DYNAMIC FRACTURE IN DEALLLOYING INDUCED STRESS-CORROSION CRACKING

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The so-called film-induced cleavage (FIC) mechanism of stress-corrosion cracking (SCC) is based on the hypothesis that the nanoporous structure resulting from dealloying can sustain a high-speed crack that injects into the undealloyed parent phase solid. In metallic alloys susceptible to this form of cracking, a high-speed crack is nucleated within the nanoporous structure that penetrates into the undealloyed parent phase material for distances of order microns prior to coming to arrest by plastic processes. Current theory requires crack velocities within the porous layer to be greater than ~ 150 ms^{-1} in order for the crack to be injected a distance of several microns. This SCC process is discontinuous: a nanoporous layer forms by dealloying corrosion, then the crack propagates exposing more parent phase to the electrolyte, which in turn corrodes further and the cycle repeats. Central to understanding dealloying-induced SCC are the dynamic fracture properties of nanoporous morphologies.

The prototypical example of a dealloyed morphology is nanoporous gold (NPG) which forms when Ag-Au alloys are immersed under free-corrosion in nitric acid. NPG has an isotropic bi-continuous solid/void morphology that forms by a self-organization process involving Ag dissolution and surface diffusion. The crystal orientation of the parent phase is retained in the nanoporous structure which is characterized by a mean ligament diameter/length and similar measures of the void phase. In the past 25 years, numerous experimental and computational publications have appeared, aimed at characterizing both the nano-scale structure and the mechanical properties of these solids. In order to rule out the operation of other SCC mechanisms, such as hydrogen embrittlement, Ag-Au alloys, which are immune to hydrogen effects, serve as a model system for the study of various aspects of the FIC mechanism. Our own previous research has shown that at a fixed volume of NPG, the nanometer-scale dimensions of the pores and ligaments characterizing the morphology, determine its ductile or brittle response. This behavior is analogous to the extreme value statistical size effect in the “weakest link” theory of brittle fracture.

In this presentation, I will focus on three aspects of our recent work aimed at exploring the SCC of Ag-Au alloys: (1) Results (Figure 1) will be presented that demonstrate that monolithic NPG structures with a mean ligament diameter of 40 nm can support dynamic fracture at crack speeds as large as 260 m/s corresponding to 65% of the Rayleigh wave speed. (2) Under suitable time-dependent conditions, thin layers (~ 0.5 μm) of NPG can inject cracks into undealloyed parent phase material for distances of order 100 μm. Under typical SCC conditions these thin layers are composed of 5 nm diameter ligaments. (3) In the case of Ag-Au single crystals, the fracture surface orientations (characterized by EBSD) found in crack penetration experiments are similar to those obtained in stress-corrosion cracking. In both sets of experiments these orientations are determined by that of the tensile axis.

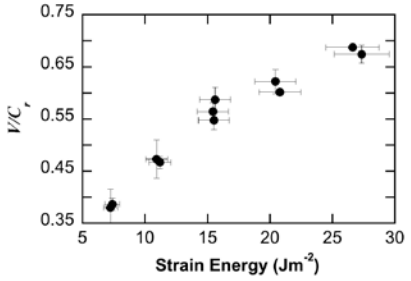

Figure 1. Summary of dynamic fracture experiments on strip samples. v/c_r is the normalized crack speed, where c_r is the Rayleigh wave speed in NPG equal to 400 m/s., Error bars are based on the standard deviation of 6 samples tested at the indicated values of strain energy.

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