COMBINED HIGH ENERGY X-RAY DIFFRACTION AND SMALL-ANGLE SCATTERING MEASUREMENTS OF STRAIN, DISLOCATION DENSITY AND POROSITY NEAR STEEL FATIGUE CRACKS GROWN IN HYDROGEN

Matthew J. Connolly, National Institute of Standards and Technology,325 Broadway, Boulder CO 80305
Matthew.connolly@nist.gov
Zachary N. Buck, National Institute of Standards and Technology,325 Broadway, Boulder CO 80305
May L. Martin, National Institute of Standards and Technology,325 Broadway, Boulder CO 80305
Robert L. Amaro, Advanced Materials Testing Technologies, Pell City, AL 35128
Peter E. Bradley, National Institute of Standards and Technology,325 Broadway, Boulder CO 80305
Damian S. Lauria, National Institute of Standards and Technology,325 Broadway, Boulder CO 80305
Jun-Sang Park, Argonne National Laboratory, Lemont, IL, 604393
Andrew J. Slifka, National Institute of Standards and Technology,325 Broadway, Boulder CO 80305

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Elucidating the mechanisms of hydrogen embrittlement of steels is complicated by the fact that multiple mechanisms may be activated at once or may even require a synergistic co-existence for activation. Some leading proposed mechanisms of hydrogen embrittlement include hydrogen-enhanced decohesion (HEDE), the hydrogen-enhanced localized plasticity (HELP) mechanism, and the Nano-Void Coalescence Mechanism (NVC). In HEDE, accumulation of hydrogen at locations of high triaxial stresses leads to the weakening of Fe-Fe bonds once the hydrogen concentration reaches a critical concentration. In HELP, the introduction of hydrogen gas influences the behavior of dislocations in the Fe lattice, usually enhancing dislocation mobility in the steel framework. In NVC, hydrogen is predicted to lead to the stabilization and promotion of vacancy (“nano-scale void”) agglomeration. A full understanding of these mechanisms, their relationship to fatigue properties, and their interaction with each other requires a measurement capable of probing all three mechanisms at once. Here we present simultaneous High Energy X-ray Diffraction (HEXRD) and Small-Angle X-ray Scattering (SAXS) measurements during in-situ fatiguing of a steel crack in hydrogen. HEXRD measurements probe HEDE And HELP through a determination of strain and dislocation density; SAXS measurements probe NVC through a determination of nano-pore size distribution. We will present strain, dislocation density, and pore size distributions ahead of crack tips grown in air and in hydrogen. We will discuss the differences in each between the crack tips grown in air and in hydrogen in the context of the HELP, HEDE, and NVC mechanisms.