Materials Science & Engineering Doctoral Defense

Dealloying Induced Stress Corrosion Cracking

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abstract

Dealloying induced stress corrosion cracking is particularly relevant in energy conversion systems (both nuclear and fossil fuel) as many failures in alloys such as austenitic stainless steel and nickel-based systems result directly from dealloying. This study provides evidence of the role of unstable dynamic fracture processes in dealloying induced stress-corrosion cracking of face-centered cubic alloys. Corrosion of such alloys often results in the formation of a brittle nanoporous layer which we hypothesize serves to nucleate a crack that owing to dynamic effects penetrates into the un-dealloyed parent phase alloy. Thus, since there is essentially a purely mechanical component of cracking, stress corrosion crack propagation rates can be significantly larger than that predicted from electrochemical parameters. The main objective of this work is to examine and test this hypothesis under conditions relevant to stress corrosion cracking.

Silver-gold alloys serve as a model system for this study since hydrogen effects can be neglected on a thermodynamic basis, which allows us to focus on a single cracking mechanism. In order to study various aspects of this problem, the dynamic fracture properties of monolithic nanoporous gold (NPG) were examined in air and under electrochemical conditions relevant to stress corrosion cracking. The detailed processes associated with the crack injection phenomenon were also examined by forming dealloyed nanoporous layers of prescribed properties on un-dealloyed parent phase structures and measuring crack penetration distances.

Dynamic fracture in monolithic NPG and in crack injection experiments was examined using high-speed (10^6 frames s^{-1}) digital photography. The tunable set of experimental parameters included the NPG length scale (20-40 nm), thickness of the dealloyed layer (10-3000 nm) and the electrochemical potential (0.5-1.5 V). The results of crack injection experiments were characterized using the dual-beam focused ion beam/scanning electron microscopy. Together these tools allow us to very accurately examine the detailed structure and composition of dealloyed grain boundaries and compare crack injection distances to the depth of dealloying.

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