New insight into early growth of solid thin films

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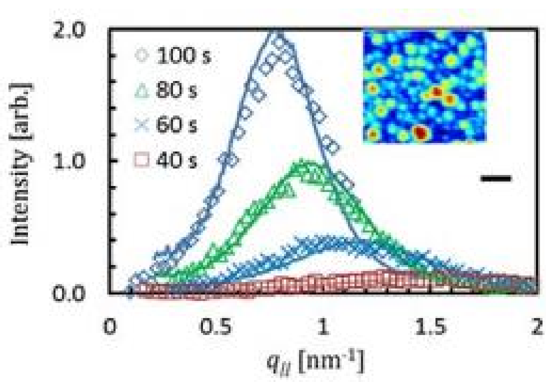

Evolution of the x-ray scattering patterns during the vapor phase deposition of Al atoms on silicon oxide. Inset: an atomic force microscope image of the film at the end of the experiment.

(Phys.org) —The foundation of many modern electronic devices, such as computer chips, are thin films – nanoscale-thickness layers of one material grown on the surface of another. As consumers continue to demand products that are sleeker and faster, understanding the evolution of thin-film growth will help scientists learn to tailor thin films for new technologies.

In some cases films grow layer by layer, each layer one atom thick, while in other cases atoms deposited onto a surface form three-dimensional islands that grow, impinge and coalesce into a continuous film. In this latter case, scientists have traditionally assumed that the growing islands are homogeneous, with similar sizes, and coalesce at roughly the same time. However, in a recent study, using x-rays produced at the National Synchrotron Light Source (NSLS), Boston University (BU) researchers investigated island growth in real time, discovering that the process is more dynamic than suggested by the traditional view.

The group determined that island evolution matches the behavior predicted by a simple yet detailed model of the deposition, growth, and coalescence of liquid droplets, known as the Family-Meakin (FM) model. Moreover, they propose that other types of thin films grown by the island mechanism may behave the same way during the early stages of growth. They describe their work in the September 7, 2012, edition of *Physical Review Letters*.

BU physicist Karl Ludwig explains, "It's surprising to many people that there are still fundamental things to learn about a process as apparently simple as three-dimensional thin film growth. However, as so often occurs, when we have a new tool that enables real-time investigation with unprecedented detail, we learn that reality is more complex, and more intriguing, than had often been assumed."

At NSLS beamline X21, using a research endstation developed to study materials surfaces and thin films in real time, the BU group deposited aluminum onto two surfaces, silicon oxide and sapphire. The samples were placed inside an ultrahigh vacuum chamber, and the thin film was deposited very slowly so that the scientists could take multiple x-ray scans of the surface during growth and "watch" the aluminum film evolve in real time.

The x-ray scans suggested that the deposited atoms initially gathered to form tiny islands with diameters of just a couple of nanometers (billionths of a meter) and then began to coalesce, forming larger islands about 10 nm across (the experiment was not long enough to complete film growth, but the islands would eventually merge into a continuous layer). This was later confirmed by atomic force microscope (AFM) images of the sample, taken after the experiment was finished and the sample had been extracted from the chamber. With final heights of about 3 nm, the islands were "strongly three-dimensional." Indeed, the AFM images taken at the end of the study showed relatively tall islands with approximately hemispherical shapes.

The results show several ways in which the film's evolution agrees with liquid-droplet behavior as predicted by FM theory – even though the film is solid, not liquid. For instance, the evolution of the islands is self-similar, meaning that the average geometry at a later time looks similar to that at an earlier time, but with length scales increased ("scaled") by a power law.

The key ingredient that the FM model incorporates, which was missing in the traditional view of island growth, is the coalescence of islands to form new, compact islands when they impinge. This leads to a characteristic morphology observed in the AFM images in which many smaller islands are dispersed among larger islands that form as the small ones combine. Such coalescence should be a widespread phenomenon for small islands on surfaces, and understanding it could lead to better control of ultra-thin films for technological use.

More information: Summary Slide (pdf)

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