The 27th international liquid crystal conference, ILCC2018 in Kyoto, Japan

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General introduction of ILCC2018

The 27th International Liquid Crystal Conference (ILCC2018) was held in Kyoto from 22 to 27 July 2018. The venue was Kyoto International Conference Center (Figure 1) in which many significant international conferences, such as COP3 to determine the Kyoto Protocol, have been held. Kyoto is one of the most historical cities in the world and had been the capital city of Japan from 794 to 1867. There are many historical temples, traditional palaces, and beautiful parks in Kyoto area. In the past, Japan hosted two ILCCs in 1980 at Kyoto and 2000 at Sendai.

The Japanese Liquid Crystal Society set up the ILCC2018 organising committee chaired by Takashi Kato, Professor of the University of Tokyo. ILCC2018 was organised by the Japanese Liquid Crystal Society and Science Council of Japan.

In total, 731 participants came from 40 countries and areas to this conference. Scientific program consisted of 646 presentations including 5 plenary lectures, 52 invited talks, 179 contributed presentations, and 410 posters. In addition, public program was held on 22 July. The organising committee planned a tutorial consisting of six lectures for young scientists and two public lectures for high school students and citizens.

P2. Overview of scientific programs

Science and technology of liquid crystals are characterised by the interdisciplinary nature. Collaboration of basic science and applied technology has promoted the development of this research area. Considering this fact, the organising committee planned general sessions for existing fields of science and technology of liquid crystals as well as special sessions for research fields related to liquid crystals and industrial applications in order to extend the territory of liquid crystal science and technology. The special sessions consisted of only invited presentations. The sessions are listed below.

A. General Sessions
A01 Molecular design, synthesis and materials
A02 Phases, structure and ordering
A03 Theory, simulation and modelling
A04 Dynamics and pattern formation
A05 Symmetry, chirality, polarity and bent-core molecules
A06 Self-assembly, colloids, chromonics and biological systems
A07 Frustrated phases and complex systems
A08 Nanostructured systems, supramolecules, and hydrogen-bonded systems
A09 Polymers, elastomers and gels
A10 Surfaces, confined systems and alignment control
A11 Displays and devices
A12 Optics and photonics
A13 Electronics, energy and environment
A14 Functional materials for devices, optical films, optical devices

S. Special Sessions
S01 Future displays
S02 Future materials
S03 Life science and liquid crystals
S04 Ultra-high definition display systems in 8K era

P3. Opening ceremony

In the opening ceremony, Prof. Takashi Kato, chair of ILCC2018 organising committee and the Japanese Liquid Crystal Society, Prof. Kazuhiko Takeuchi, vice-chair of Science Council of Japan, and Prof. Hiroshi Yokoyama, president of International Liquid Crystal Society, provided opening addresses (Figure 2). Their encouraging speeches warmed up the atmosphere of the conference.

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P4. Plenary session

Prof. Dirk J. Broer from the Eindhoven University of Technology, the Netherlands, delivered the first plenary lecture entitled ‘Reactive Mesogens: from Display Optics to Complex Soft Robotic Functions’ (Figure 3). He presented the development of liquid-crystalline polymers that deform by external stimuli, such as electric field and light. The significance of the designs of reactive mesogens, incorporating stimuli-responsive moieties in the liquid crystal molecules, was clearly indicated in the lecture. He also mentioned robotics applications of the materials. Actuators based on liquid-crystalline polymers will play a more important role in the future robotics.

Prof. Nicholas Lawrence Abbott from the University of Wisconsin, USA (currently at Cornell University), gave the second plenary lecture entitled ‘Liquid-crystalline Materials That Provide Chemo-Optical Responses to Biological Stimuli’. He gave an overview of liquid crystals as ‘sentient materials’ that are capable of releasing microcargo (aqueous microdroplets or solid microparticles and their chemical contents), initially trapped within the liquid crystal, in response to external stimuli. Several examples were given on liquid crystals performing complex functions such as detecting mechanical shear stresses generated by motile bacteria, and releasing just the right amount of biocidal agent to cause bacterial cell death, through the interplay of elastic, electrostatic, and mechanical forces acting in the sample.

The third plenary lecture was given by Prof. Oleg D. Lavrentovich from Kent State University, USA, entitled ‘Liquid Crystals – Based Active Matter’. He gave a detailed description of ‘living liquid crystals’, in which swimming bacteria are placed in a lyotropic liquid crystal environment. In such a system, the self-propelling motion of bacteria becomes coupled to the liquid crystal director distribution, enabling control of the spatial distribution, trajectories, and even the polarity of motion. He also presented newest results (which incidentally was published online on the same day as his lecture) on electrically driven solitary waves traveling as director bullets in a nematic liquid crystal slab.

Prof. Atsushi Yoshizawa from Hirosaki University, Japan, delivered the fourth plenary lecture entitled ‘Nanostructured Assemblies of Liquid-crystalline Supermolecules: From Display to Medicine’. He presented three topics. The first topic was the design of blue phase III for next-generation displays. The second was mirror symmetry breaking in the dark conglomerate phase of an achiral flexible trimer. The third was the effects of liquid crystallinity on anticancer activities. Throughout these topics, he emphasised the potential utility of liquid crystals as soft materials in next generation.

The last plenary lecture was delivered by Prof. Maria Helena Figueiredo Godinho from Universidade NOVA de Lisboa, Portugal, on ‘Cellulose-Based Liquid Crystal Structures for Stimuli-Responsive Materials’. It was noted that hierarchical-oriented cellulose nano, micro, and meso structures in sclerenchymal tissue were related to its responsive ability against stimuli and interactions.
with the environment. She showed the functionality and structural performance of cellulose-based fibres and films that were designed through control of the cholesteric-like organisation of cellulose structures. It was expected that the improvement of the understanding of cellulose structures would open up a new way for creating soft interactive materials for future.

P5. Normal session

Session A01: ‘Molecular design, synthesis, and materials’ comprised 19 oral and 33 poster contributions. In this session, several new molecular designs of liquid crystals were presented. For example, the use of dimer structures, ionic moieties, flying-seed-like moieties, and halogen-substitutions was reported by many presenters. Six invited lectures were given. Lehmann presented the self-organisation behaviour of star-shaped phthalocyanine mesogens with/without C60 fullerenes. He noted that it is possible to generate fullerene quadruple helices structures by controlling the mixing ratio of these two mesogens. Laschat reported a new series of liquid-crystalline molecules consisting of an amino acid amphiphile and a crown ether unit. Tschierske reported the effects of fluorine-substitution for bolapolyphosphate compounds having two polar 1,2-diol groups on their molecular assemblies. He found that the core fluorination resulted in the formation of \( \pi-\pi \) interaction between fluorinated and non-fluorinated aromatics, which influences the tilt patterns of the cores. Lemieux reported the effect of ethynyl spacers into the design of tricarboxilane-terminated mesogens on their mesomorphic and ‘de Vries-like’ properties. Imrie presented the design principle of twist-bend nematic phase. He also noted the potential applications of these new type of nematic liquid crystals. Saez developed supermolecular liquid crystals consisting of inorganic cages and dendritic parts. These giant molecules exhibit smectic, nematic, and chiral nematic phases. Liquid-crystalline molecules with no long alkyl chains were reported by several groups. Throughout these presentations, the participants strongly felt the increase of the relationship between the molecular structure and macroscopic superstructure that is formed.

Session A03: ‘Theory, simulation, and modelling’ comprised 14 oral and 21 poster contributions. Diverse topics were covered in the session ranging from defects, liquid crystal composites, molecular theories of complex phases, biological and lyotropic liquid crystals, and elastomers. The session had three invited speakers. Lu gave a detailed description of the forces acting on line defects in smectic liquid crystals. Michele showed that liquid crystal ordering exhibited by water suspensions of DNA duplexes could be reproduced by Monte Carlo simulations. Palffy-Muhoray explained the importance of developing accurate models of liquid crystal elastomers and then showed examples of effective potential approaches to modelling their optomechanical response. The presentations demonstrated the power of computational science in bridging the gap between molecular structure and macroscopic properties.

Session A04: ‘Dynamics and pattern formation’ comprised 17 oral and 23 poster contributions. Dynamic patterns were presented in various materials (nematic, cholesteric, smectic, blue phase, colloidal, and biological materials) using various stimuli (electric field, light, and flow) in diverse geometries (thin film, droplet, and shell). In line with recent trends, an impressive number of out-of-equilibrium phenomena were reported by pumping liquid crystals by electric/flow fields, heat, or light. The session had two invited speakers. Aya presented electrically pumped, motile topological solitons in a nematic liquid crystal film. Takeuchi presented the existence of a universal scaling law, known as the Kardar-Parisi-Zhang universality class, to exist at the interface of two well-known electro-hydrodynamic instabilities, dynamic scattering modes 1 and 2.

Session A05: ‘Symmetry, chirality, polarity, and bent-core molecules’ comprised 9 oral and 21 poster
contributions. A considerable number of papers reported studies on bent-core molecules, but other phases (smectic, cholesteric, columnar) and phenomena (symmetry breaking, chirality transfer, solvatochromism) were also discussed, providing an opportunity for participants to get an update on all aspects of symmetry, chirality, and polarity-related phenomena. Two invited talks were given. Ros showed that pyrene-containing bent-core mesogens can self-assemble into fluorescent nanotubes and gels, even without hydrogen-bonding functionality. Vij presented the synthesis and characterisation of a series of new ferroelectric liquid crystals showing the de Vries behaviour, for potential applications. Vij presented the synthesis and characterisation of a series of new ferroelectric liquid crystals showing the de Vries behaviour, for potential applica-

Session A06: ‘Self-assembly, colloids, chromonics and biological systems’ comprised 31 oral and 42 poster contributions. The larger number of presentations indicated that these topics have attracted great attention. There were many presentations focusing on the design of novel lyotropic liquid-crystalline systems based on a variety of colloids and nanoparticles, such as rod-like viruses, nanoDNA, cellulose nanocrystals, oxide nanosheets, graphenes, and calcium carbonate/hydroxyapatite nanorods. Four invited lectures were given. Dierking presented various functional systems composed of colloidal graphene oxides and liquid crystals. Donnio reported that the combination of polycatenar-coated nanoparticles and dendronised ones gave rise to the formation of AnBm binary superlattices of the Frank-Kasper type crystal structures. Collings presented Brownian motion of colloidal particles suspended in uniaxially aligned nematic phases. There were also many presentations focusing on the relationships between liquid crystals and biological systems. For example, liquid-crystalline systems based on bio-compounds, such as glycolipids and nucleic acids, were presented by several groups. Focusing on the similarity between vesicles and red blood cells, Komura investigated the thermal and active fluctuations of compressible bilayer vesicles.

Session A07: ‘Frustrated phases and complex systems’ comprised four oral and eight poster contributions. Despite the smaller number of presentations compared to other sessions, the participants were given the opportunity to learn about cutting-edge research providing insight into frustrated liquid crystals. Two talks showed how optical microscopy, with the aid of numerical simulations, can provide detailed information on liquid crystal alignment in confined and three-dimensional chiral systems (blue phases). One talk presented resonant X-ray scattering measurements of a super-lattice structured subphase (with up to 6-layer periodicity!) in antiferroelectric liquid crystals, and another talk presented results on the linear and nonlinear rheology of blue phase liquid crystals, which shows strong hysteresis attributed to the rearrangement of disclination lines.

Session A08: ‘Nanostructured systems, supramolecules, and hydrogen-bonded systems’ comprised 10 oral and 24 poster contributions. In this session, various nanostructured materials were reported. Three invited lectures were delivered. Serrano developed columnar liquid-crystalline assemblies by using a combination of hydrogen-bonding acceptor templates and donor dendrons. By polymerising the dendrons and removing the inner templates, he succeeded in preparing nanostructured porous materials. There were several reports on the use of hydrogen-bonding for inducing cylinder assemblies. For example, Soberats designed liquid-crystalline dye molecules consisting of a diketo-pyrrolo-pyrrole core and two wedge-shaped groups. The diketo-pyrrolo-pyrrole core formed stacked dimers via a quadruple H-bonding motif, which leads to the formation of 1D columnar assemblies. Mehl reported the helical twisting power (HTP) of gold nanoparticles functionalised with ligands based on the binaphthol motif and with nematogenic groups. He pointed out that the HTP of the nanoparticles in host liquid crystals is significantly larger than that of the chiral groups dispersed in the same host. Taking into accounts these new studies, the audiences felt a great progress of molecular design principle of liquid crystals, which would lead to a finding of new application of liquid crystals.

Session A09: ‘Polymers, elastomers, and gels’ comprised 17 oral and 40 poster contributions. In this session, a large part of presentations was about liquid-crystalline elastomers. An invited lecture was delivered by Zentel. Focusing on the actuating ability of liquid-crystalline elastomers, he developed novel micro-particles, such as core/shell type and Janus-type particles, of liquid-crystalline elastomers by using microfluidic process. These micro-particles act as micropumps and micro-actuators. Several new liquid-crystalline elastomers were reported to exhibit novel functions and properties, such as heavy lifting ability, negative Poisson’s ratio, stiffening upon photo irradiation, and two-photon absorption ability upon irradiation with femtosecond laser pulses. These new designs would open up new applications of liquid-crystalline elastomers.

Session A10: ‘Surfaces, confined systems, and alignment control’ comprised 17 oral and 47 poster contributions. In this session, three invited papers were presented. Yokoyama described a dependence on the chirality of the twist disclination lines, crossing lines in 3D space can be made either stable or metastable. Seki
described reversible control of the mesogen orientation between the homeotropic and planar modes alternatively with UV and visible light. Drevensek-Olenik described the fabrication and characterisation of electrically and magnetically switchable optical diffraction gratings and electrically tunable q-plates for the generation of vector vortex beams by using their proposed method. Surface, alignment control, etc., of liquid crystals are one of the most interesting fields for liquid-crystalline physical phenomena. It is expected that new alignment technologies, polymer technology, application of cholesteric crystals and so on will be widely discussed in the future.

Session A11: ‘Displays and devices’ comprised 11 oral and 45 poster contributions. In this session, not only display applications but also novel optical applications using liquid crystal technologies such as smart window, lens, phase shifter, laser and so on were shown. Three invited papers were presented. Hyodo described the technologies for the sheet liquid crystal display (LCD) applying transparent PI substrates. The thickness of the inorganic layer on the PI film was adjusted to control the residual stress in the glass substrate. Yamaguchi described the controllable twist angle cell. Applying out-of-plane filed in the TN cell, the controllable twist angle cell demonstrated lower driving voltage display. Lee described dynamic control of the reflective colour of a cholesteric liquid crystal cell. The reflective colour was controlled by electrically tuning the central wavelength of the Bragg reflection band via the dielectric heating effect. The technology of LCD is considered to be mature. However, we believe that new optical devices using LCD technologies will continually be developed.

Session A12: ‘Optics and photonics’ comprised 22 oral and 50 poster contributions including an invited lecture. Lorenz presented the molecular behaviour of a nematic liquid crystal on Fe doped LiNbO3. It was noted that the laser irradiation on the surface, leading to the creation of localised electric field, induces the formation of umbilic and line defects. This technology can be used for various applications including micro-manipulation of liquid crystals, lens, and photoinduced grating formation.

Session A13: ‘Electronics, energy, and environment’ comprised 4 oral and 18 poster contributions. In the session A13, liquid-crystalline materials as transport media for ion, electron and substances were presented. For example, perylene bisimide derivatives were shown to exhibit an anisotropic redox activity in the columnar phases due to their anisotropic ion and electron conductive properties. Phenylbenzothienobenzothiophene derivatives were used for the development of SmE thin films showing high carrier transport properties. Apart from the transport of ion and electron, the use of nanostructured liquid crystals for the transport of substances was also presented. For example, bicontinuous cubic nanostructured membranes were reported to be used for the removal of virus from water. These studies clearly implied that the use of liquid-crystalline assembly is one of the promising approaches for bringing innovations in the design of transport materials.

Session A14: ‘Functional materials for devices, optical films, optical devices’ comprised 17 oral and 21 poster contributions. In this session, the applications of liquid crystals such as lens, optical devices, and luminescence materials were presented. Four invited lectures were presented. Bunning reported a new technology to convert linearly polarised light to right- or left-handed circular polarisation, which can be used for diffractive waveplate lens with various advantages. Lu presented a unique photo-alignment technology that enables to control liquid crystal directors in an arbitrary manner. He also showed the recent advances of the alignment technology for various wavelength bands, such as mid-infrared and THz ranges. Choi presented the light absorption and luminescence properties of rigid rod-like liquid crystals. Shishido reported a dye-free alignment patterning technique based on a scanning wave photopolymerisation (SWaP) concept.

P6. Special session

Session S01: Four invited papers were presented. Takahashi presented a new LCD design based on polymer wall technology. He also showed three potential applications of liquid crystals, such as smart window, adaptive head light for automotive and novel antenna. Harding presented the recent advances in curved displays. He noted that the development of organic transistors plays a key role in allowing low-temperature processing, which enables the use of some plastics, such as the ubiquitous TAC, as the display substrate. Komura presented novel display technologies for future automotive applications based on a short pitch lurch control in-plane switching technology. Wang presented a new concept for holographic near-eye applications based on liquid crystal on silicon technology for spatial light modulator. Despite this year is the 50th anniversary of LCDs, LCDs are still growing and will still be considered as new developments.

Session S02: Four presenters made lectures on future materials. Henmi presented a new design of separation membranes for water treatment that were
prepared by polymerisation of nanostructured liquid crystals. These membranes show high filtration performance and selectivity of ions. Kim explained graphene-based materials exhibiting liquid-crystalline behaviour in aqueous dispersion. Nakajima made a presentation on hydrogels having lamellar structures. By controlling the lamellar distances, these gels show structural colours. Takimiya showed molecular design of π-conjugated molecules. He explained that the control of packing of these molecules largely influences their ability as organic semiconductors. Throughout these presentations on these new liquid crystals and liquid-crystalline-related materials, the audiences can feel the new uses of liquid crystals.

**Session S03:** Four invited papers were presented. Imai presented the design of novel vesicles that grow and divide into two vesicles by incorporating amphiphiles in the external solution. This system has a great potential to be a model of the self-reproducing automaton. Tanaka presented the impact of carbohydrates on cell surfaces on the inter-membrane coupling and bending rigidity of cell membranes. He explained ‘membrane physics’, which is now attracting attention in soft matter and biological physics. Hegmann presented that liquid crystal elastomers can be used as scaffolds for culturing cells. She explained the key properties of LC elastomers in this application. Ishiwata explained that the various bio-motile systems have liquid-crystalline ordered structures. Throughout these presentations, it is expected that liquid crystal science will be more important in the field of bio-related researches.

**Session S04:** Four invited papers were presented. Kim presented 360 degree viewable tabletop holographic display with full parallax support. Tanioka presented 8K imaging technology and its medical application. Yatagai presented optical memory for ultra-high definition imaging systems. Suh presented technologies for QUHD (8K · 4K) LCD. In this session, a new application of 8K LCD was introduced. The technologies of high-resolution LCDs are expected to be applied not only to information displays but also to new optical applications.

**P7. Poster session**

Poster session is an important part of the conference. More than 400 posters that cover a wide range of the fields of liquid crystals were presented (Figure 4). The names of poster award winners are shown below.

**ILCC-Kyoto Poster Awardees**

Hiroshi Yokota (Japan)

**P8. Tutorial session**

In ILCC, a tutorial course for young researchers and students was held on Sunday, 22 July. In ILCC2018, the organising committee invited six leading researchers working in the field of liquid crystals and related areas. The names of the lecturers and titles are indicated below.

1. Slobodan Žumer (University of Ljubljana & Jožef Stefan Institute, Slovenia) Continuum Physics of Liquid Crystals
The course attracted a broad interest of the attendants working in various research fields, including chemistry, physics, theory, and applications of liquid crystals as well as biology.

**P9. Public lecture**

On one day before the conference started, public lectures on liquid crystals were held (Figure 5). Prof. Takashi Kato from the University of Tokyo and Dr. Shinichiro Oka from Japan Display Inc. acted as the lecturers. Kato made a lecture on the basis and state-of-the-art technology of liquid crystals. In addition, he explained the properties of liquid crystals through a simple experiment. Oka presented the history of liquid crystal display and the leading edge of liquid crystal display technology. There were over 60 attendances including junior and high school students, university students, citizens in the area of Kyoto and Osaka. They enjoyed the lectures and deepened their understandings on liquid crystals. We expect this event will become one of important opportunities that encourage peoples to be interested in science.

**P10. Excursion**

As a custom of ILCC, the organising committee planned excursions around Kyoto city on Wednesday afternoon, 25 July. As mentioned in the introduction, Kyoto has been the centre of the Japanese culture and there are many good places for excursions. Kyoto UNESCO World Heritage half-day tour, tour to Fushimi area, tour to Sagano-Arashiyama area, and tour to 2 UNESCO World Heritages in southern Kyoto area were carried out. It was extremely hot this summer in Japan because of the abnormal climate. During the period of ILCC2018, the temperature exceeded 35°C every day in Kyoto. Many participants from Europe and northern America were very astonished at this hotness. Happily, everyone could enjoy the history and culture of Kyoto during the excursions without suffering heatstroke.

**P11. Banquet**

The conference dinner was held in the Sakura hall of the conference centre in the evening on 25 July. As the traditional way of Japan, the dinner was started by Kagami-wari (Figure 6), in which plenary lecturers broke a wooden plate covering the sake cask by wooden hammers. Prof. Shunsuke Kobayashi proposed a toast to a drink. Since the hall is connected to the Japanese garden, the attendants enjoyed delicious foods as well as beautiful scenery. They also enjoyed the attraction of Japanese drums (Figure 7). By the courtesy of the drummers, some attendants actually played the Japanese drums with the help of the drummers.
P12. Conclusion

The International Liquid Crystal Conferences have provided excellent opportunities for sharing new ideas, stimulating discussions, and exchange of information for researchers and engineers in the fields of liquid crystal science and technology since the first conference was held in Kent State University in 1965. ILCC2018 has also greatly contributed to the promotion of the science and technology of liquid crystals. We thank all the attendees for making the ILCC2018 a success and hope to see everyone at the 28th conference, to be held in Lisbon, Portugal.

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