Colloidal gold nanosphere dispersions in smectic liquid crystals and thin nanoparticle-decorated smectic films

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We demonstrate that the layer structure and elasticity stabilize dispersions of colloidal nanoparticles in smectic liquid crystals. We use surface plasmon resonance spectra of gold nanospheres to probe their spatial distributions in the bulk of smectic lamellae. The average interparticle distances between the well-separated nanoinclusions in thin (<100 nm) smectic films are probed by atomic force microscopy. We show that limited motion of nanoparticles across layers due to the one-dimensional quasi-long-range solid-like structure and their elasticity-mediated interactions preclude irreversible aggregation and enhance the stability of the ensuing nanoscale dispersions in thermotropic smectic liquid crystals.
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I. INTRODUCTION

Dispersions of colloidal particles in anisotropic liquid crystalline media are interesting from both fundamental physics and technological applications standpoints. Studies of colloidal microparticles in nematic[1–5] and smectic[6–11] liquid crystals (LCs) reveal strongly anisotropic long-range interactions that can be of both attractive and repulsive nature.[2] The interactions depend on topological defects and *director* structures occurring around the particles and are mediated by orientational elasticity of the surrounding LC medium. In the case of micron-sized inclusions embe-9 [R5nclusion2(inclusion1)-322.998clusion2(LC,8(nature11.64259.842fectcle)-36ar.842fec1s)-270.42fecn

(Φ) of GNPs, the suspension of the PVP coated GNPs in ethyl alcohol was mixed with the LC in the smectic A phase and the mixture was continuously stirred for about 5 h. For the optical absorption studies most of the ethyl alcohol was evaporated and the mixture filled into cells made of rubbed glass plates with thin polyimide alignment coatings. The remaining alcohol was allowed to evaporate over a few hours. Well-aligned smectic A samples with the *director* along the rubbing direction were obtained. The absorption spectra in the smectic A phase (at C) were obtained using the Ocean Optics nature ber optic spectrometer (B) integrated with a polarizing microscope Olympus BX (Tokyo Japan) For the AFM studies the mixture of the coated GNPs in ethyl alcohol and LC which was homogenized by continuous stirring for was spin coated at revolutions per minute on a silicon ( ) substrate The sample surface morphology was studied using nanoscope III AFM (from Digital Instruments) in the tapping mode To measure the average thickness of the smectic surface supported the surface profile shows the defect induced dimples in the case of pure CB [Fig. (f)] and the raised bumps due to particle induced layer deformations in the case of the LC-GNP dispersions [Fig. ( )]. Since the smectic A material is a D solid that possesses a quasi-long range translational order in the direction perpendicular to layers, the surface morphology visualized by AFM reflects the profile of the top smectic layer in the thin film. The apparent variation in the height of individual bumps might be due to polydispersity of particle sizes (transmission electron microscopy data show that particle diameters vary from to nm with an average size of ∼ nm) formation of dislocation loops of dif

sphere dispersions in isotropic fluids, it is of great fundamental interest to explore the feasibility of achieving ordered periodic self-assembly of nanoparticles and spatial structures composed of nanoparticles and particle-like structures in lamellar LCs.

IV. CONCLUSIONS

In conclusion, we have demonstrated the enhanced colloidal stability of smectic A LC nanoparticle dispersions as compared to those in nematics. Using experimental and computer-simulated spectra, we have shown that the interparticle separations between isolated metal nanoparticles in the bulk of smectic lamellae remain large even for highly concentrated suspensions. Nanoparticles in thin films also do not agglomerate but rather modify the free surface profile of the film due to layer distortions around the inclusions in the LC bulk. The nanoscale dispersions are of interest for technologies that require composites consisting of nanoparticles and a dielectric matrix with tunable properties and interparticle distances, which may provide means of spatial structur