Effect of Laser Irradiation Condition on the Fabrication of Microstructure on Aluminum via Anodizing, Laser Irradiation, and Electroplating

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Introduction

Local metal deposition is a very important technique to fabricate microstructures or micro-patterns in micro-electromechanical systems (MEMS), and is usually performed through photolithography, where a photo-sensitive resin film on the substrate is illuminated by light through a mask to polymerize or de-polymerize the resin locally before film-stripping and metal deposition. Photolithography, however, involves many steps and uses harmful reagents. The authors recently proposed a new technique for fabrication of micro-pattern using laser irradiation and electrochemical method[1)].

In the present investigation, Au fine-patterns were fabricated on an insulating board using anodizing of aluminum, laser irradiation, Au electroplating, insulating board attaching and aluminum substrate dissolution. Laser irradiation condition was examined to obtain fine patterns.

Experimental

i) Specimen: Highly pure aluminum foil (99.99 %, 0.35 mm thick) was cut into 20 x 18 mm^2 with handle, and then electrochemically polished. After electropolishing, the specimen was anodized in 0.16 M-$H_2C_2O_4$ solution at 293 K with a constant current of 100 Am^{-2} to form porous type oxide film with d = 9~54 μm thickness. The anodized specimen was immersed in 2%-alizarin red S solution at 323 K for 5min to dye the film in red.

ii) Laser irradiation: The specimen was immersed in doubly distilled water or a commercial Au electroplating solution (ECF-60, N. E. CHEMCAT), and then irradiated with a pulsed Nd-YAG laser (532 nm wavelength and 8ns pulse duration) to remove the anodic oxide film. During laser irradiation, the specimen was moved at v = 1.5~12.0 μms^{-1}, and laser power was adjusted at P = 0.2~5.0 mW. The width, W, and depth, D, of grooves formed by laser irradiation were measured as functions of v and P.

iii) Electroplating: Laser irradiated specimen was polarized cathodically in the Au electroplating solution for 15~90 min at a constant potential of –0.7 V (vs. Ag/AgCl) and 323 K to deposit Au layer at the laser irradiated area.

iv) Pattern fabrication on epoxy resin: The Au-deposited specimen was attached on a epoxy resin board at 393 K for 40 min, and then immersed in 0.1~6.0 M-NaOH solution at room temperature to dissolve the aluminum substrate. The NaOH solution was diluted from 6.0 M to 1.0 M with time gradually to avoid the removal of Au layer from the resin.

v) Characterization: The surface and the vertical cross-section of specimen were observed by scanning electron microscopy (SEM) and confocal laser microscopy.

Results and discussion

Figure 1 shows the changes in the a) width, W, and b) depth, D, of grooves with the scanning rate, v, obtained for specimens with d = 9 μm. The W and D are larger at higher P at each v. The W decreases slightly with increasing v, while D decreases exponentially. Figure 1 suggests that the aluminum substrate as well as the oxide film is removed during laser irradiation at the scanning rates examined. The anodic oxide film was not removed completely at P = 0.2 mW, suggesting the existence of a threshold of laser power foe the fabrication of grooves. The threshold of laser power increased with increasing d.

Figure 2 shows the SEM image of an Au fine pattern fabricated on an epoxy resin by the successive processes described above.

Reference

1) T. Kikuchi, M. Sakairi, H. Takahashi, Y. Abe, and N. Katayama, *J. Surf. Finish. Jpn.*, **50**, 829 (1999)

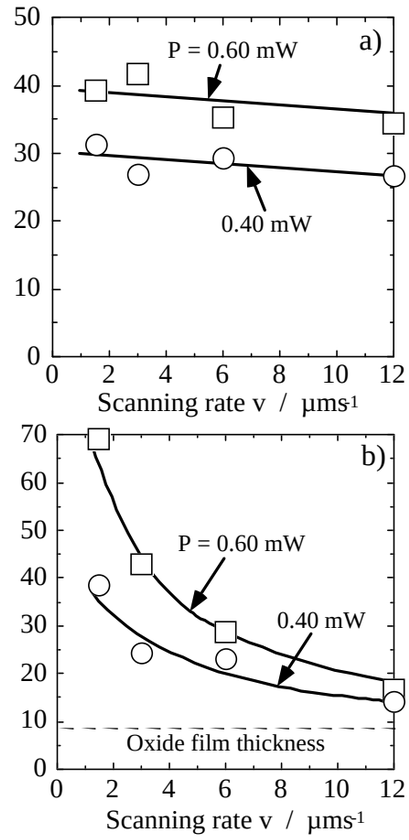

Fig. 1 Changes in a) the width and b) depth of grooves with scanning rate, v, for specimens with d = 9 μm.

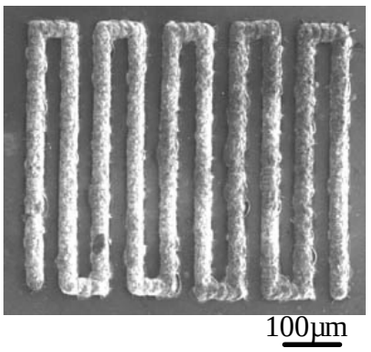

Fig. 2 SEM image of Au fine patterns fabricated on an epoxy resin by anodizing, laser irradiation, electroplating, resin attachment, and substrate removal.