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1. Main Research Results

1) Banana-shaped Liquid Crystals 6, 7, 18, 23, 25, 26, 32, 33, 37, 39

We continuously studied banana-shaped liquid crystals. Some of the noticeable achievements are: the discovery of very different ratio of splay and bend elastic constants [6]; physical behavior of orthogonal smectic phases [7,23,32], emergence of blue phase with wide temperature range by doping banana nematic phase with chiral molecules [18,33], origin of spectral blue shift of absorption band due to phase transition [26], and chiral liquid crystal behavior of mixtures of banana-shaped and rod-shaped liquid crystals [37,39].

2) Other Liquid Crystals 2, 3, 5, 11, 12, 15, 21, 22, 27, 29, 38

We published a review article on antiferroelectric and ferroelectric liquid crystals in *Rev. Mod. Phys.* [3]. Besides banana-shaped liquid crystals, we reported several topics in wide liquid crystal areas: spontaneous deracemization in disc-like mesogens [5], SHG in paraelectric liquid crystals [12], synthesis and physical properties of discotic liquid crystals which can be aligned by an electric field [22], new type of columnar liquid crystal [27], optically isotropic nematic liquid crystal [38]. These are collaboration works with India, Kyoto university, Tokyo university, Ritsumeikan university, respectively, except for the last topic.

3) Liquid Crystals on Surfaces 36

We experimentally showed that Iso-N transition occurs at surface and in Bulk sequentially by means of highly resolved DSC and precise birefringence measurements [36].

4) Photonic Devices 4, 8, 14, 16, 20, 28

We fabricated many new photonic structures using cholesteric liquid crystals and achieved many results [4,8,14,28]. We also improved cavity structures to decrease lasing threshold [9] and developed materials to achieve low lasing threshold [20].

5) Organic Electronics 9, 10, 24, 30, 31, 35, 40

We performed work on organic electronics particularly OLED. One of the most important works is enhanced outcoupling ratio using a backling structure [9]. Using the same structure we studied physics and devices [24,31,35,40].

6) Liquid Crystals on Perfluoropolymer surface 1, 13, 17, 19, 34

We studied liquid crystal orientation on perfluoropolymer surfaces. We found that this surface provides good shock-free alignment layer for smectic liquid crystals [1]. Not only variety of physics [13,19], but also device performance were proposed and characterized [17].

2. List of Publications (Original articles, review article/books)

Original Papers

- 1) Perfluoropolymer surface for shock-free homeotropic alignment of smectic liquid crystals; S. M. Jeong, J. K. Kim, Y. Shimbo, F. Araoka, S. Dhara, N. Y. Ha, K. Ishikawa, and H. Takezoe, *Adv. Mater.* **22** (2010) 34–38.
- 2) Syntheses and Mesogenic Properties of Dimers and Trimers Consisting of Triphenylene Donor and Anthraquinone Acceptor; S. K. Varshney, H. Nagayama, V. Prasad, and H. Takezoe, *Mol. Cryst. Liq. Cryst.* **517** (2010) 97–112.
- 3) Antiferroelectric liquid crystals –interplay of simplicity and complexity –
H. Takezoe, E. Gorecka, and M. Cepic
Rev. Mod. Phys. **82** (2010) 82 (2010) 897–937.
- 4) Colour- and reflectance-tunable multiple reflectors assembled from three polymer films
N. Y. Ha, S. M. Jeong, S. Nishimura & H. Takezoe
Adv. Mater. **20** (2010) 1617–1621.
- 5) Spontaneous deracemization of disk-like molecules in the columnar phase
H. Nagayama, S. K. Varshney, M. Goto, F. Araoka, V. Prasad and H. Takezoe
Angew. Chem. Int. Ed. **49** (2010) 445–448.
- 6) Splay bend elasticity of a bent-core nematic liquid crystal
P. Sathyanarayana, M. Mathew, V. S. S. Sastry, B. Kundu, K. V. Le, H. Takezoe and S. Dhara
Phys. Rev. E (rapid) **81** (2010) 010702(R)–1–4.
- 7) Polar switching in the SmA_dP_A Phase composed of asymmetric bent-core molecules
L. Guo, S. Dhara, B. K. Sadashiva, S. Radhika, R. Pratibha, Y. Shimbo, F. Araoka, K. Ishikawa,
and H. Takezoe
Phys. Rev. E **81** (2010) 011703–1–6.
- 8) Broad-band Cavity-mode Lasing from Dye-doped Nematic Liquid Crystal Sandwiched by
Broad-band Cholesteric Liquid Crystal Bragg Reflectors
H. Choi, J. Kim, S. Nishimura, T. Toyooka, F. Araoka, K. Ishikawa, J. W. Wu, and H. Takezoe
Adv. Mater. **22** (2010) 2680–2684.
- 9) Light extraction from organic light emitting diodes enhanced by spontaneously formed
buckles
W. H. Koo, S. M. Jeong, F. Araoka, K. Ishikawa, S. Nishimura, T. Toyooka, H. Takezoe
Nature Photonics, **4** (2010) 222–225.
- 10) Electric conduction in liquid crystalline phase of biaxial Gay-Berne particles
M. Goto, H. Takezoe, and K. Ishikawa
J. Chem. Phys. **132** (2010) 054506–1–10.
- 11) Non-symmetrical discotic liquid crystalline dimers: molecular design, synthesis and

mesomorphic properties

S. K. Varshneya, H. Monobe, Y. Shimizu, H. Takezoe and V. Prasad

Liq. Cryst. **37** (2010) 607–615

- 12) Second-harmonic generation in a paramagnetic all-organic chiral smectic liquid crystal
R. Kogo, F. Araoka, Y. Uchida, R. Tamura, K. Ishikawa, and H. Takezoe
Appl. Phys. Exp. **3** (2010) 041701.
- 13) Anchoring transition of bent-rod dimer liquid crystals on different surfaces
G. Lee, H.-C. Jeong, F. Araoka, K. Ishikawa, K. Kang, M. Cepic, and H. Takezoe
Liq. Cryst. **37** (2010) 883–892.
- 14) Polarization-independent multiple selective reflections from bi-chiral liquid crystal films
N. Y. Ha, S. M. Jeong, S. Nishimura, and H. Takezoe
Appl. Phys. Lett. **96** (2010) 153301.
- 15) Synthesis and liquid crystalline properties of β -bromopentakis(alkoxy)triphenylene: Reactivity of VOCl_3 , MoCl_5 and FeCl_3 as oxidants
S. K. Varshney, H. Nagayama, D. S. Shankar Rao, and H. Takezoe
Mol. Cryst. Liq. Cryst. **528** (2010) 38–48.
- 16) Extremely Low Threshold Defect-mode Lasing from a Multi-layered Cholesteric Liquid Crystal Structure
Y. Takanishi, Y. Ohtsuka, G. Suzaki, S. Nishimura, and H. Takezoe
Opt. Express **18** (2010) 12909–12914
- 17) Heat-driven and electric-field-driven bistable devices using dye-doped nematic liquid crystals
J. K. Kim, K. V. Le, S. Dhara, F. Araoka, K. Ishikawa, and H. Takezoe
J. Appl. Phys. **107** (2010) 123108–1–4.
- 18) Stable amorphous blue phase of bent-core nematic liquid crystals doped with a chiral material
S. Taushanoff, K. V. Le, J. Williams, R. J. Twieg, B. K. Sadashiva, H. Takezoe and A. Jáklí
J. Mater. Chem. **20** (2010) 5893–5898.
- 19) Electric Field Induced Inverse Fredericksz Transition in a Nematogen with weak surface anchoring
T. Arun Kumar, P. Sathyanarayana, V. S. S. Sastry, H. Takezoe, N. M. Madhusudana, S. Dhara
Phys. Rev. **E82** (2010) 011701–1–6
- 20) Development of Laser Dyes to Realize Low Threshold in Dye-doped Cholesteric Liquid Crystal Lasers,
M. Uchimura, Y. Watanabe, F. Araoka, J. Watanabe, H. Takezoe* and G. Konishi
Adv. Mater. **22** (2010) 4473–4478.
- 21) Critical behavior at transitions from uniaxial to biaxial phases in a smectic liquid-crystal

mixture

Y. Sasaki, K. Ema, K. V. Le, H. Takezoe, S. Dhara, and B. K. Sadashiva

Phys. Rev. E **82** (2010) 011709–1–6.

- 22) Columnar liquid crystal with a spontaneous polarization along the columnar axis
D. Miyajima, F. Araoka, H. Takezoe, J. Kim, K. Kato, M. Takata, T. Aida
J. Am. Chem. Soc. **132** (2010) 8530–8531.
- 23) Optically Uniaxial Antiferroelectric Smectic Phase in Asymmetrical Bent-core Compounds Containing 3-Aminophenol Central Unit
K. Gomola, L. Guo, D. Pocięcha, F. Araoka, K. Ishikawa, and H. Takezoe
J. Mater. Chem. **20** (2010) 7944–7952.
- 24) Spontaneously buckled microlens for improving outcoupled organic electroluminescence
W. H. Koo, H. J. Yun, F. Araoka, K. Ishikawa, S. M. Jeong, S. Nishimura, T. Toyooka, and H. Takezoe
Appl. Phys. Exp. **3** (2010) 082501–1–3.
- 25) Rotational viscosity of a bent-core nematic liquid crystal
P. Sathyanarayana, T. Arun Kumar, V. S. S. Sastry, M. Mathews, Q. Li, H. Takezoe, and S. Dhara
Appl. Phys. Exp. **3** (2010) 091702–1–3.
- 26) Spectral blue shift via intermolecular interactions in the B2 and B4 phases of a bent-shaped molecule
F. Araoka, T. Otani, K. Ishikawa, and H. Takezoe
Phys. Rev. E, **82** (2010) 041718–1–5
- 27) Oriented salts: dimension-controlled charge-by-charge assemblies from planar receptor-anion complexes
Y. Haketa, S. Sasaki, N. Ohta, H. Masunaga, H. Ogawa, N. Mizuno, F. Araoka, H. Takezoe, and H. Maeda
Angew. Chem. Int. Ed. **49** (2010) 10079–10083..
- 28) Color-temperature tunable white reflector using bichiral liquid crystal films
N. Y. Ha, S. M. Jeong, S. Nishimura, and H. Takezoe
Opt. Exp. **18** (2010) 26339–26344.
- 29) Room-temperature discotic cholesteric and nematic phases: Influence of 3,7-dimethyloctane peripheral chain on the molecular self-assembly of radial polyalkylbenzoate
S. K. Varshney, V. Prasad and H. Takezoe
Liq. Cryst. **38** (2011) 53–60.
- 30) Thin-film field-effect transistors of copper phthalocyanine on a rubbed polyethersulfone
H. G. Kim, J. S. Jang, S.-T. Hur, S.-W. Choi, S. S. Kim, H. Takezoe and K. Ishikawa
Thin Solid Films **519** (2011) 2011–2014.

- 31) Polarization conversion in surface-plasmon-coupled emission from organic light emitting diodes using spontaneously formed buckles
W. H. Koo, S. M. Jeong, S. Nishimura, F. Araoka, K. Ishikawa, T. Toyooka, and H. Takezoe
Adv. Mater. **23** (2011) 1003–1007.
- 32) Transition between two orthogonal polar phases in symmetric bent-core liquid crystals
L. Guo, K. Gomola, E. Gorecka, D. Pocięcha, S. Dhara, F. Araoka, K. Ishikawa, and H. Takezoe
Soft Matter, **7** (2011) 2895–2899.
- 33) Liquid Crystalline amorphous blue phase and its large electrooptical Kerr effect
K. V. Le, S. Aya, Y. Sasaki, H. Choi, F. Araoka, K. Ema, J. Mieczkowski, A. Jakli, K. Ishikawa, and H. Takezoe
J. Mater. Chem. **21** (2011) 2855–2857.
- 34) Perfluoropolymer as planar alignment layer for liquid crystal mixtures
T. A. Kumar, H. Takezoe and S. Dhara
Jpn. J. Appl. Phys. **50** (2011) 040203–1–3
- 35) Simultaneous extraction of ITO/organic and substrate waveguide modes from buckled organic light emitting diodes
W. H. Koo, F. Araoka, K. Ishikawa, S. M. Jeong, S. Nishimura, T. Toyooka, and H. Takezoe
Appl. Phys. Exp. **4** (2011) 032101–1–3
- 36) Observation of two isotropic–nematic phase transitions near a surface
S. Aya, Y. Sasaki, F. Araoka, K. Ema, K. Ishikawa, A. V. Emelyanenko, and H. Takezoe
Phys. Rev. Lett. **106** (2011) 117801–1–4.
- 37) Calorimetric studies on isotropic–B4 phase transition in the mixture of bent-shaped and rod-like molecules
Y. Sasaki, Y. Setoguchi, H. Nagayama, H. Yao, H. Takezoe and K. Ema
Physica E **43** (2011) 779–781.
- 38) Nano-size-induced optically isotropic nematic phase
S. Aya, K. V. Le, F. Araoka, K. Ishikawa, and H. Takezoe
Jpn. J. Appl. Phys. in press.
- 39) Electric-field controllable optical activity in the nano-segregated system composed of rod- and bent-core liquid crystals
F. Araoka, G. Sugiyama, K. Ishikawa, and H. Takezoe
Opt. Mater. Exp. accepted.
- 40) Controlling bucking structure by UV/ozone treatment for light extraction from organic light emitting diodes
W. H. Koo, S. Y. Boo, S. M. Jeong, S. Nishimura, F. Araoka, K. Ishikawa, T. Toyooka, and H.

Takezoe

Org. Electron. in press.

Reviews & Books

- 1) Tuning laser light from liquid crystal lasers
H. Takezoe, N. Y. Ha, M. H. Song, S. M. Jeong, and B. Park
Liquid Crystal Microlasers, Chap. 4. Ed. L. Blinov and R. Bartolino
Transworld Research Network, (2010) 67-87.
- 2) 有機色素液晶レーザー — 実用化を目指した低閾値化の試み —
渡邊陽、荒岡史人、竹添秀男
光アライアンス, **21** (2010) 5-9.
- 3) 省エネ型有機光ダイオードの開発
竹添秀男、クウオンヘ、ジョン スンムン、西村涼
月刊ディスプレイ, **10** (2010) 34-38.
- 4) バナナ形液晶の物理と化学
竹添秀男
液晶 — 構造制御と機能化の最前線 — (分担)
シーエムシー出版、東京(2010) 86-93
- 5) コレステリック液晶レーザー発振
(最新フォトニクスポリマー材料と応用技術; 小池康博、平坂雅男 監修)
竹添秀男
CMC出版、印刷中
- 6) アキラル分子が巨大キラリティを作り出す
大谷健人、荒岡史人、石川謙、竹添秀男
液晶, 印刷中
- 7) バナナ形ネマチック液晶の2軸性
レバンコア、竹添秀男
液晶、印刷中

3. List of invited lectures

International Conferences

- 1) Japan-Korea Liquid Crystal Workshop, invited
Jan. 14, 2010 (Seoul, Korea)
“Anchoring Transition –Physics and Application –“
- 2) Advanced Polymeric Materials and Technology Symposium (AMPY2010), invited
Jan. 24, 2010 (Jeju, Korea)

- “Liquid Crystal Polymers for Photonic Devices”
- 3) Inter-Continental Advanced Materials for Photonics Summer/Winter School, invited
June 21, 2010 (Sydney, Australia)
“Liquid Crystal Microlasers”
 - 4) Jpn-Italy Liquid Crystal Workshop, invited
July 7, 2010 (Cetraro, Italy)
“Anchoring Transition –Physics and Application –“
 - 5) 23 th International Liquid Crystal Conference, invited
July 15 (2010) (Krakow, Poland)
“Optically Isotropic Phases for Display Applications”
 - 6) 3rd International Symposium on the Manipulation of Advanced Smart Materials – Recent Developments in Spectroscopic Studies of Oriented Phases –, invited
Sep. 2 (2010) (Osaka)
“Spontaneous Buckled Structure for Enhancing Outcoupled Organic Electroluminescence”
 - 7) 2010 International Chemical Congress of Pacific Basin Societies (PACIFICHEM 2010)
Dec. 18, 2010 (Hawaii, USA) Invited
“Chirality Enhancement by Achiral Molecules”
 - 8) 9 th International Symposium on Display Materials and Characterizationa, invited
Busan, Jan. 26, 2011
“Enhanced light extraction from organic light emitting diodes using spontaneously formed buckles”
 - 9) 11 th European Conference on Liquid Crystals, invited
Maribor (Slovenia) Feb. 11, 2010
“Anchoring Transition –Physics and Application–

Invited talk in universities and companies

- 1) SungKyunKwan University, invited
Jan. 14, 2010 (Seoul, Korea)
“Liquid Crystal Photonic Devices”
- 2) Univ. of Wollongon
June 21, 2010 (Sydney, Australia)
“Ferroelectricity and Antiferroelectricity in Liquid Crystals”
- 3) Physical Institute, Moscow, Oct. 5, 2010
“Organic Photonic Devices: Organic LED and Liquid Crystal Microlasers”
- 4) State University of Moscow, Oct. 1, 2010
“Anchoring Transition –Physics and Application –“

- 5) Univ. Ljubljana, Ljubljana (Slovenia), March 21, 2011
“Liquid Crystal Displays –Principle, Current Status and Prospect –“
- 6) Univ. Maribor, Maribor (Slovenia), April 5, 2011
“Liquid Crystal Displays –Principle, Current Status and Prospect –“
- 7) 産総研九州センター、鳥栖、Feb. 22, 2010
“液晶フォトニックデバイス”
- 8) 九州大学先導研究所、福岡、Feb. 23, 2010
“液晶の不思議 –最近の話題から–”
- 9) 名古屋大学 G-COE 報告会、基調講演 June 16, 2010
“Chirality Created by Nonchiral Liquid Crystal Molecules”
- 10) サイエンスカフェ
東工大 国際高分子基礎研究センター、June 18, 2010
“液晶の発見史と液晶ディスプレイの発展史”
- 11) 三重大学、津、Aug. 31, 2010
“有機光デバイス –有機 LED と液晶マイクロレーザ–“
- 12) 大阪大学、大阪、Nov. 5, 2010
“Spontaneous Buckled Structure for Enhancing Outcoupled Organic Electroluminescence”
- 13) LG Display, Tokyo, Dec. 28, 2010
“次世代高速ディスプレイを目指して”
- 14) 鳥取大学工学部附属電子ディスプレイ研究センター公開セミナー、
Jan. 29, 2011
“次世代高速液晶ディスプレイを目指して”

4. Patent applications

特許申請

1)

発明の名称: 太陽電池用透明導電性基板、その製造方法及びそれを用いた太陽電池

発明者: 竹添秀男、他

出願人: 国立大学法人東京工業大学、新日本石油株式会社

出願番号: 特願 2010-049630

提出日(出願日): 2010/3/

2)

発明の名称: 有機 EL 素子用のマイクロレンズ、それを用いた有機 EL 素子、及びそれらの製造方法

発明者: 竹添秀男、ク ウオンへ、西村涼、鄭旬紋

出願人: 国立大学法人東京工業大学、新日本石油株式会社

出願番号:特願 2010-111867

提出日(出願日):2010/5/14

3)

発明の名称:表示素子、表示素子の製造方法

発明者:竹添秀男 他

出願人:国立大学法人東京工業大学、DIC 株式会社

出願番号:特願 2010-140758

提出日(出願日):2010/6/21

国際特許出願

4)

発明の名称:回折格子及びそれを用いた有機EL素子、並びにそれらの製造方法

発明者:竹添秀男 他

出願人:国立大学法人東京工業大学、新日本石油

国際出願番号:PCT/JP2010/062110

国際出願日:2010/7/16

基礎出願番号: 特願 2009-168056, 特願 2009-200436, 特願 2009-297868,

5)

発明の名称:有機 EL 素子用のマイクロレンズ、それを用いた有機EL素子、及びそれらの製造方法

発明者:竹添秀男 他

出願人:国立大学法人東京工業大学、JX 日鉱日石エネルギー

米国出願番号:12/881025

出願日:2010/9/13

基礎出願番号: 特願 2010-111867

国際特許公開

6)

発明の名称:有機EL素子及びその製造方法

発明者:竹添秀男他

出願人:国立大学法人東京工業大学

国際出願番号:PCT/JP2008/063444

国際出願日:2008年7月25日

国際特許公開番号:WO 2010/010634 A1

国際公開日:2010年1月28日

7)

発明の名称:回折格子及びそれを用いた有機EL素子、ならびにそれらの製造方法

発明者: 竹添秀男他

出願人: 国立大学法人東京工業大学

国際出願番号: PCT/JP2010/062110

国際出願日: 2010年7月16日

国際特許公開番号: WO 2011/007878

国際公開日: 2011年1月20日

国際特許登録

8)

発明の名称: 光ダイオード

発明者: Hideo Takezoe et al.

出願人: 国立大学法人東京工業大学、新日本石油

Patent No.: US 7,701,537

Application No.: 11/712,954

Issue date: April 20, 2010

Inventor(s): Hideo Takezoe et al.

5. Award

1) 日本液晶学会論文賞(A部門)

大谷健人、荒岡史人、石川謙、竹添秀男

“Enhanced Optical Activity by Achiral Rod-like Molecules Nano-segregated in the B4 Structure of Achiral Bent-core Molecules”

2) 日本液晶学会奨励賞(a部門)

Khoa Van Le

2) 日本液晶学会討論会虹彩賞(ポスター賞)

謝曉晨

「ナノサイズ効果による光学的等方性ネマチック相の出現と電気光学応答」

3) 日本液晶学会討論会虹彩賞(ポスター賞)

レバンコア

「バナナ形液晶の形成するアモルファスブルー相」