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1. Main Research Results

(1) Banana-shaped Liquid Crystals

The number of citation of the first banana LC paper (J. Mater. Chem. 1996) reported together with Prof. J. Watanabe's group became 562 (April 21, 2008, ISI), and that of the review paper (Jpn. J. Appl. Phys., 2006) became 76 (April 21, 2008, ISI). We continued to investigate this liquid crystal system.

(1.1) Chirality, 1, 4, 8, 17, 18

It is known that molecules spontaneously segregate into chiral domains in some phases in banana-shaped liquid crystals. We showed that chiral domains are selectively formed if one of the twisted nematic structures is formed in the nematic phase [1]. In [4] we reported chirality control by using circularly polarized light. We measured vibration circular dichroism (VCD) using large chiral domains and clarified that twist of ester linkage of molecules is the origin of molecular chirality [17]. We also reported chiral transfer between two phases [18]. Ref. [8] is an invited review article on chiral control by circularly polarized light in side-chain-type and main-chain-type polymers with azo linkages.

(1.2) Polarity, 21, 31

So far we showed the odd-even effect for the emergence of ferroelectric and antiferroelectric phases depending on the carbon numbers of homologous series of banana-shaped liquid crystals. In [21], we made detailed investigation on the mixtures of the homologous series with odd and even numbers of carbons experimentally and theoretically, and found that van der Waals interaction between methyl groups attached to chiral carbons plays an important role for the emergence of ferroelectric phase. We also investigated the emergence of ferroelectric and antiferroelectric phase in molecules with an asymmetric naphthalene core [43].

(1.3) Else, 24, 30, 38, 43

Besides chirality and polarity, we also made phase identification and found new phenomena. In [24], [30], [38], we investigated characteristic banana phases in novel molecules. We found characteristic electroconvection and pattern formation in the nematic phase of a banana-shaped liquid crystal. We concluded the existence of a twist structure which has never been observed in calamitic liquid crystal [43].

(2) Columnar Liquid Crystals, 14, 22

We continued the columnar LCs which can switch their polar order. We measured Kerr effect in the isotropic phase right above the columnar phase for the first time and determined the Kerr constant

[14]. We also observed the relaxation process from a polar state to a nonpolar state when terminating an electric field, and found there are three relaxation processes [22].

(3) Other liquid crystals, 6, 7, 10, 19, 33

We performed studies on de Vries LCs [6], polar polymer LCs [7], discotic LCs [19, 33]. In [10], we studied the origins why achiral ester molecules act as chiral molecules when they are located in chiral circumstances.

(4) Photonic devices

We continued the studies on optical devices utilizing various periodic structures such as cholesteric LCs. We made considerable progress on OLED, lasers and optical reflectors.

(4.1) OLED device, 3, 13, 35, 39, 41

We succeeded in increasing output intensity and directionality by fabricating OLED devices on cholesteric LC films [3] and in increasing external efficiency by using Bragg diffraction from imprinted 1D [35] and 2D [39] structures. We also develop circularly polarized OLED devices [13] and polarization-tunable OLED devices [41].

(4.2) Application to laser devices, 9, 12, 16, 23, 26, 36, 37, 40, 42

We continued the studies on improved defect mode lasing [9,16], decreasing threshold of DFB mode lasing [12, 22, 36]. We started new studies on lasing devices covering a full visible wavelength region using gradient of helical pitch [26, 40], surface-emitting lasers using in-plane 1D periodic structure and its polarization control [42], RGB simultaneous lasing using a unique structure consisting of cholesteric LC films and isotropic films [37].

[4.2] Application to other optical devices, 5, 32

We succeeded in getting RGB reflector using a unique structure consisting of cholesteric LC films and isotropic films, which contradicts the common wisdom that cholesteric LCs reflect light corresponding to their optical pitch in a narrow wavelength range [32]. We also reported simulation results of wide-range reflection from cholesteric LCs with Fibonacci defects [5].

(5) Organic transistor, 11, 15, 25, 28, 29, 34

We published many papers on organic transistors under the collaboration with Prof. T. Mori [11, 15, 25, 29, 34]. We also made simulation of electron carrier mobility in the nematic phase and compared with the existing experimental results [28].

(6) Others, 2,20, 27

We made some other studies. In [27], we succeeded in getting monodomain twisted nematic cells without reverse twist by using chiral surface agent.

2. List of Publications

Original Papers

- 1) Intrinsic Chiral Domains Enantioselectively Segregated from Twisted Nematic Cells of Bent-Core

Mesogens

- S.-W. Choi, S. Kang, Y. Takanishi, K. Ishikawa, J. Watanabe and H. Takezoe
Chirality, **19** (2007) 250-254.
- 2) Defect-free twisted-nematic cells with low pretilt using chiral polyimide surfaces
S.-W. Choi, Y. Takanishi, K. Ishikawa and H. Takezoe
Appl. Phys. Lett. **90** (2007) 033115-1-3.
- 3) Sharply directed emission in microcavity organic light-emitting diodes with a cholesteric liquid crystal film
S. M. Jeong, Y. Takanishi, K. Ishikawa, S. Nishimura, G. Suzuki and H. Takezoe
Opt. Commun. **273** (2007) 167-172.
- 4) Chirality induced by circularly polarized light in liquid crystalline twin dimmers with azo linkages
Y. Hoshino, S.-W. Choi, T. Izumi, Y. Takanishi, K. Ishikawa, J. Watanabe and H. Takezoe
Mol. Cryst. Liq. Cryst. **465** (2007) 153-163.
- 5) Simultaneous RGB reflections from single-pitched cholesteric liquid crystal films with Fibonacci defects
N. Y. Ha, Y. Takanishi, K. Ishikawa and H. Takezoe
Opt. Express, **15** (2007) 1024-1029.
- 6) Quasi-two-dimensional Ising critical behavior of de Vries liquid crystals observed in the heat capacity and dielectric response
K. Takekoshi, Y. Sasaki, K. Ema, H. Yao, Y. Takanishi, and H. Takezoe
Phys. Rev. E **75** (2007) 031704-1-6.
- 7) Unusual nematic liquid crystal with polar Cs symmetry formed from aromatic polyesters with head-tail character
M. Koike, C.-C. Yen, Y. Liu, H. Tsuchiya, M. Tokita, S. Kawauchi, H. Takezoe, and J. Watanabe
Macromolecules **40** (2007) 2524-2531.
- 8) Photoinduced chirality in azobenzene-containing polymer systems
S.-W. Choi, S. Kawauchi, N. Y. Ha and H. Takezoe
Phys. Chem. Chem. Phys. **9** (2007) 3671-3681.
- 9) Defect-mode lasing from a three-layered helical cholesteric liquid crystal structure
Y. Takanishi, N. Tomoe, N. Y. Ha, T. Toyooka, S. Nishimura, K. Ishikawa and H. Takezoe
Jpn. J. Appl. Phys. **46** (2007) 3510-3513.
- 10) Why achiral rodlike compound with ester group amplifies chiral power in chiral mesophase
S. Kawauchi, S.-W. Choi, K. Fukuda, K. Kishikawa, J. Watanabe and H. Takezoe
Chem. Lett. **36** (2007) 750-751.
- 11) Synthesis and solution-processed field effect transistors of liquid crystalline oligothiophenes
M. Ashizawa, R. Kato, Y. Takanishi, and H. Takezoe

- Chem. Lett. **36** (2007) 708-709.
- 12) Lowering lasing threshold in chiral nematic liquid crystal structure with different anisotropies
M. G. Chee, M. H. Song, D. Kim, H. Takezoe and I. J. Chung
Jpn. J. Appl. Phys. **46** (2007) L437-L439.
 - 13) Highly circularly polarized electroluminescence from organic light-emitting diodes with wide-band reflective polymeric cholesteric liquid crystal films
S. M. Jeong, Y. Ohtsuka, N. Y. Ha, Y. Takanishi, K. Ishikawa and H. Takezoe, S. Nishimura and G. Suzuki
Appl. Phys. Lett. **90** (2007) 211106-1-3
 - 14) Electro-optic Kerr effect in the isotropic phase above the columnar phase of a urea derivative
Y. Okada, F. Araoka, Y. Takanishi, K. Ishikawa, S. Nakahara, K. Kishikawa, H. Choi, J. W. Wu and H. Takezoe
Phys. Rev. E **75** (2007) 050701(R)-1-4.
 - 15) (Tetrathiafulvalene)(tetracyanoquinodimethane) as a low-contact-resistance electrode for organic transistors
K. Shibata, H. Wada, K. Ishikawa, H. Takezoe, T. Mori
Appl. Phys. Lett. **90** (2007) 193509-1-3
 - 16) Defect mode lasing from a double-layered dye-doped polymeric cholesteric liquid crystal films with a thin rubbed defect layer
S. M. Jeong, N. Y. Ha, Y. Takanishi, K. Ishikawa, H. Takezoe, S. Nishimura and G. Suzuki
Appl. Phys. Lett. **90** (2007) 261108-1-3.
 - 17) Vibrational Circular Dichroism Spectroscopic Study on Circularly-Polarized-Light-Induced Chiral Domains in the B4 phase of a Banana Mesogen
S.-W. Choi, S. Kawauchi, S. Tanaka, J. Watanabe, and H. Takezoe
Chem. Lett. **36** (2007) 1018-1019.
 - 18) Chirality transfer between weakly-birefringent- and electric-field-induced highly-birefringent B2 phases in a bent-core mesogen
S. K. Lee, L. Shi, M. Tokikita, H. Takezoe and J. Watanabe
J. Chem. Phys. B **111** (2007) 8698-8701
 - 19) Indo-substituted triphenylene-based discogens: by metal-mediated oxidative cross-coupling
S. K. Varshney, C. V. Yelamaggad and H. Takezoe
Liq. Cryst. **34** (2007) 787-790.
 - 20) Experimental Investigation on the Pretilt Angle in a Binary Liquid Crystal Composed of Highly Polar Molecules
S. Dhara, K. V. Le, Y. Takanishi and H. Takezoe
Jpn. J. Appl. Phys. **46** (2007) 5920-5923.

- 21) Polar structures in the binary mixtures of bent-core liquid crystals showing ferroelectric and antiferroelectric B2 phases
Y. Niigawa, K. Nishida, W. J. Kim, S. K. Lee, S. Heo, J. G. Lee, F. Araoka, Y. Takanishi, K. Ishikawa, K.-T. Kang, M. Čepič and H. Takezoe
Phys. Rev. E **76** (2007) 031702-1-7.
- 22) Three relaxation processes from an electric-field-induced polar structure in a columnar liquid crystalline urea derivative
Y. Okada, S. Matsumoto, F. Araoka, M. Goto, Y. Takanishi, K. Ishikawa, S. Nakahara, K. Kishikawa, and H. Takezoe
Phys. Rev. E **76** (2007) 041701-1-6
- 23) Dependence of lasing threshold power on excitation wavelength in dye-doped cholesteric liquid crystals
Y. Wang, T. Manabe, Y. Takanishi, K. Ishikawa, G. Shao, A. Orita, J. Otera, H. Takezoe
Opt. Commun. **280** (2007) 408-411.
- 24) Mesomorphic behaviour in bent-shaped molecules with side wings at different positions of central naphthalene core
S. K. Lee, Y. Naito, L. Shi, M. Tokita, H. Takezoe, and J. Watanabe
Liq. Cryst. **34** (2007) 935-943.
- 25) Crystal structures and transistor properties of phenyl-substituted tetrathiafulvalene derivatives
B. Noda, H. Wada, K. Shibata, T. Yoshino, M. Katsuhara, I. Aoyagi, T. Mori, T. Taguchi, T. Kambayashi, K. Ishikawa and H. Takezoe
Nanotechnology **18** (2007) 424009-1-10.
- 26) Position-sensitive cholesteric liquid crystal dye laser covering a full visible range
K. Sonoyama, Y. Takanishi, K. Ishikawa and H. Takezoe
Jpn. J. Appl. Phys. **46** (2007) L874-L876.
- 27) Usefulness of substrate cleaning with carbon dioxide for organic electronic devices
M. Susukida, M. Mamei, H. Takezoe and K. Ishikawa
Jpn. J. Appl. Phys. **46** (2007) L910-L912.
- 28) Carrier transport simulation of anomalous temperature dependence in nematic liquid crystals
M. Goto, H. Takezoe and K. Ishikawa
Phys. Rev. E **76** (2007) 040701(R)-1-4
- 29) Air stability of n-channel organic transistors based on Nickel coordination compounds
H. Wada, T. Taguchi, B. Noda, T. Kambayashi, T. Mori, K. Ishikawa and H. Takezoe
Org. Elect. **8** (2007) 759-766.
- 30) Structure of a B6-like phase formed from bent-core liquid crystals determined by microbeam X-ray diffraction

- S. Kang, M. Tokita, Y. Takanishi, H. Takezoe and J. Watanabe
Phys. Rev. E **76** (2007) 042701-1-4.
- 31) Ferroelectric and antiferroelectric behavior in chiral bent-shaped molecules with an asymmetric central naphthalene core
S. K. Lee, M. Tokita, Y. Shimbo, K.-T. Kang, H. Takezoe and J. Watanabe
Bull. Korean Chem. Soc. **28** (2007) 2241.
- 32) Fabrication of a simultaneous red-green-blue reflector using single-pitched cholesteric liquid crystals
N. Y. Ha, Y. Ohtsuka, S. M. Jeong, S. Nishimura, G. Suzaki, Y. Takanishi, K. Ishikawa and H. Takezoe
Nature Mater. **7** (2008) 43-47.
- 33) Discotic liquid crystals: synthesis and characterization of radial polyalkynylbenzene derivatives
S. K. Varshney, H. Takezoe and D. S. S. Rao
Bull. Chem. Soc. Jpn. **81** (2008) 163-167.
- 34) Contact resistance of dibenzotetrathiafulvalene-based organic transistors with metal and organic electrodes
K. Shibata, K. Ishikawa, H. Takezoe, H. Wada and T. Mori
Appl. Phys. Lett. **92** (2008) 023305-1-3.
- 35) Enhancement of normally-directed light outcoupling from organic light-emitting diodes using nano-imprinted low-refractive-index layer
S. M. Jeong, F. Araoka, Y. Machida, K. Ishikawa, and H. Takezoe
Appl. Phys. Lett. **92** (2008) 083307-1-3.
- 36) Lowering Threshold by Energy Transfer between Two Dyes in Cholesteric Liquid Crystal Distributed Feedback Lasers
K. Sonoyama, Y. Takanishi, K. Ishikawa, and H. Takezoe
Appl. Exp. Lett. **1** (2008) 032002-1-3.
- 37) Simultaneous red, green, and blue lasing emissions in a single-pitched cholesteric liquid crystal system
N. Y. Ha, S. M. Jeong, S. Nishimura, G. Suzaki, K. Ishikawa, and H. Takezoe
Adv. Mater. in press.
- 38) Effect of Molecular Structure in Smectic Phases of Two Homologues Series of Bent-shaped Molecules with Asymmetric Central Naphthalene Core
S. K. Lee, M. Tokita, H. Takezoe, and J. Watanabe
Ferroelectrics, in press.
- 39) Enhancement of Light Extraction from Organic Light-Emitting Diodes with Two-Dimensional Hexagonally Nano-Imprinted Periodic Structures Using Sequential Surface Relief Grating
S. M. Jeong, F. Araoka, Y. Machida, Y. Takanishi, K. Ishikawa, and H. Takezoe

Jpn. J. Appl. Phys., in press.

40) Toward practical application of cholesteric liquid crystals to tunable lasers

T. Manabe, K. Sonoyama, Y. Takanishi, K. Ishikawa, and H. Takezoe

J. Mater. Chem. in press.

41) Polarization-tunable electroluminescence using phase retardation based on photonic bandgap liquid crystal

S. M. Jeong, N. Y. Ha, H. Takezoe, S. Nishimura, G. Suzuki

Appl. Phys. Lett. in press.

42) Electro-tunable polarization of surface-emitting distributed feedback laser with nematic liquid crystals

S. M. Jeong, N. Y. Ha, F. Araoka, K. Ishikawa, and H. Takezoe

Appl. Phys. Lett. in press.

43) Alternative twist structures formed by electroconvection in the nematic phase of an achiral bent-core molecule

S. Tanaka, S. Dhara, B. K. Sadashiva, Y. Shimbo, Y. Takanishi, F. Araoka, K. Ishikawa and H. Takezoe

Phys. Rev. E, in press.

Review & Book

1) Organic dye lasers

Y. Takanishi and H. Takezoe

O Plus E 29 (2007) 485-491.

2) Chirality in banana mesogens

H. Takezoe

EKISHO 11 (2007) 267-273.

3) Novel liquid crystal display mode using bent-core mesogen

Y. Shimbo and H. Takezoe

EKISHO 11 (2007) 342-348.

4) Story of liquid crystals –search for their mysterious behavior-

H. Takezoe

Nihon Kikaku Kyokai (Tokyo, 2008)

3. Invited talk in international conferences

1. “Chirality in Liquid Crystals”

Gordon Research Conference

June 10-15, 2007, (NH, USA) invited

2. "Liquid Crystal Photonic Devices"
22th Japan-Korea Joint Symposium on Advanced Functional Polymers
July 3, 2007, (Hokkaido Univ.) invited
3. "Chiral Structure Formation by Electroconvection in the Nematic Phase of Achiral Banana Mesogen"
3rd Banana-shaped Liquid Crystal Workshop
Sep. 10-12, 2007 (Tokyo) Invited
4. "Photonic Devices using Cholesteric Liquid Crystals"
6th International symposium on Display Materials and Characterizations
Nov. 23, 2007 (Suwon, Korea) invited
5. "Polymer Cholesteric Liquid Crystals for Photonic Devices"
Korea-Japan International Symposium on Polymer Nanomaterials
Jan. 28 ~ 31, 2008 (Daejeon, Korea) invited

4. Others

Award

- 1) H. Takezoe and Y. Takanishi
Review Paper Award (Japan Applied Physics Society) (Sep. 2008)
- 2) H. Takezoe
Fellow of Japna Appl. Phys. Soc. (Aug. 2008)
Research on Science and Application on Liquid Crystals

International Collaboration

Jpn-Hungary collaboration research (JSPS)

Others

Chair of 11th International Conference on Ferroelectric Liquid Crystal (Sapporo, Sep. 3-7, 2007)