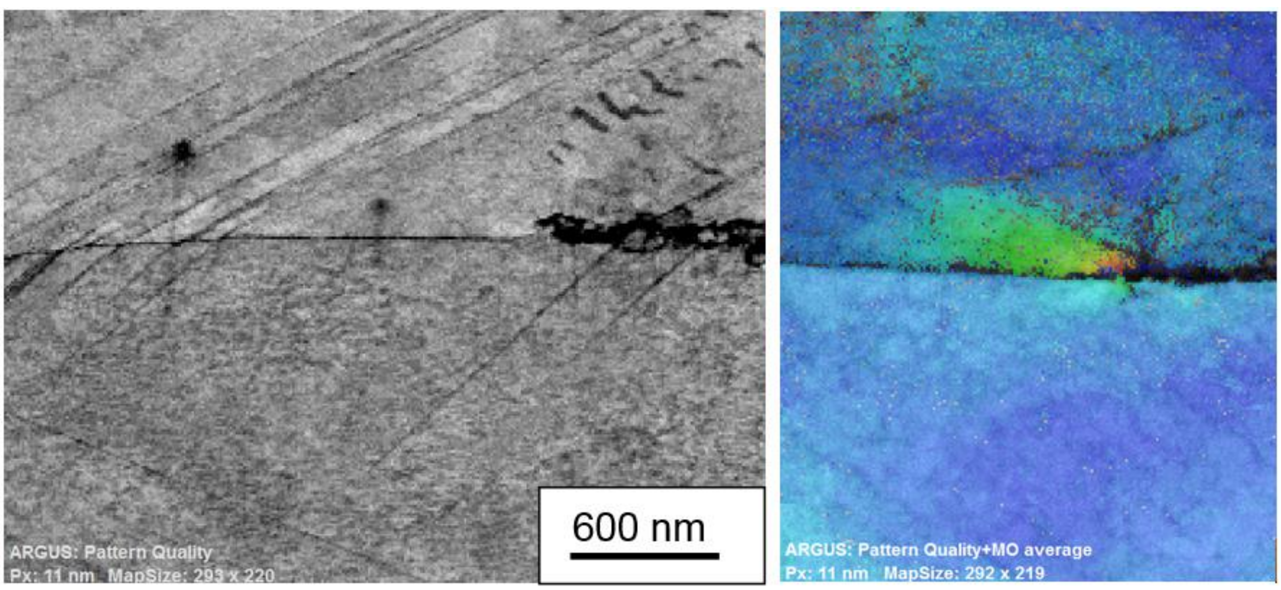

Figure 1: Transmission Kikuchi Diffraction (TKD) results from a 316 stainless steel sample tested under simulated PWR primary water conditions. (Left) Quality map showing grain boundary (horizontal), deformation bands, and crack tip (on right hand side of image). (Right) Kernel misorientation map revealing localized deformation around the crack tip (step size is 10nm).

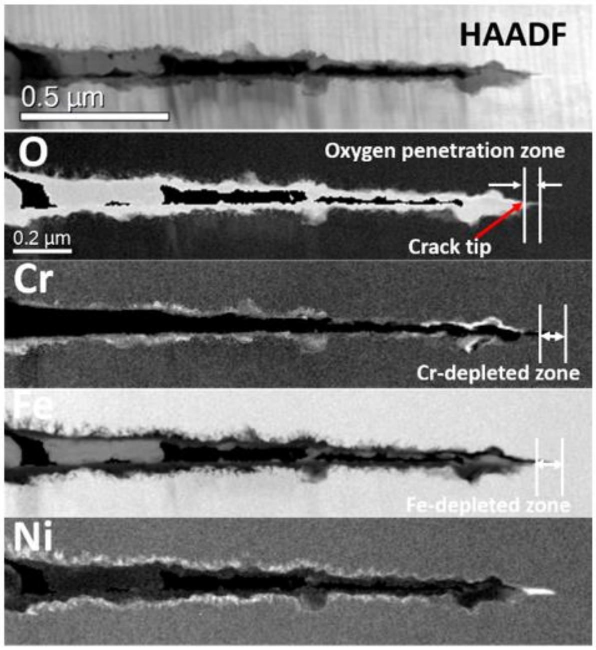

Figure 2: STEM HAADF image (top) and EELS SI maps from a 316 stainless steel sample tested under simulated PWR primary water conditions. Local changes in chemistry ahead of the crack tip have been highlighted.

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