Dynamics of Super-cooled state in Cholestric and Smectic Blue Phases

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Abstract

Cholesteric Blue phase (ChBP) is constructed by the regular arrangement of the double helix, whereas the Smectic Blue phase (SmBP) has the inter-connected multi-lamellar structure. Orientation fluctuations of polymer stabilized ChBP and spontaneously super-cooled SmBP are discussed. Spatial topology of the defects play key role on the dynamic properties.

Introduction

We have found the novel isotropic smectic blue phase ($SmBP_{Iso}$) produced by the disordering of the spatial regularity of the inter-connected multi-lamellar structure[1]. $SmBP_{Iso}$ can be interpreted as multi-lamellar sponge phase. SmBPIso show true spherical isotropic symmetry, nevertheless both helix and smectic layer orders break local symmetry of the system. Then, we call this novel state as an "Isotropic order"

Since lattice constant of the ChBP and SmBP reach the visible light wave-length dependent on the chirality and temperature, so the both phases exhibit characteristic color due to the selective reflection, which is equivalent to the helical pitch of the twist. We have found that SmBP have characteristic fluctuation mode which attributed to the elongation and shrinkage of the lattice constant, whereas the similar mode cannot be recognized in ChBP. We have also proved that conventional orientation director fluctuation also clearly exists both in ChBP and SmBP as similar to the nematic phase. Besides, both ChBP and SmBP are characterized by the topology of the spatial distribution of the defects, such as disclination lines and screw dislocations. For this reason, the dispersion relations of the above fluctuation modes are seriously affected by the topology and dynamics of defects distributed in the space.

Result

Now, we focus our attention especially on the spatially heterogeneous dynamics in the novel topological super-cooled state in ChBP and SmBP. One is artificial super-cooling state in polymer stabilized ChBP invented by Prof. Kikuchi et.al[2], the other is spontaneous supper-cooling SmBP found by author's group. We emphasizes that the microscopic molecular motions do not be frozen both in the super-cooled ChBP and SmBP, nevertheless the macroscopic phase completely is stabilized lower 50 degree than original phase transition, which shows a remarkable contrast with the conventional liquid-glass transition. Furthermore, dynamics of the director fluctuation is also completely does not affected by the polymer stabilization in the super-cooled ChBP. On the contrary, we have found the novel glassy slow dynamics in the super-cooled SmBP, and the fluctuation spectrum shows the power law singular behavior. It should be noted that only the topological re-conformation motion of the multi-layer inter-connected structure is frozen in the super-cooled SmBP, besides another short-range-scale degree of freedoms, such as translational molecular diffusion, thickness of the smectic layer, and even the lattice constant of the multi-lamellar lattice, are freely varied with temperature thermo-reversibly.

Figure 1 shows the typical Rayleigh spectrum of the orientation fluctuation measured by the heterodyne dynamic light scattering method in the ChBP. Center of the frequency was shifted about 80MHz due to the dynamic range of the spectrum analyzer. Relaxation frequency of the orientation fluctuation can be determined by the FWHM of the spectrum. We can measure the order parameter fluctuation in the isotropic phase near ChBP transition temperature.

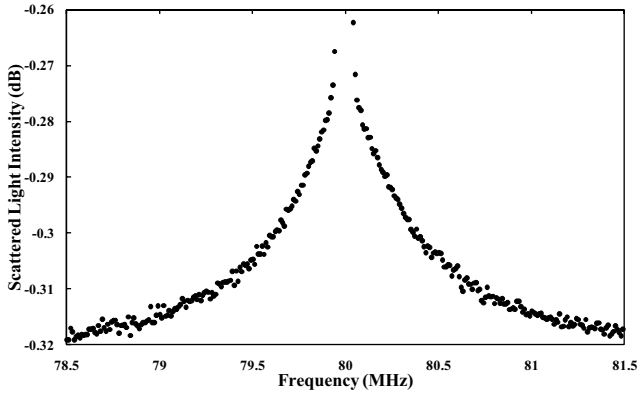

Fig. 1. Rayleigh spectrum of the orientation fluctuation in pure ChBP.

Figure 2 shows the temperature dependence of the relaxation frequency of the fluctuation. ChBP phase appears only in very tiny temperature range. Relaxation frequency of the orientation fluctuation is almost constant in the ChBP. In the isotropic phase, the fast order parameter fluctuation exists around 1MHz, which shows the critical slowing down in the vicinity of the isotropic to ChBP phase transition. It is evident that the relaxation frequency of the order parameter fluctuation is almost proportional to the $T-T_c$, where the T_c is the critical phase transition temperature as predicted by the phenomenological theory.

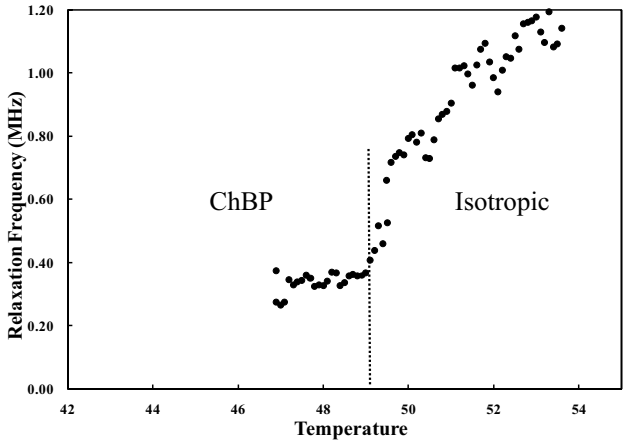

Fig. 2. Temperature dependence of the relaxation frequency of pure ChBP sample.

Figure 3 shows the temperature dependence of the relaxation frequency of the fluctuation in the polymer stabilized ChBP sample. It is remarkable that the relaxation frequency of the orientation fluctuation is almost constant far below from the ChBP-isotropic phase transition temperature, nevertheless the macroscopic ChBP is well stabilized and super-cooled below 10 degree from the original phase transition. In this sense the molecular scale freedom could not be affected by the existence of polymer net-work as contradicted to the conventional glass transition.

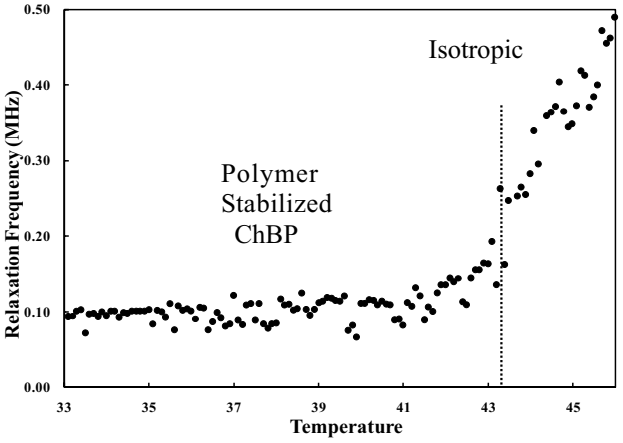

Fig. 3. Temperature dependence of the relaxation frequency of polymer stabilized ChBP sample.

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References

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