Distribution of Nanoparticles in Photopolymer Controlled Holographically

Applications for holograms include three-dimensional displays, data storage, and photonics. In recent years, holographic gratings have been fabricated from two-component mixtures of organic photopolymers and from polymer-dispersed liquid crystals. The incorporation of materials that extend the range of the refraction index profile will result in more efficient holograms. For example, a system composed of organic photopolymers and inorganic nanoparticles, which, unlike organic compounds, display a wide range of refractive indices (n), were recently proposed by researchers from the Department of Electronics Engineering, University of Electro-Communications (UEC), Tokyo, although heretofore, the formation mechanism of such holographic gratings was not clearly understood.

As reported in the April 15 issue of *Optics Letters*, UEC researchers Y. Tomita and N. Suzuki and K. Chikama from Chemical Research Laboratories, Nissan Chemical Industries, demonstrated holographic control of morphology in nanoparticle-dispersed photopolymers and explained the formation of the holographic gratings in relatively simple terms of the chemical potential (μ) of non-interacting particles. The researchers combined either SiO_2 nanoparticles (n = 1.46, diameter = 13 nm) or TiO_2 nanoparticles (n = 2.55, diameter = 15 nm) at a volume fraction of 0.34 with methacrylate monomers (n = 1.55 in the liquid and 1.59 in the solid phase at a wavelength of 589 nm) and the initiator titanocene to cast films ~50 µm thick. Transmission-type holograms were then recorded at a grating spacing of 1 µm by exposing the films to two mutually coherent beams at a wavelength of 532 nm. The researchers used transmission electron microscopy to show that the nanoparticles followed the intensity interference fringe pattern at a grating spacing of 1 µm.

Tomita and his colleagues hypothesized a mutual diffusion model in which monomers polymerize in the bright regions, where their μ decreases, leading to the diffusion of monomers from dark to bright regions. The photoinsensitive inorganic nanoparticles, on the other hand, are not consumed during polymerization, and their μ increases in the bright regions, causing them to diffuse to the dark regions. The researchers reasoned that the phase shift (ϕ) between the intensity interference fringe pattern and the recorded holograms should be 0° for the SiO_2 hologram, that is, the change in n (Δn) is highest in the bright regions, because n for SiO_2 is less than n for the polymer. Similarly, ϕ for the TiO_2 hologram should be 180°, that is, Δn is highest in the dark regions, because n for TiO_2 is greater than n for the polymer. Both of these predictions were confirmed by the researchers.

Tomita and his colleagues said that their finding of all-optical control of nanoparticle distribution in photopolymers will facilitate the addition of new functionality to holographic applications, such as the fabrication of nonlinear periodic structures and nonlinear photonic crystals, through the incorporation of nonlinear optical nanoparticles. Other possibilities mentioned by the researchers include holograms with magnetic nanocrystals for magneto-optic applications and the incorporation of inorganic nanocrystals for multifunctional light-emitting devices.

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