Formation of Microstructures by Laser Sintering of Metal Nanoparticle/POSS Hybrid Films

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1. Introduction

The control of the morphology of metallic surface is very important issue in many industrial fields. The morphology has a close relation with the chemical and physical properties of metallic surface. In recent years, much attention has focused on the functionalization of metallic surface by 2-D and 3-D micropatterning [1]. The micropatterning of the metallic surface gives a special wettability, which provides many applications in anti-corrosion, heat transfer devices, microfluidic systems, liquid transportation, and other fields. In the 2-D and 3-D micropatterning of metallic surface, laser processing has played an important role. The formation of various periodic nanostructures on a metallic surface by laser ablation using femtosecond pulsed laser have been reported [2].

It is a top-down approach to control the morphology of metallic surface. In this paper, we report a new bottom-up method to fabricate 2-D and 3-D patterned metallic surfaces by laser sintering of a self-organized metal nanoparticle/POSS (polyhedral oligomeric silsesquioxane) hybrid film. The procedures are schematically illustrated in Fig.1. The metal nanoparticle/POSS hybrid film is formed by blending of Ag nanoparticles dispersed in an organic solvent with POSS and then spin-coating on a substrate. The POSS has a nano-sized cage structure with a silica core and organic side chains and the solubility in common organic solvents. The laser sintering of the Ag nanoparticle/POSS hybrid film is carried out by scanning irradiation of laser beam.

2. Experimental

The Ag nanoparticle/POSS hybrid film was prepared by spin-coating (2000 rpm, 30 s) on a glass substrate from a toluene solution of Ag nanoparticle Ag1T (ULVAC) and octavinyl-POSS (Aldrich). The morphology of Ag nanoparticle/POSS hybrid film was observed by a confocal microscope (Keyence VK-9700). The film was irradiated by a picosecond fiber laser (100PS, ITRI) with central wavelength of 1064 nm, repetition ate of 100 kHz,
and pulse duration of 87 ps. The laser beam was scanned by a galvanomirror system (SCANLAB).

3. Results and discussion

The Ag nanoparticle/POSS hybrid film showed the formation of a self-organized microstructure immediately after the spin-coating from a toluene solution of Ag nanoparticle and octavinyl-POSS although the solution was clear and no aggregate was observed before spin-coating. Fig.2 shows confocal microscope images for the Ag nanoparticle/POSS hybrid films with various POSS weight%. The fern-like micropatterns (Figs.2a, b, and c) change into spherical one (Fig.2d) with decreasing in the POSS wt%. The influences of the organic side chain of POSS on the self-organized microstructure were also observed remarkably.

The aggregation state of the Ag nanoparticle influences the plasmon absorption band. It has been reported that the broadening of absorption band showing the increase of the absorbance at longer wavelengths is attributed to the aggregation among metal nanoparticles [4]. As shown in Fig.3, the aggregation among Ag nanoparticles is enhanced with increasing in the POSS wt%.

The confocal microscope images and the optical transmission and reflection microscope images of laser-sintered Ag nanoparticle/POSS hybrid film are shown in Fig.4. The optical transmission microscope image shows the self-organized microstructure as bright image area. The micro-Raman spectrum of the self-organized microstructure showed that the bands assigned to POSS was disappeared after laser beam irradiation, which suggests the laser ablation of POSS from the microstructure. The dark area of the optical transmission microscope image and also the bright area of the optical reflection microscope image can be assigned to the laser-sintered Ag phase. The region shows the larger height in the 3D image (Fig.4b). These results suggest that the fern-like structure of Ag nanoparticle/POSS hybrid film consists of POSS self-organized microstructure and the Ag nanoparticle aggregates surrounding the POSS region.

Fig.2. Confocal microscope images for Ag nanoparticle/POSS hybrid films with (a) 41.0, (b) 21.8, (c) 12.2, (d) 6.5, and (e) 2.7 wt% POSS.

Fig.3. Absorption spectra of pure Ag nanoparticle film (a), Ag nanoparticle/POSS hybrid films with (b) 12.2, (c) 21.8, and (d) 41.0 wt% POSS.

Fig.4. Confocal microscope image (a), the 3D image (b), and optical transmission (c) and reflection (d) microscope images of laser-sintered Ag nanoparticle/POSS hybrid film with 21.8 wt% POSS.

References