Experimental Characterization and Modeling of Templated Solid-State Dewetting of Thin Single-Crystal Ni Films

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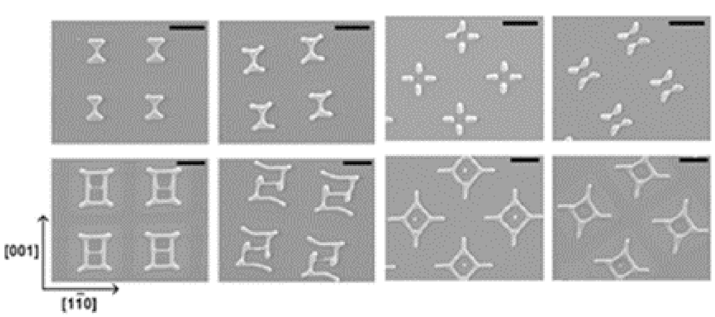
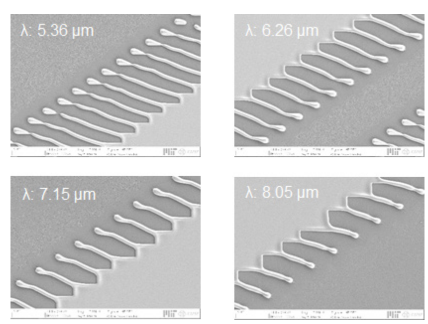
Templated solid-state dewetting provides a simple method for film patterning to form complex structures (Figure 1). The patterns that result from solid state dewetting are affected by various instabilities that develop at retracting edges and the features they lead to. These include pinch-off to form wires parallel to retracting film edges, instabilities at corners in retracting edges ("corner instabilities"), and Rayleigh-like instabilities that lead to break up of wire-like features. Previously we reported on the strong effects of crystalline anisotropy on the Rayleigh-like instability and identified factors that stabilize wire-like features. In the past year, we reported on experimental characterization and modeling of the corner instability and established the conditions that lead to the development of the unstable edge retraction when corners are present in film edges. We also characterized the effects of the annealing ambient on anisotropy in the rate of edge retraction and consequent changes in the patterns that form as a result of dewetting. We found that changing the gases and gas flow rates during annealing causes surface reconstructions that affect the anisotropy of the energy of the surfaces of the films and the anisotropy of surface diffusion. Control of the ambient gas during annealing provides an additional means of controlling the types of patterns that result from simple templating.

We are currently focusing on a fingering instability that can occur during edge retraction and results in formation of parallel wire-like features with different orientations from those that develop as a result of rim-pinch-off (Figure 2). Understanding and controlling whether pinch-off or fingering occurs is important for development of techniques for controlled pattern formation. When fingering occurs, it is also desirable to control the size and spacing of wires that form. In the past year, we have demonstrated that the initial roughness of a film edge determines whether pinch-off or fingering occurs, with rough edges leading to fingering. To further understand this phenomenon and to control it, we have used edges with controlled patterned roughness to template the fingering instability. We have found that the spacing of wires formed due to fingering can be controlled by the period of the patterned roughness. We have also found that controlling the period of the fingering process affects the kinetics of the fingering. Our ability to control the fingering process allows us to develop kinetic models that can be used to design templates that will lead to specific complex structures during solid-state dewetting. Through these studies, we are developing a suite of methods that can be used to suppress dewetting when it is undesirable and to control it for use in pattern formation.



▲ Figure 1: Patterns formed by solid state dewetting of square patches of Ni films patterned with different sizes and crystallographic orientations.



▲ Figure 2: Wires formed by templating a fingering instability using patterned periodic edge roughness.

FURTHER READING

- C. V. Thompson, "Solid-state Dewetting of Thin Films," Annual Review of Materials Research, vol. 42, 399-434, 2012.
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- G. H. Kim, W. Ma, B. Yildiz, and C .V. Thompson, "Effect of Annealing Ambient on Anisotropic Retraction of Film Edges During Solid-State Dewetting of Thin Single Crystal Films," J. Appl. Phys. vol. 120, 075306, 2016.