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Electromechanical and Chemomechanical Performance of Laser Oxide Coatings on Metallic Substrates

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Concentrated, nanosecond-pulsed laser exposure of oxidizing metals in ambient atmosphere produces highly colored, well-adhered oxide coatings, which are particularly interesting for use as unique authenticity identifiers on welded or sealed components. The combined properties of the oxide-substrate system control the coupled electromechanical behavior and environmental stability of the oxide. Laser-processing parameters dictate oxide thickness, which in turn defines color, residual film stress, and fracture behavior. Oxides grown on stainless steel 304L and CP grade II titanium are residually stressed in tension leading to through-thickness cracking at film thicknesses greater than ~100 nm. Hardness, fracture behavior, and residual stress are highly dependent upon thickness suggesting that internal defects influence mechanical behavior. Conducting nanoindentation reveals an increase in conductance with decreasing oxide thickness, further suggesting the dependence of mechanical behavior on fluctuations in oxide defect density. Additionally, post mortem energy dispersive spectroscopy of oxides on SS 304L exposed to an aggressive environment manifests a Cr-denuded zone in the substrate immediately beneath the oxide, ultimately creating a microstructure that is susceptible to corrosive attack. Furthermore, the fracture behavior and environmental resistance analyses can be combined, by performing high-load, conical indentation in a fluid cell containing various inert and corrosive solutions, to evaluate the coupling of mechanical stresses and environmental effects. The integration of multiple characterization techniques provides a unique approach for defining electro- and chemo-mechanical performance of the oxides in harsh operating environments. This work was partially supported by DTRA Basic Research Award # IACRO 11-4471I and by Sandia National Laboratories, a Lockheed Martin Company for the USDOE NNSA under contract DE-AC04-94AL85000.