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種別(和文)	論文要旨
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（博士課程）
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論 文 要 旨

THESIS SUMMARY

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学生氏名： Student's Name	中杉 茂正		審査員主査： Chief Examiner	柘植 丈治	

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

In this thesis, my research focuses on the molecular design of the bent-shaped dimeric molecules to adapt low temperature ferroelectric phase with high spontaneous polarization (P_s) and dielectric strength ($\Delta\varepsilon$).

In Chapter 1, the background of this research was reviewed, and the significance and objective were described.

In Chapter 2, in order to grasp the $\Delta\varepsilon$ of the ferroelectric phase in the bent-shaped dimeric molecules and obtain the molecular design for the $\Delta\varepsilon$ enhancement, the dielectric relaxation properties of the ferroelectric smectic-A ($SmAP_F$) phase formed by mixtures of bent-shaped dimeric molecules with different alkyl chain lengths was analyzed. The $SmAP_F$ phase exhibited a collective mode with cooperative dipole orientation at about 500 Hz. The $\Delta\varepsilon$ increases dramatically with increasing the liquid crystal (LC) cell thickness. It exceeds 7000 for a 50 μm-thick cell. As the cell thickness increases, the LC domain size increases. This means that the number of interacting dipole moments is important for the achievement of the huge $\Delta\varepsilon$.

In Chapter 3, in order to obtain the molecular design for the $\Delta\varepsilon$ enhancement, the relationship between the dielectric relaxation properties and electrical switching behaviors in the $SmAP_F$, antiferroelectric smectic-A ($SmAP_A$) and antiferroelectric smectic-C (SmC_AP_A) phases was analyzed. In the $SmAP_F$ phase, a small threshold electric field (E_{th}) of less than 1 $V\mu m^{-1}$ for ferroelectric switching is characteristic and the E_{th} decreases with increasing cell thickness. In dielectric measurements, the $SmAP_F$ phase has a large $\Delta\varepsilon$ over 1500 in a 3 μm-thick cell. The $\Delta\varepsilon$ greatly depends on the cell thickness, and increases up to 10000 in a 80 μm-thick cell. In the $SmAP_A$ phase, although the E_{th} is higher than in the $SmAP_F$ phase, still low at about 2 $V\mu m^{-1}$ for a 3 μm-thick cell. A similar cell thickness dependence is also observed, with the E_{th} decreasing to 0.6 $V\mu m^{-1}$ for an 80 μm-thick cell. In the dielectric measurements, the $SmAP_A$ phase is a cell thickness dependence similar to the $SmAP_F$ phase, with the $\Delta\varepsilon$ increasing to 200 for the 3 μm-thick cell and 2000 for the 80 μm-thick cell. Another antiferroelectric phase, the SmC_AP_A phase, has the E_{th} of 10 $V\mu m^{-1}$ in a 3 μm-thick cell and a very low $\Delta\varepsilon$ of 8. A plot of the obtained $\Delta\varepsilon$ versus the reciprocal E_{th} revealed that all the data were on a straight line. The lower E_{th} (i.e., the energy barrier between the two polar states) enhances the cooperative orientation of the dipoles, resulting in higher $\Delta\varepsilon$.

In Chapter 4, in order to obtain the molecular design for the P_s enhancement, three types of the bent-shaped dimeric molecules are synthesized by fluorine substitution on the mesogenic unit and, the effect of fluorine substitution on the polar smectic phase was analyzed. The fluorine-substituted dimeric molecules form the $SmAP_F$ and SmC_AP_A phases, respectively, depending on the fluorine-substituted position. The fluorine substitution can increase the dipole moment of the molecule. The estimated dipole moments of the one-sided mesogens in the non-fluorinated dimeric molecule (C16), the two fluorinated dimeric molecule (2F-Y-C16) and the four fluorinated dimeric molecule (4F-XY-C16) are 5.99, 6.85 and 7.94 D, respectively. Furthermore, the reversal P_s of C16, 2F-Y-C16 and 4F-XY-C16 were 0.64, 1.64 and 2.42 μCcm^{-2}, respectively. A clear proportional relationship was observed by plotting the obtained P_s against the dipole moment of the one-sided mesogen. From this result, it was clarified that fluorine substitution to the mesogenic unit increases the dipole moment of the molecule, resulting in a high P_s value.

In Chapter 5, a novel dimeric molecule with large dipole moment was developed to enhance the P_s and $\Delta\varepsilon$. A dimeric molecule, di-5(3FM-C4T), with fluorine-substituted mesogenic cores as side wings connected by a pentamethylene spacer was synthesized and demonstrated for the P_s and $\Delta\varepsilon$. Due to effective fluorine substitution, the mesogenic core has a huge dipole moment of 11.2 D. From polarization switching, second harmonic generation and dielectric measurements, it was found to form the $SmAP_F$, ferroelectric nematic (N_F) and polar isotropic (Iso_P) phases. The N_F phase is composed of U-shaped molecules that behave like rod-shaped molecules. The P_s is about 8 μCcm^{-2}, reflecting the huge dipole moment of the mesogenic core. On the other hand, the $SmAP_F$ phase is formed by bent-shaped molecules. The N_F-$SmAP_F$ phases transition has a structural change from a rod-shaped to a bent-shaped molecule, which is induced by a pentamethylene spacer in the dimeric molecule. The P_s of the $SmAP_F$ phase is about 4 μCcm^{-2}, which is half that of the N_F phase as expected from the bent-shaped molecule, but is the highest among conventional bent-shaped LC molecules. Three polar phases were found to have a high $\Delta\varepsilon$ of 10000 reflecting the huge dipole moment and the oriented structure.

In Chapter 6, each chapter is summarized and the molecular design for high $\Delta\varepsilon$ and P_s using the bent-shaped dimeric molecules is proposed.

備考 ： 論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。
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