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Stabilizing Blue-Phase Liquid Crystals Using Gold Nanoparticles

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Blue phase liquid crystals(BPLCs) are self-organized double-twist cholesteric structures exhibiting Bragg-type selective reflection and stability over a narrow temperature range [1].During cooling, three types of BPs are formed depending on the temperature of LC: blue phase III (BP-III), BP-II, and BP-I [2], [3],BP-III is characterized by double twisted cylinders (DTC) with random orientation, while BP-II and BP-I are three-dimensionally ordered simple cubic (SC) and body-centered (BCC) crystals of DTC, respectively. In BP-II and BP-I, discontinuous points exist where the DTCs are in contact, and DTCs and disclination defects coexist [4].

BP have a great technological potential but a main limitation of application by narrow temperature range. Stabilization of the blue phase could be achieved by using molecules with hydrogen bonds[5], mixed with polymers[6] or mixed with nanoparticles (NPs) [7] [8]. Although NPs filling dislocations can lower system energy and broaden the stable temperature range of the blue phase, the temperature stabilization mechanism remains not fully elucidated, especially the role of NPs size and surface functionalization. Meanwhile, the plasmon resonance properties of gold NPs introduce new functional possibilities for blue phase liquid crystal composites.

This study investigates the influence of gold nanoparticles (GNPs) on the structure and optical properties of the blue phase liquid crystal DFP ($St4_{50}/St_{50}$) [5] and GNPs assemblies.Oleylamine ligand-containing GNPs with diameters of 3.4 nm and 4.2 nm were introduced into isotropic BPLCs and led to a homogeneous composite system. The results showed that the doping of GNPs significantly broadened the stable temperature range of the blue phase. Small-angle X-ray scattering (SAXS) results based on the ESRF ID02 beamlines revealed that GNPs of diameter 3.4 nm exhibited an ordered distribution within the blue phase lattice. At the same doping concentration (0.004 wt%), the same structure as reported by Gharbi[8] was obtained, and effective control of the blue phase defect lattice period was achieved by increasing the diameter of the GNPs from 3.4 nm to 4.2 nm, resulting in an increase in the blue phase defect lattice period from 338 nm to 385 nm.Optical Bragg reflection further validated the structural changes, while ellipsometry studies revealed the influence of the plasmonic effect of GNPs on the circular dichroism of blue phase liquid crystals in the presence of GNPs. This indicates that the size of the nanoparticles can effectively control the structure of the blue phase lattice and its optical properties.

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