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Article / Book Information

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Title(English)	Enhancement of Mechanical Strength in Electrodeposited Gold and Gold Alloys
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Type(English)	Summary

（博士課程）
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論 文 要 旨

THESIS SUMMARY

専攻： Department of	材料物理科学　　専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of　（　工学　）
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

In recent years, Au has become a promising material for use as the movable structures and proof mass in microelectromechanical system (MEMS) accelerometer devices. However, the mechanical strength of Au is relatively low when compared with other metallic materials, which has been a concern in practical applications in MEMS especially when used as the movable components. The primary target of this study is to fabricate high strength Au materials using electroplating techniques.

In Chapter 1, MEMS accelerometers, electroplating process, strengthening mechanisms used for electrodeposited materials, and micro-compression tests were introduced.

In Chapter 2, an enhancement in the mechanical strength of the Au films fabricated by the pulse electroplating (PEP) and the electroplating with supercritical CO_2-contained electrolyte (EP-SCE) was confirmed by micro-compression tests. Grain refinement effect was observed in the Au films prepared by the PEP and the EP-SCE. The yield strength and the compressive flow stress at 10% plastic strain of the EP-SCE micro-pillar with dimensions of 10×10×20 μm^3 reached 520 MPa and ~800 MPa, respectively. The fine grains were suggested to be the main cause of the enhancement in the mechanical properties based on the grain boundary strengthening mechanism known as the Hall-Petch relationship. For the EP-SCE pillars with different pillar dimensions, the compressive flow stress increased from 740 to 810 MPa with a decrease in the micro-pillar dimensions from 20×20×40 to 10×10×20 μm^3. The strengthening observation confirmed the sample size effect on mechanical properties of micro-pillars composed of Au crystals having an average grain size in the nano-scale.

In Chapter 3, Au-Cu alloys were fabricated by galvanostatic electroplating, and the micro-mechanical properties were evaluated by micro-compression tests. Surface morphology of the Au-Cu alloy films showed a wide variation from smooth surface to bump-clustered agglomerates as the current density varied from 2 to 9 mA/cm^2. A reduction in the grain size and an increase in the Cu content were observed with an increase in the current density. The film with the finest grain size at 5.3 nm was obtained when current density of 6 mA/cm^2 was used. For the micro-compression tests, the specimens used were micro-pillars with dimensions of 10×10×20 μm^3 fabricated from the electroplated Au-Cu alloys. The highest yield strength at 1.15 GPa was achieved for the Au-Cu alloy having grain

size of 5.3 nm and the copper content of 30.3 at%. The ultra-high yield stress was higher than the values reported in the literatures and suggested to be a synergistic effect of the grain boundary strengthening mechanism with the solid solution strengthening mechanism.

In Chapter 4, effects of the pulse current parameters on the alloy composition, grain size, surface morphology, and micro-mechanical property of the Au-Cu alloys were investigated. A wider copper content in the Au-Cu alloys ranging from 10.0 to 53.6 at% was obtained. An increase in the copper content was observed by using either or both of a high peak current density and a short current off-time. The smallest grain size of ca. 4.40 nm was achieved in films having the copper content ranged from 30 to 40 at%. Grain refinement was achieved with a high peak current density, and promoting the displacement reaction could also reduce the grain size. A higher peak current density resulted roughening of the surface, and enhancing the displacement reaction lead to a surface smoothening effect. Deformation behavior of the Au-Cu micro-pillar was affected by the copper content, which brittle fraction was observed when the copper content was higher than 35 at%. An ultrahigh yield strength at 1.50 GPa was obtained in the micro-pillar having the copper content of 36.9 at% and the grain size of 4.68 nm.

In Chapter 5, the microstructure of electrodeposited Au-Cu alloys were investigated using high resolution transmission electron microscopy. Numerous growth twins were observed in the as-deposited alloys either low or high copper content. The deformation twins were observed in the higher copper alloys. Reduction of stacking fault energy is considered to cause the deformation twinning during the plastic deformation which reflects on the flow stress in lower plastic strain.

In Chapter 6, this study is summarized. As a result, the Au and Au-Cu alloys developed in the present study is suggested to fulfill the requirement to replace the Si-based materials in next generation MEMS devices.