Nanoscale Pattern Formation during Electrodeposition of Crystalline Aluminum

Weidong Guo, and Duane T. Johnson

MINT Center and Department of Chemical Engineering

The University of Alabama

This project was funded by NSF Contract #CTS-0084425

Objective

We developed a model to predict the patterns formed during the electrodissolution of aluminum and other materials. The theoretical results are in good agreement with the experimental results for polycrystalline and crystalline aluminum. The formation of well-ordered hexagonal nano-structures could be used as patterned media for next-generation hard drives.

Mechanism of Pattern Formation

- Pattern formation comes from competition between adsorption rate, interfacial energy, and dissolution rate
- Electric field is larger at hills and smaller at valley
- Adsorption of surfactant is stronger at hills
- Interfacial energy flattens the interface

Results

- Results agree qualitatively with the experiments
- Intercalation energy is needed to predict stable hexagons and stripes.

Single Crystal Experiments

- Crystal orientation with respect to the interface gives anisotropic properties: Surface diffusion and Interfacial energy
- Experiments show that:
  - [100] gives mostly hexagons
  - [110] gives only stripes
  - [111] gives stripes and hexagons

Anisotropic Model

\[ \frac{\partial H}{\partial \tau} - s\nabla \cdot \left( D_v \nabla \left( \frac{\partial H}{\partial \tau} \right) \right) = -\nabla \cdot \left( D_s \nabla (\nabla^2 H - (\nabla \cdot H)^2 + 2\xi^1 (\nabla^2 H)^2 \right) \]

- \( s \) = operating parameter (voltage)
- \( D_v \) = anisotropic surface diffusion tensor
- \( \xi^1 \) = anisotropic parameters related to interfacial energy
- Results agree qualitatively with experiments: [110] crystal only gives striped pattern while [111] and [100] lead to competition between stripes and hexagons, which is in agreement with experiments


Conclusions

- New theory corrected the error in existing theory by considering interfacial energy and is needed to get stable hexagonal patterns
- New theory qualitatively predicts single crystal experiments
- Crystal orientation is important for pattern formation