Enhancement of Mechanical Properties in Au Films Electroplated with Supercritical Carbon Dioxide for Application in MEMS

Haochun Tang(1,2), Chun-Yi Chen(1,2), Tso-Fu Mark Chang(1,2), Daisuke Yamane(1,2), Katsuyuki Machida(1,2,3), Kazuya Masu(1,2), and Masato Sone(1,2)

1 Institute of Innovative Research, Tokyo Institute of Technology, Yokohama, 226-8503, Japan
2 CREST, Japan Science and Technology Agency, Yokohama, 226-8503, Japan
3 NTT Advanced Technology Corporation, Kanagawa, 243-0124, Japan

Background

- Au-based accelerometers
- Higher sensitivity than Si based conventional devices
- Density of gold: 19.3 g/cm³
- Low mechanical strength among metallic materials
- Concerns in the practical application of MEMS devices

Any strategy for strengthening?

Application of scCO₂ in electroplating

- Electroplating with scCO₂ contained electrolyte (EP-SCE)
- Smoother surface morphology
- Grain refinement effects

Hall-Petch relationship

\[ \sigma_y = \sigma_0 + k_y \sqrt{d} \]

Enhancement of mechanical strength

Objective

Evaluate mechanical property of Au films fabricated by EP-SCE

Experimental

- Electroplating with scCO₂
- FIB milling & micro-compression tests

Evaluation of mechanical property of Au films fabricated by EP-SCE

Surface morphology & roughness

- Similar surface morphology \( (R_a \sim 13 \text{ nm}) \)
- Brightener \( \Rightarrow \) leveling effect

Crystalline structure of Au films

- Peak broadening in EP-SCE film
- Grain size of EP-SCE film: \( \sim 13 \text{ nm} \)

Results & Discussion

- Deformation of Au micro-pillars
- Strain-stress curve of Au pillars

Surface morphology & roughness

- As-fabricated
- Compressed

CONV-EP Au

EP-SCE Au

Conclusions

- Micro-mechanical strength of gold films fabricated by EP-SCE method were evaluated.
- High mechanical strength was obtained in EP-SCE film. \( \sigma_y : 520 \text{ MPa} \)
- Ultra-fine grain can lead to a higher strength. \( \Rightarrow \) Grain boundary strengthening

Acknowledgement

This work is supported by CREST Project operated by the JST.