Dendritic Growth of Copper in Microgravity and Strong Magnetic Field

Y. Fukunaka, Y. Konishi, Y. Tanaka, E. Kusaka, R. Ishii, I. Mogi and K. Kuribayashi[a]
Dept. of Energy Science and Technology, Faculty of Energy Science,Kyoto University, Kyoto, 606 Japan
[a]Inst. of Space & Astro. Sci., Sagamihara, 229 Japan

Introduction

The electrochemical deposition or etching with high aspect ratio or strong anisotropy through photoresist masks is a quite fundamental technique. The shape evolution control requires the precise knowledge of local current density distribution around a cavity frequently immersed in the jet or centrifugal convection flow. However, a kinetic energy introduced by the forced convection might not always be enough to penetrate into such a small cavity. A kind of natural convection might be participated to seriously influence the shape evolution. However, the experimental evidence has not been throughly reported. As an idealistic experiment, the electrochemical deposition of copper was conducted under the microgravity and the strong magnetic field.

Experimental

The same experimental apparatus was employed as the quasi-two-dimensional electrolytic cell for electrodeposition[)]. A disk cathode of 1 mm in diameter was placed at the center of the cell and a flat ring shaped anode was placed at the outer edge. The thickness of cathode was adjusted to 100 μ m. The circular periphery area of this disk was used as an effective surface of cathode. Two flat faces of disk cathode were insulated with PVC. Copper foil of 100 μ m thickness was perforated to manufacture a flat ring type of anode with 20mm in inner diameter. Both electrodes were sandwiched by two sheets of slide glass. This electrolytic cell was filled with 0.6M$CuSO_4$ aqueous solution. A copper wire was perpendicularly positioned toward the cathode as a conventional reference electrode. Galvanostatic electrolysis was conducted in the microgravity and high magnetic field.

Results and Discussion

Copper was electrodeposited at various current densities in horizontal and vertical configurations of quasi-two-dimensional electrolytic cell and the amount of electricity was set to at 225 couloumb/cm^2. It is noteworthy to mention that the dendrite formation of electrodeposited copper is considerably restricted in a vertically installed electrolytic cell. Detail observation shows that the primary arm length of dendrite around the upper periphery of cathode is rather shorter than that around the lower.

Then, copper was electrodeposited under μ-G. As the first trial to estimate quantatively the morphological difference in both environments, the pictures were supplied to the image processing. The shadow area occupied by dendrite arm ensemble and the dendrite arm length were calculated by discretizing the brightness of image. The larger shadow area of dendrite arm ensemble and the longer dendrite primary arm are seen under μ-G than under 1-G. The results suggest that the dendrite morphology of copper is significantly influenced even by a microscale fluid flow among dendrite ensemble.

The superposition of magnetic field induced a more drastic change of morphology in a horizontal cell than in a vertical. The significant induction of electrolyte convection due to Lorenz force suppressed the dendrite generation, since the current vector was normal to the magnetic field vector. No dendrite was macroscopically recognized within 8s at 2.5A/cm^2 and 5T.

Reference

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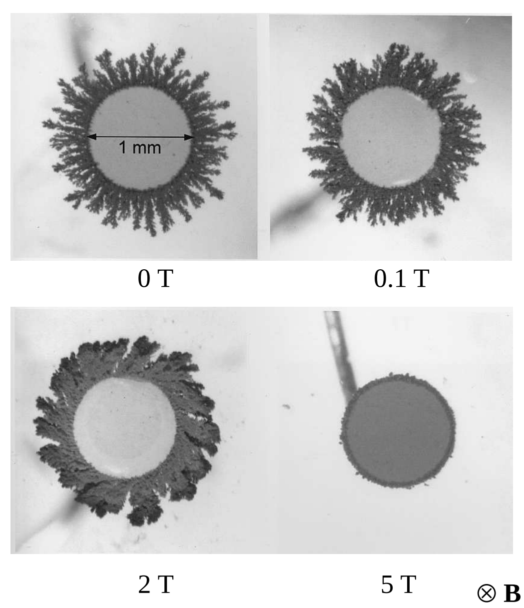

Figure. Morphological Variation of Copper Electro-deposited in a High Magnetic Field.