Integrated Contamination Layers for Corrosion Sensors

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Motivation—Atmospheric corrosion is an important degradation mode for microelectronic components. The extremely small length scales associated with such components often mean that even a small amount of corrosion can significantly degrade performance, or even be catastrophic to the functionality of the device. Consequently, device failure may provide the first indication that a corrosion problem exists. Ideal corrosion sensors would be small, inexpensive devices which could be integrated into a component, system, or tester for *in situ* detection of accelerated corrosion processes before the onset of significant corrosion of the actual electronic devices. These sensors need to controllably degrade under a wide range of environmental conditions and have a measurable response that can be correlated with corrosion of real components. The sensors must incorporate corrosive contaminants and undergo tunable degradation.

Accomplishment—In order to develop an integrated contamination layer, we investigated evaporated thin films of NaCl. This layer was integrated with a microgalvanic couple to characterize the susceptibility to corrosion in humid environments. The microgalvanic couple is a simple Al-Au or Al_2Cu-Au meander line, designed to have high sensitivity to small corrosion volumes and enhanced susceptibility to relevant corrosion mechanisms. Figure 1(a) shows that a dense, homogeneous film of ~ 150 nm NaCl crystals was achieved on thin film Al. The distribution of crystallites using thermal evaporation is much more uniform than that obtained previously by standard "salt-spray" techniques. Al–Au and Al_2Cu-Au meander lines were fabricated using electron beam evaporation of the thin films onto SiO_2 coated Si substrates, in combination with standard photolithography, as shown in Figure 1 (b). The meander line consists of a series of twenty 5 µm wide bridges of Al or Al_2Cu that span 25 µm wide Au bars. This design was chosen to test two types of sites susceptible to corrosion: the contact areas and the proximity of the long bridges to the Au bars, which provide large areas for cathodic reactions.

The resistance is measured across the entire array in humid environments. The Al_2Cu films are more susceptible to corrosion. Figure 2 (a) shows an example of the change in resistance of an Al_2Cu-Au microgalvanic couple, with a 60 nm layer of evaporated NaCl, during exposure to 79% relative humidity. The response of a bare couple in aqueous 100 mM NaCl is shown in Figure 2 (b) for comparison. Mass transport limitations within the electrolyte layer in humid environments lead to a longer time to failure relative to aqueous exposures. The time to failure in humid environments is sensitive to both the thickness of the NaCl layer and the relative humidity.

Significance—Engineered aging structures that are susceptible to corrosion in humid environments are needed to act as early warning detectors of potential corrosion problems. This work, which integrates a contamination layer with an Al_2Cu-Au microgalvanic couple, demonstrates a sensor with tunable susceptibility to corrosion in humid environments. Calibration of this prototype sensor will ultimately allow *in situ* monitoring of device degradation in humid environments.

Sponsors for various phases of this work include: Nuclear Weapons: Enhanced Surveillance Campaign

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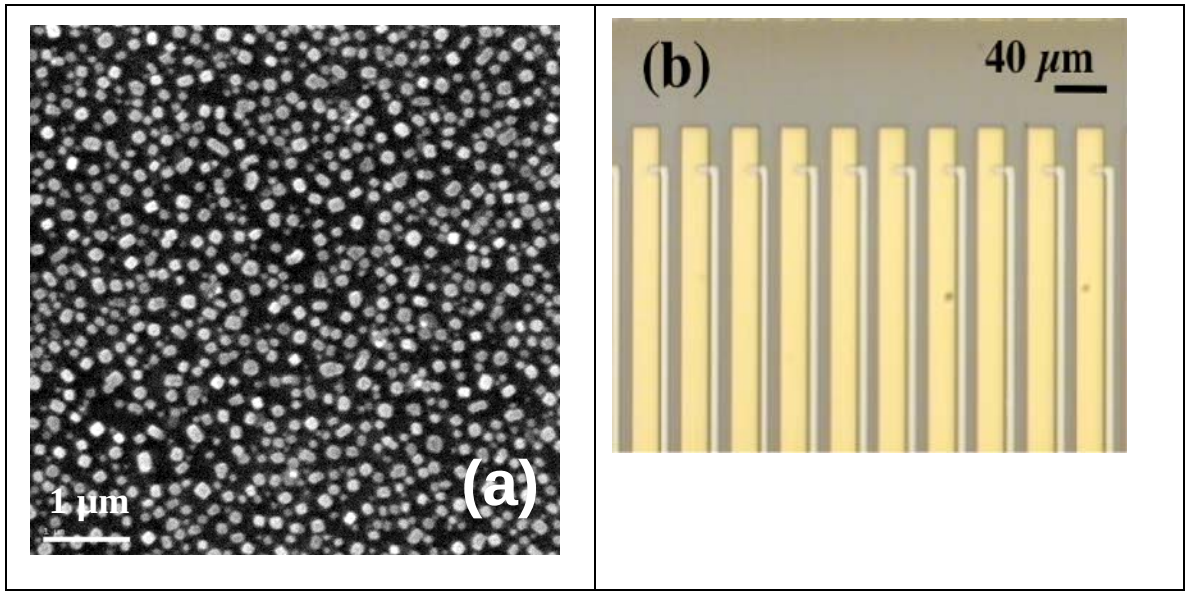

Figure 1. (a) Scanning electron micrograph of thermally evaporated NaCl crystals on Al showing homogeneous distribution. (b) Optical image of Al-Au meander line.

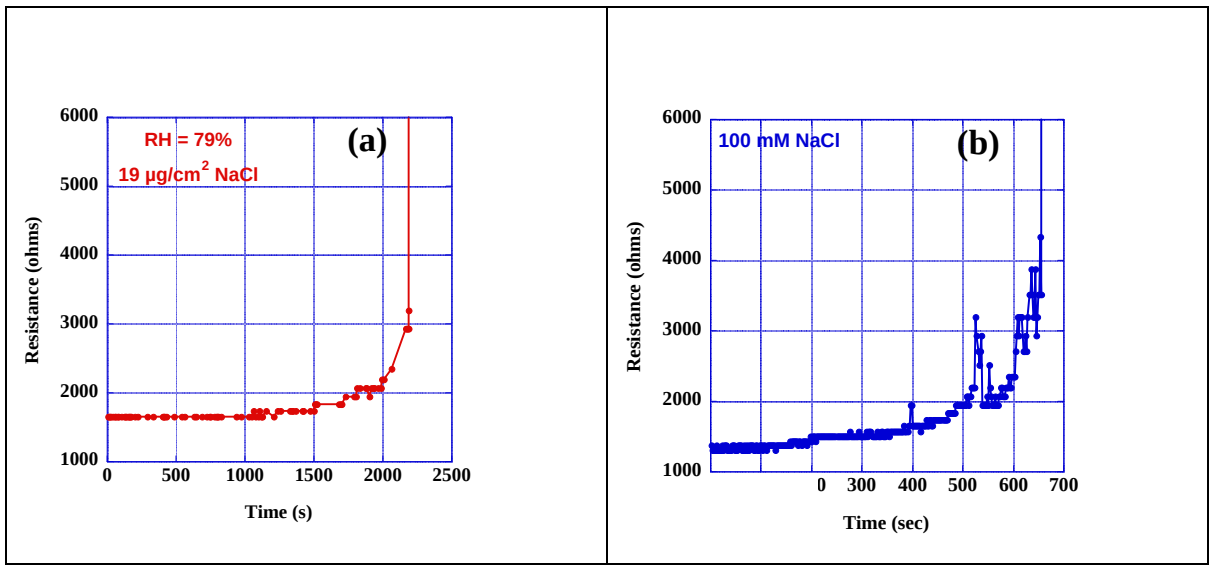

Figure 2. (a) Resistance change of a microgalvanic couple with incorporated NaCl layer during exposure to 79% relative humidity. (b). Resistance change of a microgalvanic couple (without incorporated NaCl layer) during exposure to aqueous 100 mM NaCl. Longer time to failure in 79% RH is indicative of mass transport limitations in the adsorbed water layer.