

Scanning Probe Studies of Water Nucleation and Growth on Aluminum Oxide

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Motivation—Understanding the interaction of nanoscale water layers with surfaces is important for many processes, such as atmospheric corrosion, stiction in MEMS and microfluidics. The initial layers of water that adsorb on a surface are thought to have a structure and properties that differ from the bulk. The defects, impurities, and morphology at the surface may profoundly influence the distribution of the water layer and thereby impact the properties of the water/solid interface.

Accomplishment—One approach to investigate the water/solid interface at the nanoscale is to use scanning probe microscopy to image the distribution of the water layer as a function of relative humidity. Initially, we have focused on the aluminum oxide covered aluminum surface, which is important in gaining understanding of atmospheric corrosion of interconnects in microelectronic components. Corrosion of the underlying aluminum occurs when the passive surface oxide is locally compromised through its interaction with water and aggressive halide species in the environment. The specific nature of the initiation sites is not known. However, if water adsorption is influenced by surface inhomogeneities, then by imaging the water layer distribution and measuring its properties we may gain a better understanding of the corrosion mechanisms and initiation sites.

We imaged the nucleation and growth of water droplets on aluminum thin films as a function of

relative humidity using *in-situ* atomic force microscopy (AFM). A gold-coated hydrophobic tip, operated in tapping mode, minimized the interaction between the tip and the water layer and allowed imaging without distortion. Scanned images were acquired in an environmental chamber for humidities ranging from < 2% up to 99%. Although the interaction force between the probe tip and the sample surface showed an abrupt increase near 20% RH, topographical contrast due to the presence of a water layer was not observed until reaching 80% RH. Figure 1 shows the amplitude image as the RH is increased from (a) < 2% to (b) 80%. The hemispherical water droplets observed in (b) range in size from 20 nm to 200 nm. After 5 min. at 80% RH, the droplet size is observed to grow, while the distribution remains constant. The results for decreasing relative humidity are shown in Fig. 2. Here the droplets were observed to gradually evaporate, leaving behind a surface residue. Although the properties of this surface residue have not yet been investigated, its presence may impact corrosion of components that undergo cyclic variations in relative humidity.

Significance—These results suggest that there are preferred sites for water nucleation on the aluminum oxide surface. If these sites do play a role in the initiation of localized corrosion, then a greater understanding of these sites will contribute to our ability to make accurate lifetime predictions for electronic components.

Sponsors for various phases of this work include: Nuclear Weapons/Engineering & Science Campaigns (ESC) and Nuclear Weapons/Readiness Technical Base & Facilities (RTBF)

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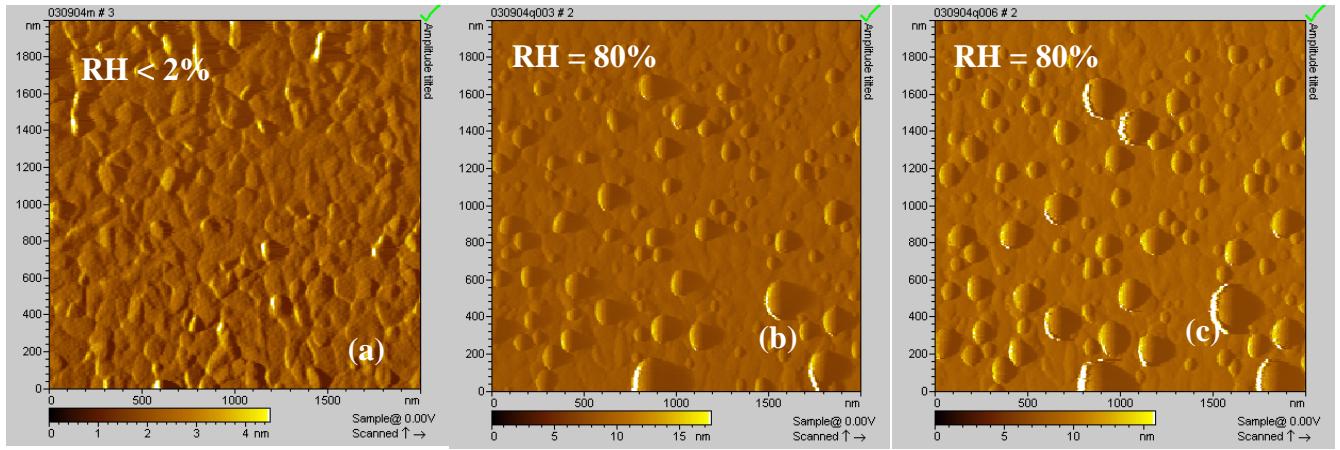


Figure 1. AFM images of an aluminum oxide covered aluminum thin film (a), showing the nucleation of hemispherical water droplets at 80% RH (b). After 5 minutes at 80% RH the droplets grow in size (c).

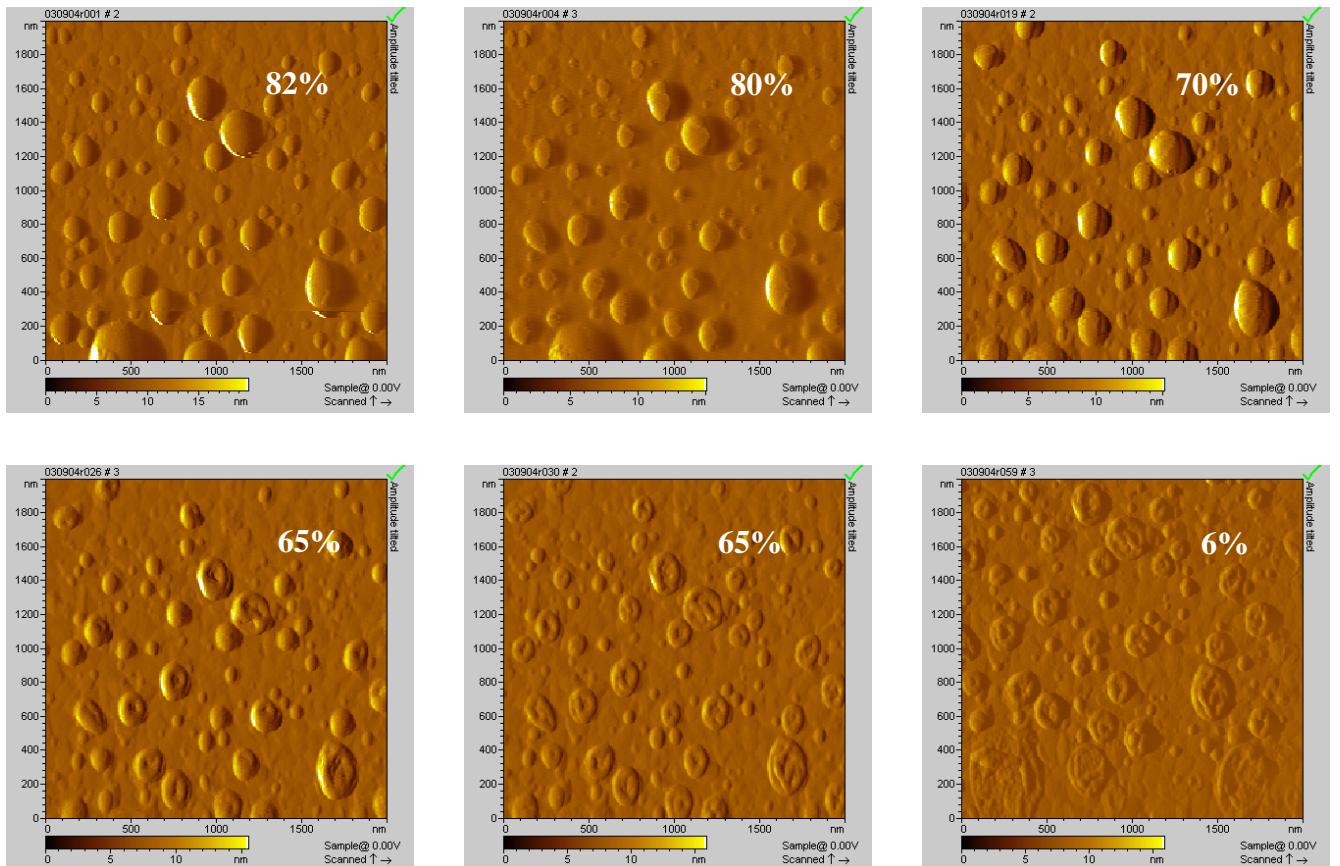


Figure 2. AFM images of an aluminum oxide covered aluminum thin film as a function of decreasing relative humidity following droplet nucleation at 82% RH. Droplets evaporate gradually as the RH decreases, leaving behind a surface residue.