N1-P007

Invention of Ultralow – n SiO2 Thin Films

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Very low refractive index (<1.4) materials have been proved to be the key factor improving the performance of various optical components, such as reflectors, filters, photonic crystals, LEDs, and solar cell. Highly porous SiO2 are logically designed for ultralow refractive index materials because of the direct relation between porosity and index of refraction. Among them, ordered macroporous SiO2 is of potential material since their theoretically low refractive index ～1.10. However, in the conventional synthesis of ordered macroporous SiO2, the time required for the crystallization of organic nanoparticles, such as polystyrene (PS), from colloidal solution into well ordered template is typical long (several days for 1 cm substrate) due to the low interaction between particles and particle - substrate.

In this study, polystyrene - polyacrylic acid (PS-AA) nanoparticles synthesized by miniemulsion polymerization method have hydrophilic polyacrylic acid tails on the surface of particles which increase the interaction between particle and with substrate giving rise to the formation of PS-AA film by simply spin - coating method. Less ordered with controlled thickness films of PS-AA on silicon wafer were successfully fabricated by changing the spinning speed or concentration of colloidal solution, as confirmed by FE-SEM.

Based on these template films, a series of macroporous SiO2 films whose thicknesses varied from 300nm to ～1000nm were fabricated either by conventional sol - gel infiltration or gas phase deposition followed by thermal removal of organic template. Formations of SiO2 films consist of interconnected air balls with size ～100 nm were confirmed by FE-SEM and TEM. These highly porous SiO2 show very low refractive indices (<1.18) over a wide range of wavelength (from 200 to 1000nm) as shown by SE measurement. Refraction indices of SiO2 films at 633nm reported here are of ～1.10 which, to our best knowledge, are among the lowest values having been announced.