Strong Light-induced Birefringence and Phase Grating Recording in Isotropic Phase of a Photostable Nanocrystal Colloid

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Owing to a strong optical response to external electric and magnetic fields, isotropic phases of colloids have a strong application potential in electro- magneto-optical devices. The basic mechanism of the electro- and magneto-optical effects in colloids is a field-driven orientation of the anisometric nanoparticles that results in induced birefringence of an initially isotropic dispersion [1]. Similar effects should occur upon irradiation of the colloids with polarized light, but the light field strength of cw-operating lasers in the visible spectral range is too low to expect large nanoparticle alignment. This seems to be the reason why light-induced birefringence effects in colloids have not been reported so far.

Here we report on the strong effects of light-induced birefringence and photo-refraction in the isotropic phase of a nanocrystal dispersion. The dispersion consists of azo-containing nanocrystal rods suspended in dodecane (concentration \( c \approx 5\% \) wt.) [2]. The nanocrystals absorb light in the green-blue spectral region and are transparent in the red part of the spectrum.

The refractive index changes were observed by recording of optical gratings by two laser beams with the parallel polarizations, and the light-induced birefringence was observed by recording of the gratings with beams with opposite circular polarizations. The characteristic values of the refractive index changes and of the light-induced birefringence were \( \Delta n \sim 10^{-3} \), and \( \Delta n_v \sim 10^{-4} \), respectively. The dynamics of gratings recording and decay is well described by an exponential law with characteristic time of 10-20 s. At long exposures, permanent surface amplitude gratings were observed as well. We have not observed any light-induced effects following irradiation by a red laser beam. The dynamics of grating recording and decay is well described by an exponential law with characteristic time of 10-20 s. At long exposures with the parallel beams, permanent surface amplitude gratings due to light-induced particle-density variations were observed as well. We have not observed any light-induced effects following irradiation by a red laser beam.

The effects observed clearly show that even a very weak light irradiation can cause strong nonlinear optical effects in nanocrystal dispersions. A somewhat puzzling issue is why these effects are so strong, and what is the origin of the aligning torque on the nanocrystals. The spectral dependence of the effects means that they are related to the light absorption. At the same time we found, in contrast of photosensitivity of the dispersion, a photostability of the polycrystalline film. A speculative explanation suggests light-induced orientational and/or positional redistribution of the crystallites in the dispersion: light absorption might produce a Frenkel exciton in the molecular nanocrystals. Subsequent charge separation could result in a strong light-induced polarization and, therefore, lead to the reorientation of the crystalline rods towards the light polarization direction.

We believe that such original effects open new ways for the development of novel highly effective nonlinear optical materials.

References:

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