Fabrication and Evaluation of Au-Cu Alloy 3D Structures toward MEMS Movable Components

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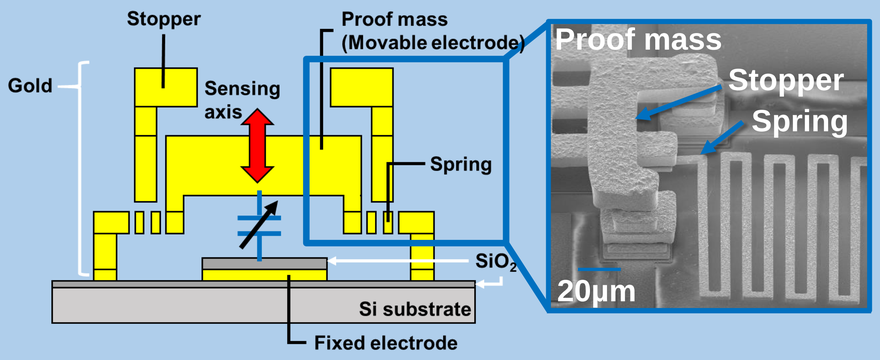
Introduction

Au materials

- High density
- High electrical conductivity
- High corrosion resistance

Applications in MEMS Devices

- Au-based MEMS acceleration sensor[1] capable to detect Sub-1μG



Strengthening by Au-Cu alloy plating

- Solid solution strengthening
- Grain boundary strengthening

⇨ The yield strength was improved from 0.22 GPa to 1.1 GPa [2]

Objective

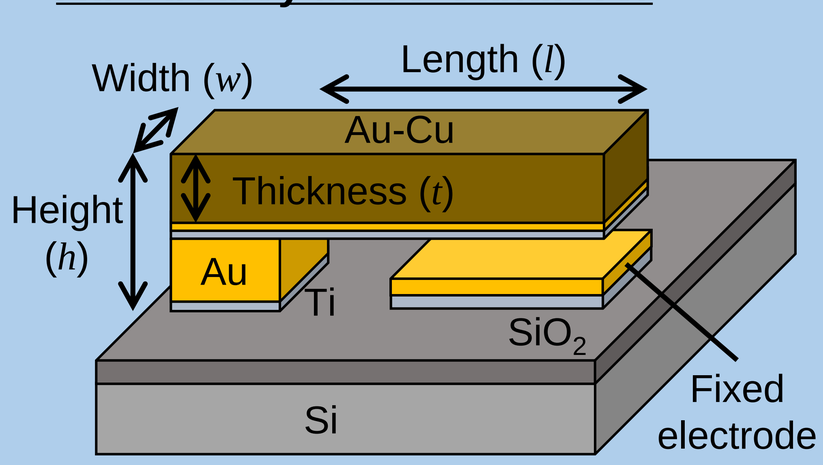
Evaluate effective Young's modulus of the electrodeposited Au-Cu alloy

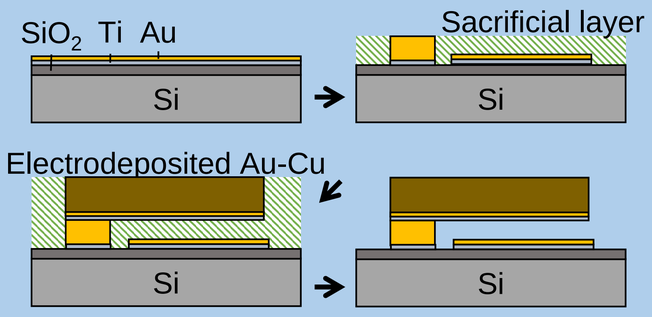
[1] D. Yamane *et al.*, *Applied Physics Letters*, **104** 074102 (2014)

[2] H. Tang *et al.*, *J Electrochem Soc*, **164** 04D244 (2017)

Experimental

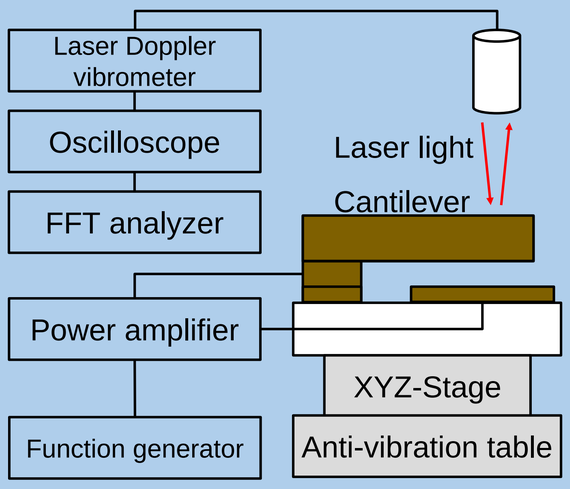
Au-Cu Alloy Micro-Cantilever

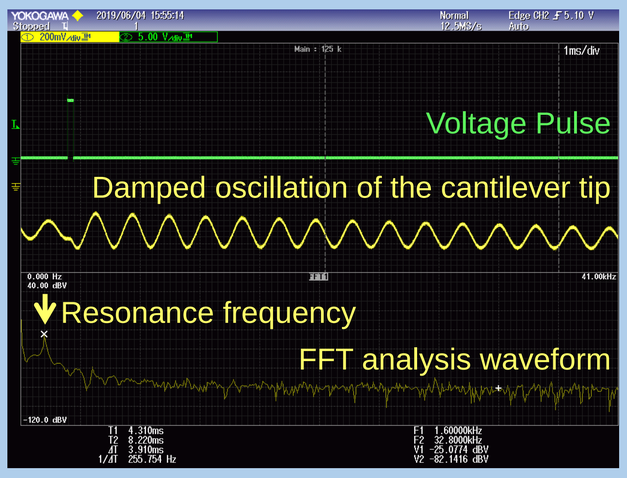




Length (l) : 50 ~ 1000 μm
Width (w) : 10 ~ 20 μm
Ti thickness : 0.1 μm

Evaluation of effective Young's modulus: Resonant frequency method[3]





$$f_{exp} = 0.162 \frac{t}{L^2} \sqrt{\frac{E_e}{\rho}}$$

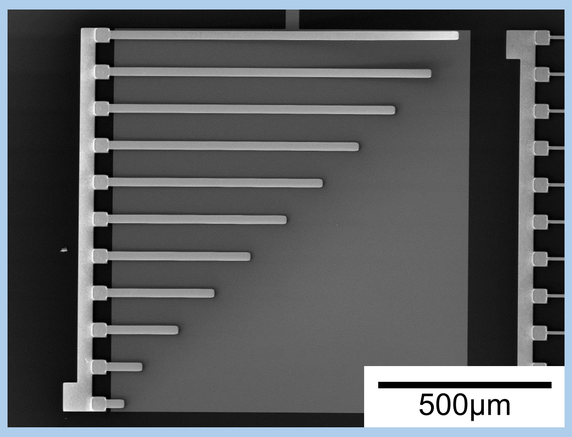
f_{exp}: Resonance frequency
t: Thickness E_e: Effective Young's modulus
L: Length ρ: Density (Au-Cu Alloy)

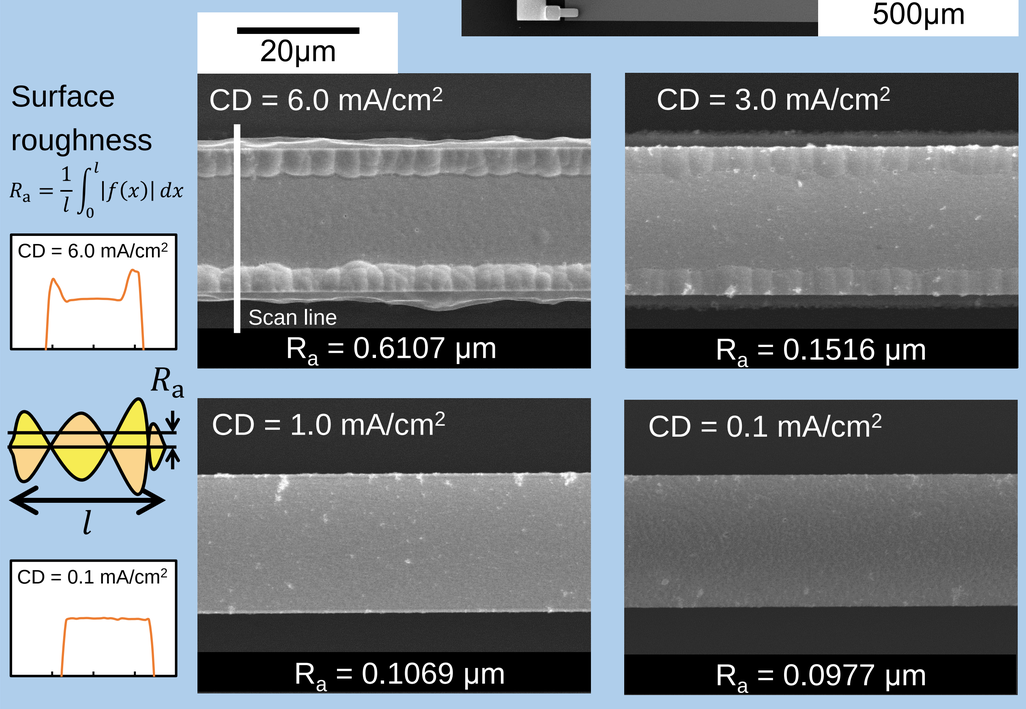
[3] C. W. Baek *et al.*, *Sensors and Actuators A*, 117 17–27 (2005)

Results & Discussion

SEM Image

- No cracks and defects
- Remains straight
- Hardly changed

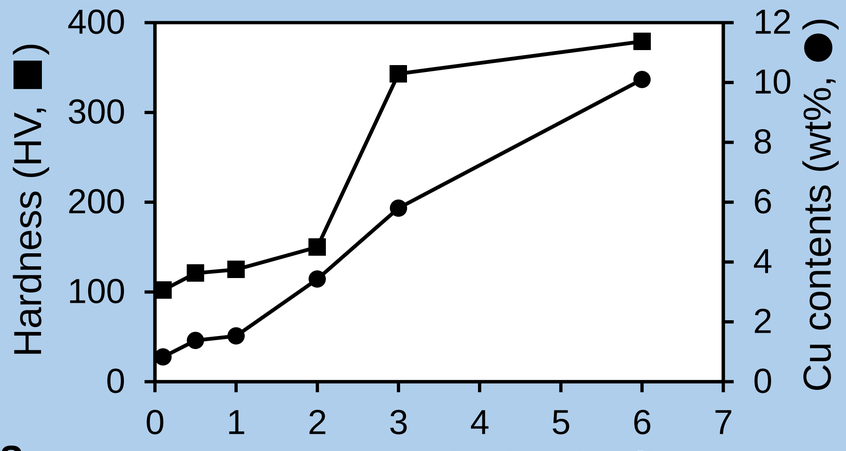




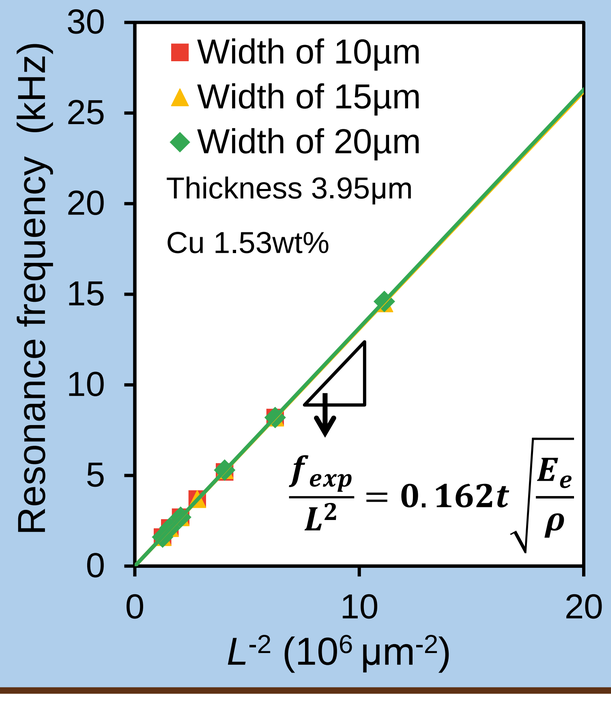
- Current Density ↗ Surface roughness ↗

Vickers hardness

- Current Density ↗
  - Cu contents ↗
  - Hardness ↗



Effective Young's modulus



Thickness (μm)	Width (μm)	Cu contents (wt%)	Effective Young's modulus (GPa)
3.93	20 / 15 / 10	1.38	76.0 / 68.7 / 71.7
3.95	20 / 15 / 10	1.53	79.5 / 78.9 / 79.2
2.85	20 / 15 / 10	1.61	73.8 / 71.3 / 68.0
3.80	20 / 15 / 10	3.43	72.1 / 69.1 / 76.8
2.62	20 / 15 / 10	4.03	75.2 / 75.0 / 75.8

- The Young's moduli were smaller to Young's modulus of bulk gold (79 GPa[4]).

[4] C.A. Volkert et al., Philos. Mag. 86 5567-5579 (2006)

Conclusions

- The cantilevers deposited at high current density has high Cu contents, hardness but surface roughness.
- Effective Young's moduli of the Au-Cu alloy micro-cantilevers were ranged from 68.0 GPa ~ 79.5 GPa.

Acknowledgement

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