초청강연1

Micro- and Nano-Technology on Aluminum Surface Using Anodizing

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Local surface modification of metal and semiconductors is a key technology in the development of mechano-electrical micro systems. Here, a novel technique is introduced in the fabrication of micro- or nano-scale structure on the surface of aluminum by laser irradiation and AFM probe processing, combined with anodizing.

In the laser technique, aluminum covered with anodic oxide films is irradiated with a pulsed YAG laser to remove the oxide film locally, and then electro-plating, electroless-plating, or electrophoretic deposition was carried out for the surface modification at the film-removed area. Fabrication of pores and grooves on the aluminum surface is also attempted by the combination of local anodizing and electro-etching with laser irradiation.

In the AFM probe processing, aluminum covered with anodic oxide films is scratched with Si-tips of AFM probe in different atmospheres to examine the effect of applied force and scratching number, and solution pH. The metal deposition behavior is followed by in situ AFM observation after the film removal by scratching.

a)Local electro-plating

Aluminum was anodized in sulfuric or oxalic acid solution to form porous anodic oxide films, and then was dyed by dipping in alizarine red-S solution. The dyed specimens were immersed in boiling distilled water to seal pores. The pore-sealed specimens were immersed in solutions containing Cu^{2+}, Ni^{2+}, or Au^{2+} ions, and then irradiated with a pulsed Nd-YAG laser with the wavelength of λ =532nm, pulse width of 8 ns through a beam splitter, an iris diaphragm, a convex lens, and a quartz window.

The anodic oxide films could be removed by the laser irradiation only at the laser irradiated area, due to a local, rapid thermal expansion of the oxide. Adjusting laser beam energy, laser beam diameter, and defocusing distance could control the line width of film-removed area accurately between 3 and 500 mm.

Electroplating of Cu, Ni, or Au after laser irradiation enabled the metal deposition only at the film-removed area, since the pore-sealed oxide film blocked effectively the metal deposition at the area without laser irradiation. Patterns fabricated by laser irradiation and electroplating on aluminum were transferred on an epoxy resin by attaching the patterned aluminum on it and by removing the metal substrate by dissolution. A new process for the fabrication of a proto-type printed wiring board is proposed using this procedure.

b) Local electroless-plating

Porous anodic oxide films were formed on aluminum, dyed, and sealed. The specimen was then irradiated with a pulsed YAG laser in solutions containing metal ions, Pd^{2+}, Cu^{2+}, and Ni^{2+} with / without a reducing reagent, sodium hypophosphite. The Ni-P or Cu electroless-plating was carried out after laser irradiation. During laser irradiation, small metal particles were found to be deposited on the aluminum substrate at the area film-removed by laser irradiation, due to a redox reaction between the metal ions and aluminum substrate. The subsequent electroless-plating enabled the deposition of metal layer only at the laser-irradiated area, due to a catalytic action of the metal particles deposited during laser irradiation for the redox reaction at the initial stage of electroless plating. Aluminum alloys showed a faster metal deposition than pure aluminum, and this could be explained by the catalytic action of the second-phase particles exposed to the solution by laser irradiation. An application of this procedure is introduced for the fabrication of an aluminum mold for injection molding of plastics.

c) Local organic coating

Porous anodic oxide films were formed on aluminum, dyed, and sealed. The specimens were then irradiated with a pulsed YAG laser in distilled water to remove the anodic oxide film, and anodically polarized in an acrylic resin prepolymer solution. Acrylic resin coating could be obtained at the laser-irradiated area. A possibility of the application of this procedure is introduced for the fabrication of a pre-sensitized plate in offset printing.

d) Fabrication of grooves and pores

Aluminum specimens were anodized in a neutral borate solution to form barrier type oxide films, and then irradiated with a pulsed YAG laser. After laser irradiation, the specimen was anodized in a sulfuric acid solution to allow porous oxide films to grow only at the laser irradiated area, and then immersed in a chromic acid / phosphoric acid solution to dissolve the porous oxide film. Thus, semi-circular grooves with 30 mm diameter were obtained on the aluminum surface.

Aluminum specimens covered with porous anodic oxide films were immersed in a NaCl solution, and then irradiated with a pulsed YAG laser with / without anodic polarization. A long period of laser irradiation enabled a "laser drilling" of the metal substrate, fabricating a cone-shaped pore at the open circuit potential and a hemispherical pore under anodic polarization. A possibility of the application of this procedure is introduced for the fabrication of a micro total analysis system (m-TAS).

e) Nano-scale pattern fabrication by AFM probe processing

Aluminum specimens covered with thin barrier anodic oxide films were scratched with Si-tip with / without diamond coating, using a probe of atomic force microscope in air, distilled water, $CuSO_4$, NaOH, and Cu-electroless-plating solutions, and the change in the surface morphology with scratching time was followed by in situ AFM observation. The scratch process enabled the fabrication of grooves with 100 - 300 nm width 30 - 100 nm depth, and the formation rate of the groove strongly depended on the atmosphere, solution composition and pH. Immersion of the groove-fabricated specimen in a Cu-electroless-plating solution showed a copper deposition in and around the groove. The wear of Si-tip was much greater than that of diamond-coated one.