APPROVAL SHEET SUBMISSION

OPTICAL CHARACTERIZATION OF A PHOTONIC CRYSTAL COMPOSED OF METAL-DIELECTRIC MULTILAYERS

By

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To

MY PARENTS

MY BROTHERS
&
SISTERS

MY WIFE

MY KIDS
ALAA
&
ALBARAA

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- *Mohamed Shaban, Hany Hamdy, Fayez Shahin, Joonmo Park, and Sang-Wan Ryu* ," Uniform and Reproducible Barrier Layer Removal of Porous Anodic Alumina Membrane", J. Nanosci. Nanotechnol. 10, 3380-3384 (2010).
- *Mohamed Shaban, Hany Hamdy, Fayez Shahin, and Sang-Wan Ryu*," Strong Surface Plasmon Resonance of Ordered Gold Nanorod Array Fabricated in Porous Anodic Alumina Template", J. Nanosci. Nanotechnol. 10, 3034-3037 (2010).
- Mohamed Shaban, Hany Hamdy, Fayez Shahin, and Sang-Wan Ryu, " Optical properties of porous anodic alumina membrane uniformly decorated with Ultra-thin porous gold nanoparticles arrays", J. Nanosci. Nanotechnol. 10, Accepted (2010).

ABSTRACT

The self-ordering of porous anodic alumina (PAA) membranes of different pore diameters and thicknesses were investigated. Scanning electron microscopy (SEM) images revealed that the pore diameter and the PAA thickness depend on the pore widening time and the second anodization time, respectively. According to the measured reflection spectra, PAA membrane exhibits a bright color in the visible light range due to the interference of light. The color is bright but its saturation is very low. In addition, the effective refractive indices of PAA membranes were calculated.

A method for the fabrication of PAA membrane without bottom barrier layer on Al substrate is described. In this method, two-step anodizing followed by a barrier thinning process at the end of the second anodization was used to prepare wide range highly-ordered PAA membrane with a thin barrier layer. Finally, cathodic polarization and pore widening processes were combined to remove the barrier layer completely between the oxide film and Al substrate. From the SEM images, the PAA membrane prepared with the assistance of cathodic polarization showed more homogeneous pore diameters and pore wall quality than that made by pore widening only. In addition, the barrier layer was removed completely with 7.5 min of cathodic polarization and 70 min of pore widening without corrosion in the Al substrate. It was possible to control the pore diameter without any damage to the PAA template from 70 to 90 nm. The

fabricated PAA template can be applied to the growth of ordered nanowires, nanorods, nanoparticles, nanotubes, and similar nanostructures.

High-density, uniform-sized and vertically aligned gold nanorods were grown on aluminum substrate by DC electrodeposition into PAA membrane without bottom barrier layer. Optical reflection measurements using s- and p-polarized light showed strong surface plasmon resonances (SPRs), for both Au/PAA composites and freestanding Au nanorods arrays. By changing the aspect ratio of the Au nanorods, the angle of incidence of the polarized light, and the dielectric environment, it was possible to vary the position and the intensity of the SPR reflection minima in a reproducible and predictable manner. We successfully measured higher order transverse SPR, which proves the formation of highly uniform Au nanorods.

We directly develop a facile method to decorate modified porous anodic alumina membrane (PAA) with ultrathin porous film of gold nanoparticles with sub-gaps less than 25 nm and particle size less than 40 nm on the top surface and Au nanoparticles uniformly attached to the pore walls as well as the bottom of the pores, utilizing r.f. magnetron sputtering. The size as well as the interparticle distance of the gold nanostructures is adjusted by changing the structural properties of PAA membrane and the sputtering time. According to the measured reflection spectra, the saturation of interference color is significantly enhanced and as a result, the Au-coated PAA membrane exhibits a brilliant and tunable color. Field enhancement can be achieved in these structures through the excitation and constructive interference of surface plasmon waves. In addition, the role of localized surface plasmon (LSP) and propagating surface plasmon (PSP) was discussed. Four-layered model is presented to describe the reflectance data that show agreement with the experimental data. The brilliant Au-coated PAA membranes is useful for decorative purposes and holds promise as an effective SERS-substrate.