Photo-induced molecular reorientation of dye-doped liquid crystals containing inorganic nanorods

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[Introduction] In the past few decades, the development of light modulating materials and optical switches that respond to light intensity has been widely studied. These devices utilize nonlinear optical phenomena in which the refractive index and other optical properties change in response to the light intensity. However, the light intensity required to develop such materials is relatively high, hindering its applications in spatial light modulators and optical switches. Polymer-stabilized liquid crystals have been used to reduce the required intensity to induce such nonlinear optical effects,[1] expanding their horizons as the main component for optical limiter devices.[2] In this study, a new approach to lower the threshold intensity of liquid crystal systems is established by doping a small amount of precision-polymer-grafted inorganic nanorods. The addition of the polymer-grafted nanorods significantly reduced the threshold intensity needed to induce molecular reorientation of the constituent molecules.

[Experimental] Liquid crystal molecules 5CB, precision-polymer-grafted nanorods ZnO-PMA(4OPB), and oligothiophene dyes TR5 were mixed and injected in a 100 μm thick cell made of glass substrates with a vertical alignment layer. The optical nonlinearity of the sample was measured by irradiating the sample with a 488 nm laser beam with a focused diameter of 50 μm at different light intensities, resulting in the formation of self-diffraction rings due to a degree change of molecular reorientation.

[Results and Discussion] Polarized light microscopy and polarized UV-visible absorption spectroscopy (UV-vis) confirmed the out-of-plane molecular orientation of the liquid crystal, guest-dye, and polymer-grafted nanorod in the initial state. Concentric diffraction rings appeared on a screen behind the irradiated sample at a light intensity above a threshold value. This is attributed to the refractive index modulation in the sample caused by the orientation change of liquid crystal and dye molecules, including polymer-grafted nanorods, resulting in self-focusing and self-phase modulation. The threshold intensity to induce a diffraction ring of hybrid systems containing dye and liquid crystal molecules with doped nanorods was lowered than the system doped with no nanorods. The polymer-grafted nanorods stabilized the nematic order of the liquid crystal, while inducing a slight molecular disordering of the dye and liquid crystal molecules, all of which made the liquid crystal more susceptible to align parallel to the polarization direction of an optical electric field at a lower light intensity.

【References】

[1] J. Wang, A. Shishido, et al., *Sci. Rep.* **2015**, *5*, 1–7.

[2] K. Usui, K. Matsumoto, A. Shishido, et al., *ACS Appl. Mater. Interfaces* **2021**, *13*, 23049–23056.