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論 文 要 旨

THESIS SUMMARY

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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Ferroelectric liquid crystals(FLCs) are chiral smectic liquid crystals with ferroelectric property. They are widely used in optoelectronic devices due to the fast response time to the electric field. During the investigation of FLCs, several subphases were discovered including the antiferroelectric liquid crystal(AFLC) phase, SmC*α phase, ferrielectric SmC^*_{FI1} phase and antiferroelectric SmC^*_{FI2} phase. The emergency of these subphases arises from the long-range interaction between the polarization of each layer and can be regarded as a result of a competition between the antiferroelectric and ferroelectric interactions in the adjacent smectic layers. To understand the phase transition between these subphases is a critical issue for fundamental soft matter research and also helpful for finding better materials for future optoelectronic industry. In this thesis, several novel chiral smectic subphases are found in two mixture systems and we construct some novel photonic devices using antiferroelectric liquid crystals.

In the binary MC452-MC881 mixture system, we find a novel SmC* subphase exhibiting antiferroelectricity. This subphase appears in the mixture whose concentration is close to the phase boundary between FLC and AFLC. A quite wide temperature region is observed for this subphase from room temperature to around 80 centigrade both in heating and cooling process, which is much wider than common ferroelectric subphases. The antiferroelectricity is confirmed by the Bragg reflection and the dielectric relaxation spectroscopy. A systematic characterization including temperature dependence of selective reflection, dielectric spectroscopy, layer spacing and optical rotational power is carried out on this sample. One interesting phenomenon is that by removing a high DC field applied to the sample, a extremely long relaxation time was observed in this sample and a thresholdless property can be observed. The origin of the such phenomenon can be understood by that a long-range antiferroelectric helical structure is replaced by a series of nanoregions with ordering in only short range since the energy difference between the anticlinic and synclinic ordering are very small near the phase boundary.

In the 80% AS657 and 20% AS620 mixture system, the phase transition behaviour was studied with two complementary methods, electric-field-induced birefringence (EFIB) and microbeam resonant x-ray scattering(μRXS). The electric field vs temperature phase diagram with EFIB contours indicates the emergence of three additional subphases, an antiferroelectric one between SmC_A* and q_T= 1/3 subphases and antiferroelectric and apparently ferrielectric ones between q_T= 1/3 and q_T = 1/2 subphases. These

subphases were also confirmed by the μRXS result.

The next part of the thesis is concentrate on the photonic applications of the chiral smectic liquid crystal subphases, mainly AFLC. Due to the fast response time caused by the spontaneous polarization, they are promising to be widely applied to future optoelectronic devices. However, a challenge is to obtain large-size uniform alignment in an easy process. In this dissertation, homeotropic alignment technique is adapted to construct a defect free AFLC device. Due to the helical structure, AFLC shows optical uniaxiality with the optical axis parallel to the semectic layer normal without electric field. If an in-plane electric field below the threshold value is applied, the helix is distorted and the biaxiality is induced, which is called as the pre-transitional effect of AFLC. When the applied field is low, a quartic dependence of the biaxiality can be clearly seen like the Kerr effect. The change of the refractive index enables the AFLC to modulate the phase of the incident light while keep the polarization state to be invariant for either TE or TM polarized light. Using the Mach-Zehnder interferometer, we confirm that a continuous phase modulation from 0 to 2π for 632.8nm incident light is achieved with a low field(1.8V/μm) for a 50μm (S)-MHPOCBC cell. And The response time is below 300μs for the both rise and fall time, which is much faster compared with the nematic LC phase modulators.

Based on the phase modulation mode of AFLC studied above, we furtherly propose and construct an optical phase grating using AFLC. By adapting a comb-like electrodes to generate 1 dimensional periodic in-plane field, a square periodic phase retardation distribution is constructed. And the field distribution of the diffraction pattern in the far field can be calculated by Fourier transformation of this phase retardation distribution function. In the experiment, the gap between the two adjacent electrodes and the width of the electrodes are set as 50μm and 50μm, respectively. And 40μm (S)-MHPOBC cell is tested to measure the diffraction efficiency. The maximum efficiency for the ±1 orders reaches 37.0% at 1.8V/μm for the TM polarized 532nm incident light, which is very close to the theoretical value. And the rise and decay time are measured to be 510μs and 210μs. The high efficiency, fast response and easy fabrication process make it possible for high performance and wide opto-electronics applications in the future.