Pulse Electroplating of Ultra-Fine Grained Au Films with High Strength for Micro-Electrical-Mechanical System Devices

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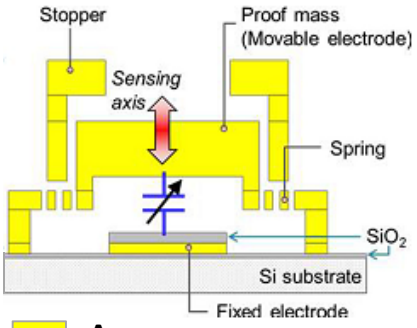
Introduction

First MEMS Motion Sensor with Au Micro-Components



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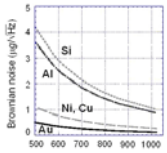
Advantage of Au

- ❖ High chemical stability
- ❖ High electrical conductivity
- ❖ Higher density than Si

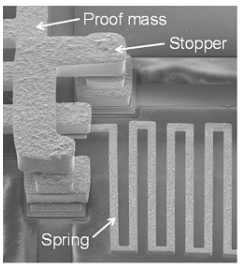
Au (19.3×10^3kg/m^3) >> Si (2.33×10^3kg/m^3)

Merits of Au Components

- ❖ Brownian noise ↓
- ❖ Size of Sensor↓
- ❖ Sensitivity ↑



Background



- ❖ Proof mass and spring are movable components
  →Structure stability and reliability issues
- ❖ Lack of mechanical properties in micro-scale due to the size effect
- ❖ Bulk Au is soft, and typical yield strength of bulk Au estimated is 55-220 MPa
  →Improvement of the mechanical properties via structure control.

Journal of the Mechanics and Physics of Solids 52, 667 (2004)

In this Study

Hall–Petch relationship

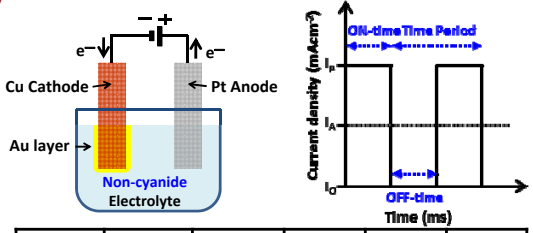
$$\sigma_y \uparrow = \sigma_o + \frac{k_y}{\sqrt{d}\downarrow}$$

σ_y: Yield stress
σ_o: Materials constant for the starting stress for dislocation
k_y: Strengthening coefficient
d: Average grain diameter

Strengthening Au materials by reducing the grain size

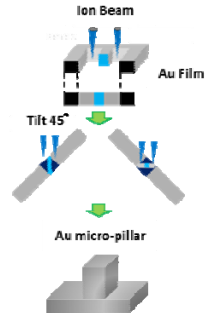
Experimental Section

Pulse Electroplating (PE)

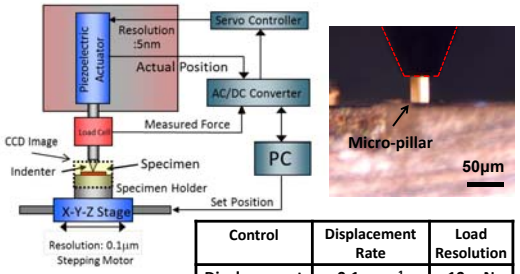


Pulse Peak Current (I_p)	Pulse Peak Current (I_o)	Average Current (I_A)	Pulse ON-time	Pulse Off-time	Reaction Time
10 mAcm^{-2}	0 mAcm^{-2}	5 mAcm^{-2}	10 ms	10 ms	100 min

Micro-pillar Fabrication



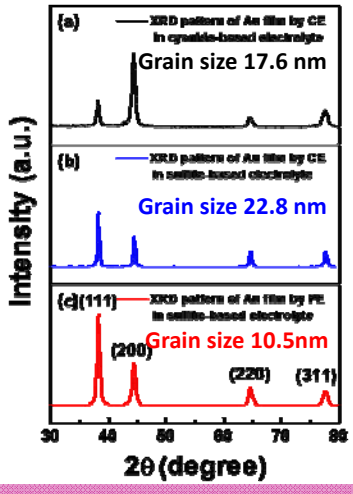
Micro Compression Test



Control	Displacement Rate	Load Resolution
Displacement Control	0.1 μms^{-1}	10 mN

Au Film Characterization

XRD Pattern of Au Films

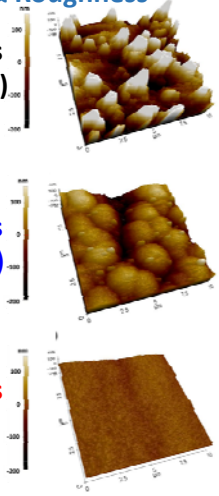


AFM images & Roughness

Surface Roughness
R_a= 117.1nm (CE-1)

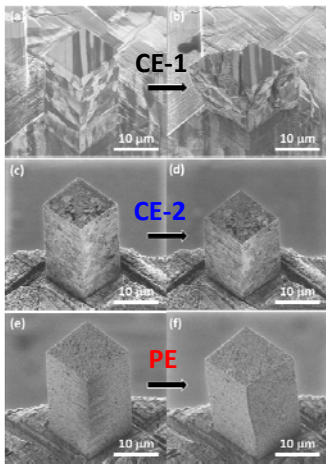
Surface Roughness
R_a= 32.5 nm (CE-2)

Surface Roughness
R_a= 10.7 nm (PE)

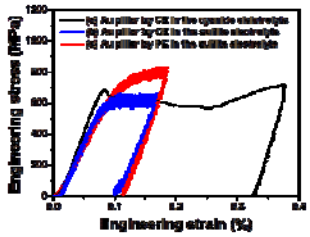


Results of Micro Compression Test

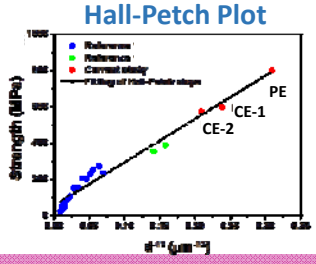
SIM Iamge of Au Micro-pillars



Stress-Strain Curves



Hall-Petch Plot



Summary: Grain refinement, surface smoothening, and compressive strength enhancement of Au films were achieved by pulse electroplating using sulfite-based electrolyte. The strengths obtained by PE followed the Hall-Petch relationships and reached 800MPa, which is the highest value reported for electrodeposited pure Au when compared with the literatures.

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