Grain boundaries control residual stress in thin films

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Stresses in thin films can limit their performance or induce failure, so understanding and controlling stress evolution during growth is critical. Although compressive stress is often observed after the film is continuous, an explanation for the stress generation has been lacking.

Researchers at Brown University have proposed a mechanism for compressive stress generation based on the non-equilibrium conditions present during deposition. In this model, atoms are driven to diffuse into the grain boundary due to the supersaturation (i.e., higher chemical potential) of atoms on the surface. To validate this picture, they have recently measured stress in Sn films because it has the high atomic mobility needed to see the diffusion-controlled effects clearly.

Wafer curvature measurements of stress integrated over the layer thickness (stress-thickness) during growth and interrupts are shown in figure 1 with schematics illustrating the corresponding atomistic processes. During growth, the stress-thickness decreases at a constant rate, indicating that the layer has reached a steady-state compressive stress due to the elevated surface chemical potential. When the growth is interrupted, the surface chemical potential drops and the stress rapidly decays as atoms diffuse out of the grain boundary. When growth is resumed, the film returns to its compressive state. Measurements were also performed during etching for comparison with growth (figure 2). When the conditions are changed from deposition to etching the stress changes rapidly from compressive to tensile as atoms diffuse out of the grain boundary in response to the change in chemical potential. After reaching a steady-state, the stress-thickness changes more slowly due to removal of the stressed layers by etching.

The Sn results (i.e., independence of the average stress on film thickness and the similarity between deposition and etching) strongly support the mechanisms proposed in the diffusive model.

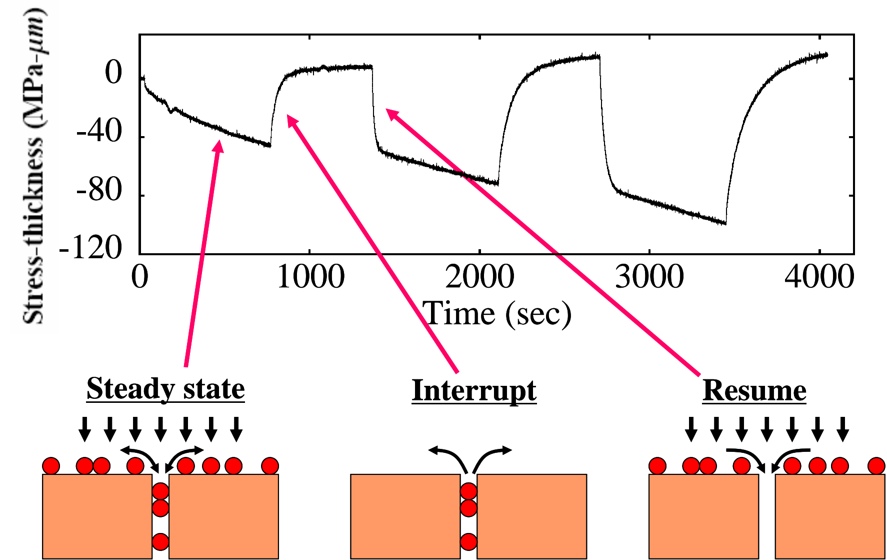

Figure 1

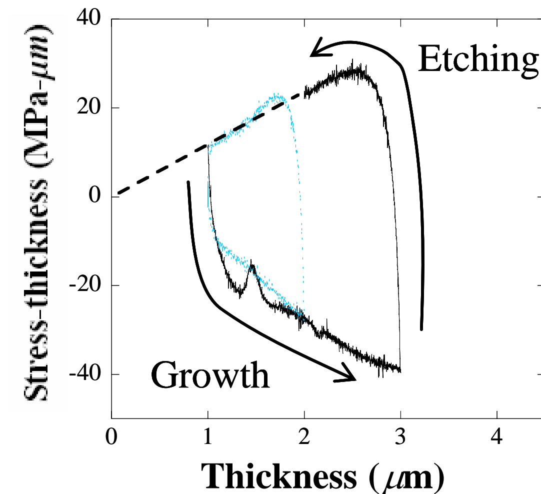

Figure 2