Sample Size Effect on Mechanical Properties of Electrodeposited Gold Evaluated by Micro-Compression Test

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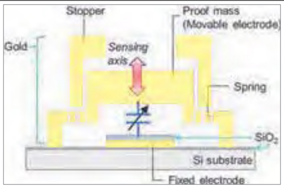
Introduction

MEMS motion sensor made of *gold*



Merits of Gold

・High chemical stability, corrosion resistance and electrical conductivity
→ideal to be used as components of electronic devices
・High density (19.30 g/cm^3)
→further miniaturization (suppress the Brownian noise) of the devices with high sensitivity

Manufacturing and evaluation of MEMS

Electrodeposition

- Near-room-temperature operating temperature
- Low cost
- Rapid deposition rates
- Capability to handle complex geometries

→Highly applicable to MEMS !

Micro-compression tests

- Reliability of the micro-components
- Mechanical properties in micro-scale are different from these of bulk materials due to size effect

→Important for MEMS !

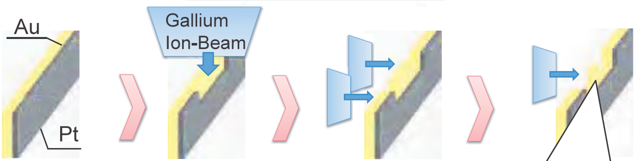
Experimental Procedures

Fabrication methods

Electrodeposition conditions

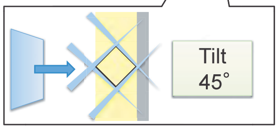
Au concentrate	pH	Temperature	Current density	Substrate	Thickness
20 g/L	5.0	60 ℃	0.4 A/dm^2	Pt	40 μm

Micro-pillars fabrication steps



Dimensions of the pillars (μm × μm × μm)

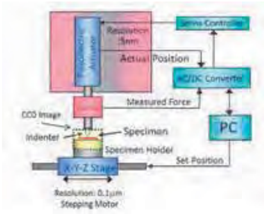
A	B
10×10×20	20×20×40

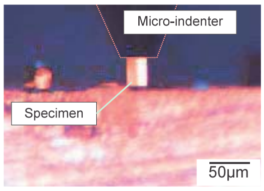


Testing conditions

Test machine

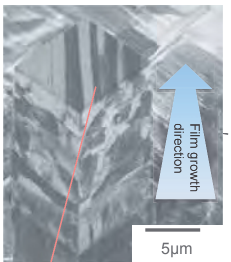
Control	Displacement rate	Load resolution
Displacement control	0.1 [μm/s]	10 [mN]



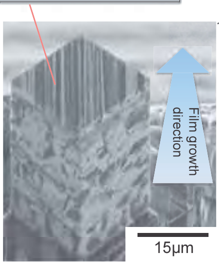


Results & Discussion

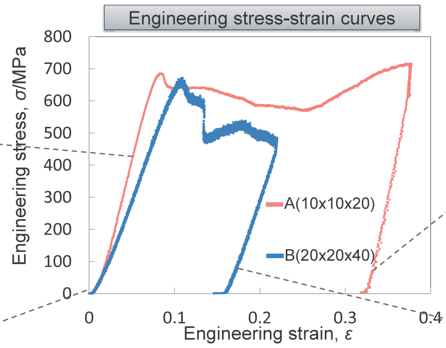
SIM images & Mechanical properties of the micro-pillars



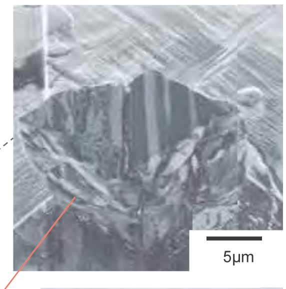
Boundaries along the film growth direction



Engineering stress-strain curves



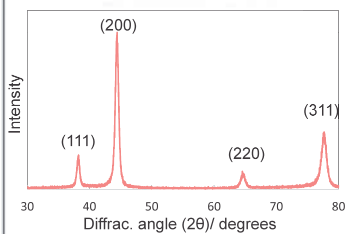
High strength
→ Much higher yield stress than bulk Au (100~150MPa)
Size effect
→ Flow stress of A (10×10×20) is higher than B (20×20×40)
Load drop
→ Brittle behavior



Brittle fracture is observed!
(However Au is known to be ductile materials)

Grain size

X-ray diffraction pattern



Scherrer equation

$$\text{grain size, } g = \frac{\lambda}{\beta \cos \theta}$$

λ: X-ray wavelength (0.15418nm)
β: Full width at half maximum, in radians
θ: Bragg angle

g=14.7 nm → Nanocrystal!
→The reason of the high strength

Conclusions

- The deformed Au micro-pillars showed brittle fracture.
- The Au micro-pillars showed higher strength, 500~600MPa, than bulk Au.
- The high strength is suggested to be a result of size effect, where grain size of the Au film used in this study is in nano-scale, 14.7 nm.

Acknowledgement

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