Effects of Current Density on Mechanical Properties of Electroplated Nickel with High Speed Sulfamate Bath

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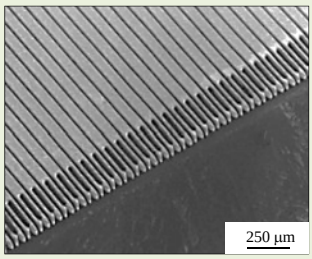
Background

Background & Objective



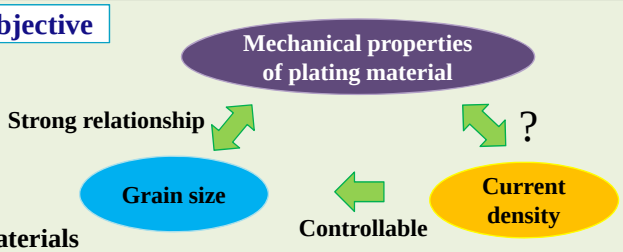
3D material of MEMS[1]

High Speed Sulfamate Bath

- High-speed film growth possible
- Low internal stress
- High current efficiency

➡ Applied to fabrication of MEMS 3D materials

Knowledge of the mechanical strength of the material is necessary

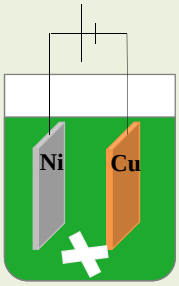


1. Effect of current density on mechanical properties
2. Evaluation of mechanical properties by micro compression test
3. Evaluation of film thickness distribution to current density

[1] Manabu Yasui, et al.; The surface finishing. ,Vol.55 No.5(2004) p225-331

Experimental

Sample preparation



Plating bath composition

Reagent	Consentration
$Ni(SO_3NH_2)_2 \cdot 4H_2O$	600 g / L
$NiCl_2 \cdot 6H_2O$	10 g / L
H_3BO_3	40 g / L

Plating condition

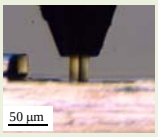
Current density	10 - 100 mA/cm²
Film thickness	50 μm
Cathode	Cu（2.2 cm²）
Anode	Ni
Temperature	60 ℃
Bath Volume	100 mL
Stirring	300 ppm

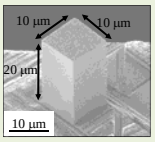
Mechanical properties

- Micro-Vickers Test

Test condition Load 0.025 kg
Retention time 15 s

- Micro Compression Test





Control method：
Displacement control
Indenter displacement speed： 0.1 μm/s

Micro Pillar SEM image
Aspect ratio 1：2

Grain Size

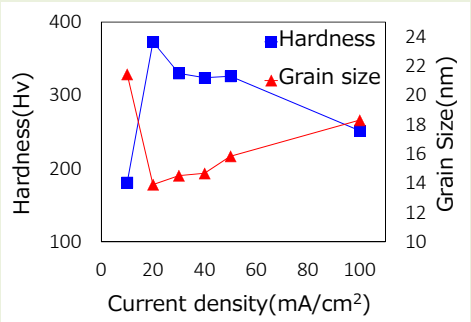
X-ray diffraction measurement & Scherrer eq.

Film Thickness Measurement

Observation of specimen cross section by optical microscope

Result & Discussion

Relation between current density, grain size and hardness



10～20 mA/cm²
Increase in nucleation rate due to increase in current density

20～100 mA/cm²
Overvoltage decreased by hydrogen evolution, resulting in coarsening of the crystal grains

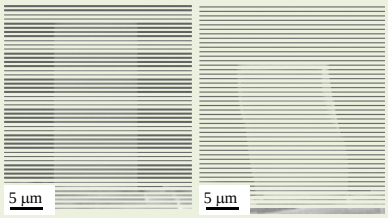
Becomes the highest hardness with minimum grain size due to grain refinement effect

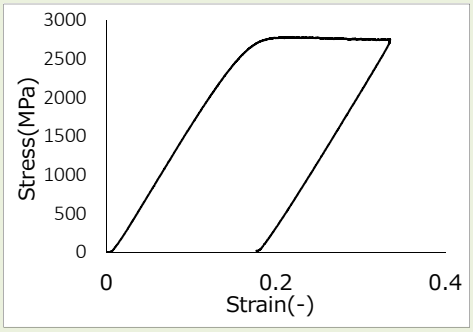
☆ The minimum grain size and the maximum hardness at 20 mA / cm²

Micro Compression Test

Current density: 20 mA/cm²

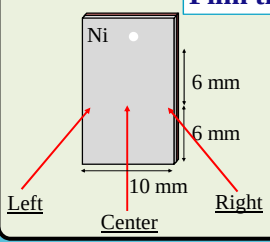
Before / After





☆ Yield Stress 2.7 GPa

Film thickness distribution to current density



Unit(μm)

Current density (mA/cm²)	Left	Center	Right	
10	43.7	40.5	47.7	分布少
20	34.3	36.1	42.4	
30	39.6	28.8	39.1	分布大
40	50.6	25.8	39.6	
50	46.5	25.1	37.1	

Conclusion

The following findings were obtained on the nickel film plated with sulfamic acid high speed bath

- At the current density of 20 mA/cm², the min. grain size was 14 nm, and the max Hardness was 370 Hv
- As a result of the micro compression test, the nickel film having the smallest particle diameter showed a very high value of yield strength of 2.7 Gpa
- It was shown that good film thickness distribution can be obtained when the current density is 20 mA cm² or less

Acknowledgment

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