Japan Academy Prize to:

Shunsuke KOBAYASHI
Professor Emeritus,
Tokyo University of Agriculture and Technology
Professor Emeritus,
Tokyo University of Science, Yamaguchi

and

Tatsuo UCHIDA
Emeritus Professor,
Tohoku University
Professor Emeritus,
National Institute of Technology, Sendai College

for "Elucidation of the Physical Properties of Liquid Crystal and the Study of High-Performance Liquid Crystal Displays"

Outline of the work:

The liquid crystal display (LCD) of the dynamic scattering mode (DSM) was reported by G. Heilmeier at RCA in the USA in 1968, and this raised the interest of researchers and industries. However, at that time, the application of liquid crystals (LCs), that are both liquids and organic materials, to electronic devices was an unexplored field, and it was necessary to clarify its physical properties.

Dr. Shunsuke Kobayashi published a book "Liquid Crystal—Its Properties and Application" (in Japanese) in 1970. This book is the world's first book to cover physical and chemical properties and LCD, which created a flow of the production of LCDs in Japan. Afterward, low-voltage and -power twisted nematic LCD (TN-LCD) was discovered by M. Schadt and W. Helfrich and by J. Fergason, independently, in 1971. However, the superiority of the TN-LCD over the DSM-LCD was not apparent because the TN-LCD had a problem of orientational defects such as reverse twist and reverse tilt disclination that considerably degraded image quality. Dr. Kobayashi conducted statistical and quantum mechanical studies to solve the defect problem and invented a rubbing machine that effectively and uniformly oriented LC molecules on a substrate surface with a small pretilt angle to the surface. He successfully avoided the reverse twist defect and reverse tilt defect and realized a defect-free TN-LCD in 1972. As a result, the TN-LCD achieved high optical quality and then became the mainstream. Afterward, the super twisted nematic (STN) method, enabling a large capacity dot matrix LCD, was invented by T. Scheffer and J. Nehring in 1984. However, this LCD required a high pretilt angle by a special surface alignment method of oblique evaporation,

which was unsuitable for producing large-area LCDs. Moreover, in the conventional rubbing method, stripe domains were generated and the contrast ratio was largely degraded. In addition, Dr. Kobayashi devised a polyimide with an alkyl branch for the surface alignment layer and realized high pretilt angles of 7°–10° using the polyimide and rubbing machine, producing a large-area and defect-free STN-LCD in 1987, which marked the beginning of producing personal computers (PCs) with large capacity dot matrix LCDs. Further, Dr. Kobayashi made a significant contribution to the development of information display by publishing many academic books on LC and LCD, in English and Japanese languages, for enlightening and educating young scientists and engineers and establishing the new international conference of information display and organizing existing conferences in this field.

Dr. Tatsuo Uchida's realization of color LCD was another significant breakthrough that led to the high performance of LCDs. He started his research on the fundamental properties of LCs through theory and experiment of LCD in 1970. He researched color LCDs, focusing on the guest–host (GH) method with dichroic dye added to LCs. It was invented by G. Heilmeier in 1968, but its display characteristics were considerably lower than the practical use level. Dr. Uchida improved the characteristics of dyes and established an optical design theory of devices, achieving high contrast, color purity, and brightness. Thus, the optical design theory was implemented in monochromatic LCDs for office machines and automobiles. In addition, he considered multicolor LCDs based on the subtractive color mixing for non-light-emitting materials and devised a method for stacking three GH cells of cyan, magenta, and yellow. Consequently, he realized the world's first color LCD. Further, to realize a high-definition color LCD, he clarified in 1981 that even a non-light-emitting material could realize an arbitrary color mixing by the two-dimensional fine arrangement of three-color pixels based on additive color mixing. Specifically, thin color films of red, green, and blue were formed on electrode arrays, which was called "in-cell micro color filter." The in-cell was essential to obtain high-quality color. The full-color LCD method invented by Dr. Uchida in this way has become an international standard in cooperation with high-resolution active-matrix LCD and has become widespread globally in LCD-TVs, note PCs, and mobile phones, etc.

These paramount technologies invented by Dr. Kobayashi and Dr. Uchida, independently, became the basis of high-performance and high-quality LCDs. Based on the efforts of many researchers, engineers, and managers, full-scale industrialization of LCDs began in Japan. In addition, around 2000, Japan became the leader in manufacturing LCDs. Afterward, the technology spread overseas, Asian countries became major manufacturers for mass production, and the industry enormously developed along with the development of information society.

List of Main Publications

Dr. Shunsuke KOBAYASHI

Papers

1. Multicolor Field-Effect Liquid Crystal Display Devices with Twisted Nematic Liquid Crystals, S. Kobayashi, F. Takeuchi and T. Shimomura, Proc. Soc. Information Display, **14**, 40–41 (1973).
2. Control and Elimination of Disclinations in Twisted Nematic Liquid Crystal Display, A. Miyaji, M. Yamaguchi, A. Toda, H. Mada and S. Kobayashi, IEEE Trans. Electron Devices, **ED-24**,

811–815 (1977).
3. Alignment of a Liquid Crystal on an Anisotropic Medium, K. Okano, N. Matuura and S. Kobayashi, Jpn. J. Appl. Phys, **21**, L109–L110 (1982).
4. A Full Color Field Sequential LCD Using Modulated Backlight, H. Hasebe and S. Kobayashi, Digest of Technical Papers, Society for Information Display (SID), **21**, 81–84 (1985).
5. A Flat Panel Field Sequential LCD Based on the Combination of Ferroelectric Switch Matrix and Modulated LED Backlight, T. Tanaka, H. Hasebe and S. Kobayashi, Proc. Japan Display, **86**, 360–362 (1986).
6. Generation of a High Pretilt Angle by Rubbing Technique: Application to Super Twist Nematic LCD, K. Yoshida, H. Fukuro and S. Kobayashi, Proc. Japan Display, **86**, 396–399 (1986).
7. Newly Synthesized Polyimide for Aligning Nematic Liquid Crystal Accompanying High Pretilt Angle, H. Fukuro and S. Kobayashi, Mol. Cryst. Liq. Cryst. **163**, 152–162 (1988).
8. A Simple Model for Pretilted Nematic Liquid Crystal Medium and Its Torisonal Surface Coupling Strength, T. Sugiyama, S. Kuniyasu, D-S. Seo, H. Fukuro and S. Kobayashi, Jpn. J. Appl. Phys., **29**, 2045–2051 (1990).
9. Reduction in Driving Voltage of In-Plane Switching Liquid Crystal Displays Using Photo-Alignment Method, X. T. Li, A. Kawakami, H. Akiyama, S. Kobayashi and Y. Iimura, Jpn. J. Appl. Phys., **37**, L743–L745 (1998).
10. Fabrication of a Zigzag Defect-Free Surface Stabilized Ferroelectric Liquid Crystal Display Using Polyimide Orientation Film, H. Furue, Y. Iimura, Y. Miyamoto, H. Endoh, H. Fukuro and S. Kobayashi, Jpn. J. Appl. Phys., **37**, 3417–3421 (1998)
11. Frequency Modulation Response of a Liquid-Crystal Electro-Optic Device Doped with Nanoparticle, Y. Shiraishi, N. Toshima, K. Maeda, H. Yoshikawa, J. Xu and S. Kobayashi, Appl. Phys. Lett., **81**, 2845–2847 (2002).
12. Enhancement of Contrast Ratio by Using Ferroelectric Nanoparticles in the Alignment Layer of Liquid Crystal Display, S. Kundu, M. Akimoto, I. Hirayama, M. Inoue, S. Kobayashi and K. Takatoh, Jpn. J. Appl. Phys., **47**, 4751–4754 (2008).
13. Further Study of Optical Homogeneous Effects in Nanoparticle Embedded Liquid Crystal Devices, S. Kobayashi, Y. Shiraishi, N. Toshima H. Furue, K. Takeishi, H. Takatsu, K-H. Chang and L-C. Chien, J. Mol. Liq., **267**, 303–307 (2018).

Books

1.『液晶－その性質と応用』、小林駿介編著、上野郷士・広瀬竹男・作佐部剛視著、日刊工業新聞社、1970 年.
2.『液晶　基礎編・応用編』、岡野光治・小林駿介編著、培風館、1985 年.
3.『液晶辞典』、小林駿介他共著、日本学術振興会情報科学用有機材料第 142 委員会・液晶部会編、培風館、1989 年.
4.『ディスプレイ』、小林駿介・遠山嘉一編著、丸善、1993 年.
5. Handbook of Liquid Crystal Research, P. J. Collings and J. S. Patel (Editors), Chapter 10 “Active Matrix Liquid Crystal Display” (pp. 415–444), S. Kobayashi, H. Hori and Y. Tanaka, Oxford University Press, New York, 1997.
6. Progress in Liquid Crystal Science and Technology: In Honor of Shunsuke Kobayashi’s 80th

Birthday, H. S. Kwok, S. Naemura and H. L. Ong (Editors), Part I “Introduction: Memories of 43 Years of Liquid Crystal Research” (pp. 3–29), S. Kobayashi, World Scientific, Singapore, 2013.
7. High Quality Liquid Crystal Displays and Smart Devices, S. Ishihara, S. Kobayashi and Y. Ukai (Editors), IET, UK, 2019.

Dr. Tatsuo UCHIDA

Papers

1. 多色液晶表示素子、和田正信・内田龍男・手島　透、特許 S62-011352（登録 1411147）（1979）.
2. Guest-Host Type Liquid Crystal Displays, T. Uchida and M. Wada, Mol. Crys. Liq. Cryst., **63**, 19–44 (1981).
3. Bright Dichroic Guest-Host LCDs without a Polarizer, T. Uchida, H. Seki, C. Shishido and M. Wada, Proc. Soc. Information Display, **22**, 41–46 (1981).
4. A Liquid Crystal Multicolor Display Using Color Filters, T. Uchida, Proc. Eurodisplay, 39–42 (1981).
5. A Full Color Matrix Liquid Crystal Display with Color Layers on the Electrodes, T. Uchida, S. Yamamoto and Y. Shibata, IEEE Trans. Electron Devices, **ED-30**, 503–507 (1983).
6. JAPAN DISPLAY ’83 記念特集　5. 液晶ディスプレイ　5-1 カラー液晶表示素子の技術動向、内田龍男、テレビジョン学会誌、**38**, 340–345 (1984).
7. Multicolored Liquid Crystal Displays, T. Uchida, Opt. Eng., **23**, 247–252 (1984).
8. Application and Device Modeling of Liquid Crystal Displays, T. Uchida, Mol. Cryst. Liquid Cryst., **123**, 15–55 (1985).
9. Cell Construction for Liquid Crystal Display Devices, T. Takamatsu, F. Funada, M. Matsuura and T. Uchida, US Patent No. 4,593,977 (1986).
10. Reflective Multicolor Liquid-Crystal Display, T. Uchida, T. Katagishi, M. Onodera and Y. Shibata, IEEE Trans. Electron Devices, **ED-33**, 1207–1211 (1986).
11. Crucial Influence of K_{33}/K_{11} Ratio on Viewing Angle of Display Mode Using a Bend Alignment Liquid-Crystal Cell with a Compensator, C.-L. Kuo, T. Miyashita, M. Suzuki and T. Uchida, Appl. Phys. Lett., **68**, 1461–1463 (1996).
12. Optically Compensated Bend Mode (OCB Mode) with Wide Viewing Angle and Fast Response, T. Miyashita and T. Uchida, IEICE Trans. Electronics, **79-C**, 1076–1082 (1996).
13. Reflective Liquid-Crystal Displays, T. Uchida and T. Ishinabe, MRS Bull., **27**, 876–879 (2002).
14. Order Parameters of the Liquid Crystal Interface Layer at a Rubbed Polymer Surface, L. Xuan, T. Tohyama, T. Miyashita and T. Uchida, J. Appl. Phys., **96**, 1953–1958 (2004).
15. Analysis of the Surface Order Parameter of Liquid Crystal on a Polymer Surface Using the Phase Transition Droplet Method, S.-J. Oh, K. Kuboki, T. Miyashita and T. Uchida, J. Appl. Phys., **102**, 014506 (2007).

Books

1. 『液晶　基礎編』、岡野光治・小林駿介編、（第 10 章　液晶材料の物性評価、内田龍男・犬飼　孝著）、培風館、1985 年.

2.『液晶デバイスハンドブック』、内田龍男他共著、日本学術振興会第 142 委員会編、日刊工業新聞社、1989 年.
3. Liquid Crystals —Applications and Uses—, B. Bahadur (Editor), Chapter 5 “Surface Alignment of Liquid Crystals”, T. Uchida and H. Seki, World Scientific, Singapore, 1992.
4.『ディスプレイ』、小林駿介・遠山嘉一編、（第 7 章 ＬＣＤ（液晶ディスプレイ）、内田龍男著）、丸善、1993 年.
5.『次世代液晶ディスプレイ技術』、内田龍男編著、工業調査会、1994 年.
6.『フラットパネルディスプレイ大事典』、内田龍男・内池平樹監修、工業調査会、2001 年.
7.『図解　電子ディスプレイのすべて』、内田龍男監修、工業調査会、2006 年.