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Micro molding of three-dimensional metal structures by electroless plating of photopolymerized resin

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1. Introduction

Three dimensional microfabrication aiming micromachining has been achieved by photopolymerization with accurate laser beam scanning [1]. The resolution of the polymerization is now as low as 100 nm with two-photon absorption method [2]. In this paper we propose a molding process for the three-dimensional metal micro structure with the photopolymeized resin via a sequence of electroless plating, electrolytic grinding, and extraction. We succeeded in plating the resin suitable for two-photon polymerization, and molded rice shape out of nickel in demonstration of the micro molding process. Plated metal properties were evaluated using x-ray analysis.

2. Microfabrication Procedure

The micro molding we propose is divided into four main processes (Fig. 1). First, we polymerize epoxy resin by two-photon absorption process to form a mold. Next, we plate the non-conductive polymerized mold, and then remove the obstructive metal plated at the opening of the mold by electrolytic grinding, that stops by itself when the non-conductive resin is exposed. Finally, we extract the microstructure.

3. Plating with Nickel Metal

We plated the pellet of resin with nickel (Fig.2). The contamination on resin surface was first rinsed out by water with ultrasonic waves and organic solvents. After water washing and catalytic process, nickel was plated at 45 ˚C with pH of 7 - 9. Etching and neutralization before catalytic process and acceleration process before plating are often performed in electroless plating process, but in this case we found that they are not only ineffective but also obstructive.

Figure 3 shows a high resolution optical microscope image of cross section of the plated film, that was stuck to another plastic with cool process for observation. The surface of the photopolymerized resin has many small pits of 2 – 5 μm in depth. We can see that the small pits are completely filled by the plated metal.

We evaluated the lattice distortion of the plated nickel metal by x-ray diffraction (XRD) measurements. Figure 4 indicates the XRD curve. The inset shows that the full width at half maximum (FWHM) of Ni(111) peak increased as pH of plate solution was raised. We think that impurities and dislocations are introduced more in the metal with the increase of pH since the plating rate gets higher as pH is raised.

4. Extraction from resin mold

We replicated a shape of rice with the molding process. Figure 5 represents the mold of resin and the plated one. We can see that the inside bottom of the mold is completely plated and has metal gloss.

We extracted the replica by cutting the part of the plated metal and immersing the mold into acetone. Figure 6 indicates the extracted nickel. We found that the glossy replica was obtained with optimized plating process. However, the rice-contacted surface always got black. We evaluated the component elements of the plated metals by x-ray fluorescence (Table I), and found that the blackish metal is oxide. We suppose that the carbohydrate of rice caused the surface oxidation at the mold.

5. Conclusions

A novel microfabrication process for three-dimensional metal micro structures was proposed. We succeeded in plating photopolymeized resin mold by nickel and separated the plated metal by immersing the mold into acetone. XRD measurements revealed that the lattice distortion of metal is decreased by reducing pH of the plate solution. We replicated rice shape with nickel in demonstration of the molding process.

Acknowledgement

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Reference

[1] S. Kawata et al., Nature 412, 697 (2001).
[2] S. Maruo et al., J. Microelectromech. Syst. 7, 411 (1998).

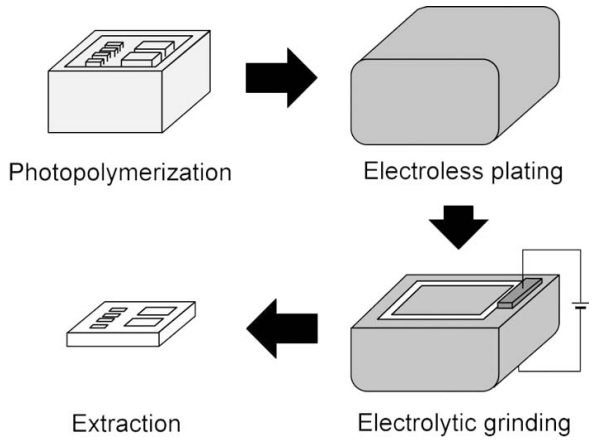

Figure 1 Micro molding process.

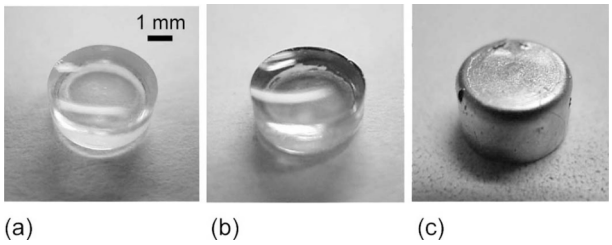

Figure 2 Pellet of resin (a) as polymerized, (b) after catalytic process, and (c) after plating.

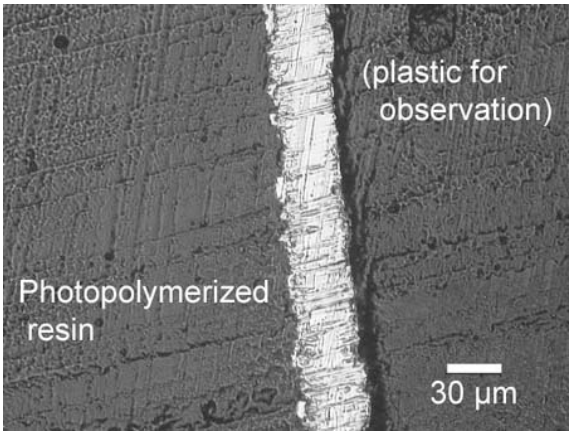

Figure 3 Cross-sectional optical microscope image of plated film.

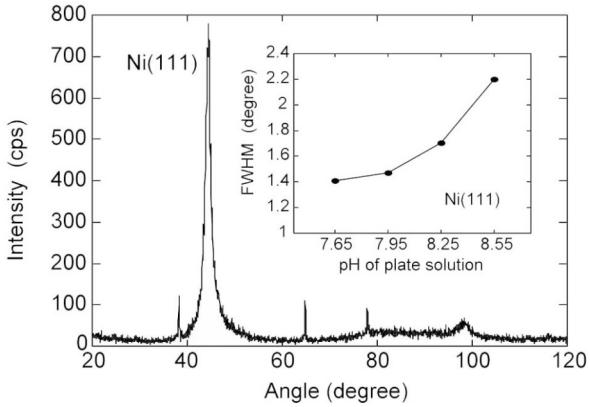

Figure 4 XRD curve of plated nickel. Inset shows FWHM of Ni(111) peak at various pH.

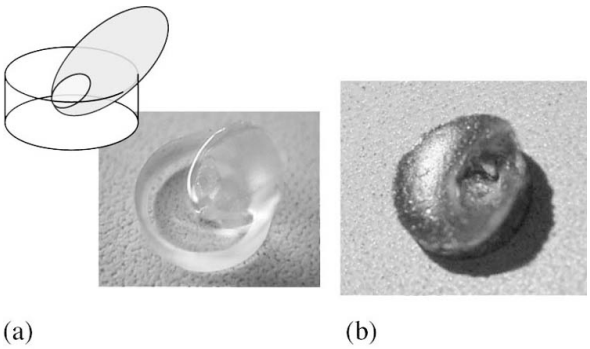

Figure 5 Top view of resin mold (a) before plating and (b) after plating.

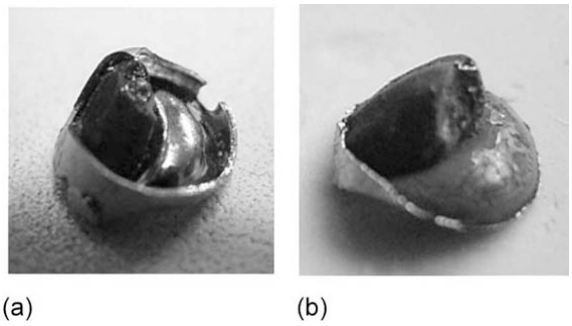

Figure 6 Replica of rice made of nickel via (a) optimized and (b) non-optimized process.

Table I Components of plated nickel.

peak	Black surface mass%	Glossy surface mass%
Ni	51.6	92.8
O	25.3	-
Cl	9.86	0.29
P	8.79	4.3
Na	2.58	1.98