Surface layer modification of metal nanoparticle supported polymer by irradiation of laser driven extreme ultraviolet light

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Abstracts: *We have studied irradiation effects of extreme ultraviolet (EUV) radiation on surface structure and interfacial properties of AuPd nanoparticle supported Polydimethylsiloxane to show the feasibility of EUV use for creation of functional materials by non-thermal interaction. Irradiation of ns high-energy EUV pulse on large area was successfully performed. Change in sample surface structure and creation of metal-polymer mixed layer were confirmed.*

Recent progress in intense extreme ultraviolet (EUV) light source for photolithography has been attracting much attention from many other research fields not only industry but also applied physics and fundamental physics. EUV-matter interaction and conventional laser-matter interaction, especially in energy transfer, are expected be fundamentally different. Due to its high photon energy ~100 eV, EUV photons directly ionize atoms by photoionization or break the chemical bonds without lattice vibration. Thus, it is expected that EUV radiation can change physical and chemical properties of material surface without or less thermal process. Polydimethylsiloxane (PDMS) is a polymer material widely used in industry. Creation of interfacial structure between PDMS and metal nanoparticles in discharge plasma has been confirmed. Although such structure allows us to create of functional materials [1], thermal effect is large and thermal/particle damage is one of the biggest concerns in discharge plasma. To avoid those negative effects on materials, EUV light would be suitable energy source for modification of material surface. This study aims at showing the feasibility of EUV use for modification of surface structure and interfacial properties.

The samples were prepared by using a DC sputter device. AuPd (Au97Pd3 wt%) layer with thickness of 10 and 20 nm were formed on the PDMS surface. Besides those samples, PDMS sample without nanoparticle layer was also irradiated by EUV radiation for comparison. Laser driven xenon plasma EUV source was used for the irradiation experiment. EUV light was collected on the samples by an Au coated elliptical toroidal mirror [2]. The broad wavelength spectrum ranged form 11 to 20 nm, pulse length was 10 ns, EUV energy was 13 mJ, and the spot size on the sample was 7 mmϕ. The surface structure and the chemical bound were analyzed using atomic force microscopy (AFM) and x-ray photoelectron spectroscopy (XPS) respectively. The original samples were also analyzed for comparison.

The color of irradiated area changed from transparent dark gray to transparent dark red indicating change in surface structure. The Original surface had ~10 nm nanoparticles distributing on the smooth PDMS, and depth profile of XPS result showed AuPd layer on PDMS bulk. On the other hand, growth of bumps (~50 nm) was confirmed, and both Si and Au peaks were detected in the most surface layer by XPS analysis. These change appeared in both 10 and 20 nm samples, but PDMS sample did not have such changes. Detailed discussion will be presented in the paper.

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[2] M. Masuda et. al, Appl. Phys. B: Lasers and Optics, 119, 421, (2015).