Pawel Pieranski – crystallographer of liquids and Alfred-Saupe-prize laureate 2019

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Laudation

Commemorating Alfred Saupe, an outstanding pioneer of liquid crystal research, the Alfred-Saupe-Foundation and the German Liquid Crystal Society bestow the Alfred Saupe Prize to honour outstanding work in the field of liquid crystals. On 28 March 2019, Prof. Dr Pawel Pieranski received this prize, which includes the Alfred Saupe Medal (Figure 1), in recognition of his outstanding works in the field of liquid crystal research and its application.

Pawel Pieranski has worked extensively in many different areas of liquid crystal (LC) research, such as the static and dynamic behaviour of nematic LCs [1–8], chiral smectics and especially ferroelectric LCs [9–11], colloidal crystals [12–19], cholesteric and blue phases [20–32], wetting and anchoring [33–36], application of atomic force microscopy (AFM) to LCs [37–41], freely suspended LC films [42–52], shapes of single crystals [53–61], cellulose derivatives [62–65], and various aspects of order, structure, symmetry, defects and topology in certain mesophases or special geometries [66–74]. Many times, he raised new scientific questions, developed experimental methods, started and established a topical research area, explored and reviewed the basic physics. Often, he pointed out that the method used, the subject studied or the cognition achieved can be applied to other systems, exhibits an analogy to a different problem in science or has an impact on another research field, so that the liquid crystal may serve as a model system that facilitates studying and visualising more general phenomena at comparably moderate conditions.

Born in Liskow (Poland), Pawel Pieranski studied Physics in Poland and France. He received the degree Magister of Physics at the University Adam Mickiewicz in Poznan. In Paris, he encountered the spirit by Pierre-Gilles de Gennes [74] and received the Diplôme d’Études Approfondies de Physique des Solides at the Université Paris-Sud in Orsay. Based on his extensive research with Etienne Guyon at the Laboratoire de Physique des Solides in Orsay, he finished his Thèse de 3ème cycle (1972), became Chargé des Recherches at CNRS (1973) and finished his Thèse d’Etat (1976). After post-doc research with R.B. Meyer at Brandeis University (USA, 1979) and independent research at the Laboratoire de Physique des Solides in Orsay, he became Directeur des Recherches at CNRS (1984). Apart from his early work published together with E. Guyon [3–6], Pawel Pieranski hitherto collaborated extensively with Patricia Cladis [1,2,21–26] and Maria H. Godinho [62–65,71–73] and occasionally published, for example (in chronological order) together with Maurice Kléman [1], with his brother Piotr Pieranski [10,17,18], with Pierre-Gilles de Gennes [7], Jaques Friedel [12], Robert B. Meyer [8], Gerd Heppke [29–31], Richard Hornreich [35], John Goodby [42], Patrick Oswald [51,75,76], Slobodan Žumer [62] and other distinguished researchers.

Pioneering work

The introduction of many scientific publications starts with the phrase ‘since Pieranski’s pioneering work …’. Indeed, Pawel Pieranski has performed groundbreaking, comprehensive works in many fields, which were recognised as being very important, later (Figure 2). However, he was typically not only the first in time, but also studied the respective subject in great detail, explored very thoroughly the underlying physical principles and basic laws, summarised his results in a comprehensive review article and was already working on different problems, when his subject became an issue of mainstream research. For example, Pawel Pieranski studied the spontaneous polarisation in LCs [9–11], while other scientists were still debating, whether ferroelectric LCs can exist at all, he worked on colloidal crystals around 1980 [12–19], which were later recognised as an important type of photonic crystals, he clarified in the 1980s the structure of blue phases [20–32], technical applications of which became feasible much later through the benefits of polymer-stabilisation, he worked on anchoring and its dependence on the substrate in the late 1980s [33–36], a field which raised strongly around 1990 and remained very important...
until today due to the development of methods for fabricating substrates with a well-defined chemical, physical and nano-mechanical properties, due to the growing diversity of quite different types of LCs that are required to be aligned, and due to rising applications in optics, information technology, biology or medicine. In the 1990s, Pieranski was among the first who applied atomic force microscopy (AFM) for studying the surface topography of glass-like liquid crystals \cite{37–39} and soft crystals \cite{40,41}, a method which is widely used today. His research interests in freely suspended LC films \cite{42–52}, faceting (next paragraph) \cite{20–23,53–61}, cellulose \cite{62–65} or the dowser texture \cite{71–73} have been less frequently shared by other researchers, but probably their crack of dawn is still ahead.

**Liquid single crystals**

Hitherto, Pawel Pieranski’s most long-lasting continuous research interest over many decades was devoted to the growth and thorough investigation of liquid single crystals, i.e. droplets of liquid crystals, which do not show a spherical shape but exhibit facets, thereby resembling the shape of solid crystals (Figure 3). His studies included colloidal crystals \cite{15}, thermotropic liquid crystals – like blue phases \cite{20–23} and thermotropic bicontinuous cubic phases \cite{40,41} – as well as lyotropic cubic liquid crystals \cite{53–61}. To grow liquid single crystals, Pieranski developed special containers for the specimen, where either the temperature and a temperature gradient \cite{21,27,61} or the humidity of the environment \cite{53–61} can be controlled very precisely. The latter type of setups facilitates not only the growth and stabilisation, but also changes of the composition of the LC droplet and thus phase transitions in lyotropic LCs at constant temperature \cite{57}. Pieranski pointed out the importance of dislocations for crystal growth rates and studied the motions of dislocations as well as the symmetry and topology of the liquid crystal structure in the vicinity of a dislocation \cite{23,27,59,70}. In solid crystals, dislocations are very important, because they can enhance the growth rate by many orders of magnitude owing to surface steps appearing in the vicinity of a dislocation \cite{70}. Due to stronger interactions, the deposition of a further atom to a surface step is much more likely than its deposition on a flat surface.

**Figure 1.** The Alfred Saupe Medal, which is bestowed to laureates of the Alfred Saupe Prize in recognition of outstanding work in the field of liquid crystal research and its applications.

**Figure 2.** Development of the number of publications per year in certain LC research fields (according to the Web of Science, Clarivate Analytics, 2019). Arrows indicate the appearance of some publications by Pawel Pieranski and his coworkers.
which is free of dislocations. Pawel Pieranski observed the shape of surface steps from a screw dislocation on surfaces of liquid single crystals: (b) blue phase; (c), (d) lyotropic cubic phase. (e) Facets of a BP1 blue phase single crystal. (f)–(h) Facets of a bicontinuous lyotropic phase grown in an L1-phase environment and calculated structures thereof; (i)–(l) liquid single crystals and soft crystals grown in a gas environment: (i), (j) lyotropic cubic phase; (k) facets of a thermotropic bicontinuous cubic phase and (l) surface steps on the facets detected by AFM. With kind permission by the respective publisher, the figures are reproduced from the following references: (a) Figure 3 from Ref. [27]. (© EDP Sciences); (b), (f), (g) Figure 9 and Figure 16 from Ref. [70]. (© Elsevier); (c), (d) Figure 7 from Ref. [59]. (© IOP Publishing); (e) Figure 1 from Ref. [20]. (© EDP Sciences); (f) Figure 18 from Ref. [61]. (© EDP Sciences); (i), (j) Figure 5(c) and Figure 7 from Ref. [54]. (© EDP Sciences); (k), (l) Figure 5 and Figure 11 from Ref. [41]. (© EDP Sciences).

Figure 3. Facets of liquid single crystals. (a) Dislocations in single crystals of a hexagonal blue phase, BPH\textsuperscript{10}. (b)–(d) Spiral-like surface steps emerging from a screw dislocation on surfaces of liquid single crystals: (b) blue phase; (c), (d) lyotropic cubic phase. (e) Facets of a BP1 blue phase single crystal. (f)–(h) Facets of a bicontinuous lyotropic phase grown in an L1-phase environment and calculated structures thereof; (i)–(l) liquid single crystals and soft crystals grown in a gas environment: (i), (j) lyotropic cubic phase; (k) facets of a thermotropic bicontinuous cubic phase and (l) surface steps on the facets detected by AFM. With kind permission by the respective publisher, the figures are reproduced from the following references: (a) Figure 3 from Ref. [27]. (© EDP Sciences); (b), (f), (g) Figure 9 and Figure 16 from Ref. [70]. (© Elsevier); (c), (d) Figure 7 from Ref. [59]. (© IOP Publishing); (e) Figure 1 from Ref. [20]. (© EDP Sciences); (f) Figure 18 from Ref. [61]. (© EDP Sciences); (i), (j) Figure 5(c) and Figure 7 from Ref. [54]. (© EDP Sciences); (k), (l) Figure 5 and Figure 11 from Ref. [41]. (© EDP Sciences).
fascinating observation was made, when liquid single crystals [Figure 3(i-j)] or soft single crystals [Figure 3(k-l)] were grown in a gas environment. In this case, a huge number (up to 60) of different kinds of facets were observed [40,53,54], including facets corresponding to large Miller indices, which are rarely found in solid crystals. This devil’s staircase scenario [53] was actually expected to appear in solid crystals close to 0 K. This very unusual observation could be explained by striking differences in the roughening temperature $T_r$ above which the smaller facets disappear. The value of $T_r$ is very small for crystals and for liquid crystals grown in a liquid environment, but well above room temperature for liquid crystal droplets in a gas environment [53].

**The cherry on the cake**

In his hitherto performed work, Pawel Pieranski developed several new experimental methods or improved the performance and precision of previous methods, which included the direct determination of the spontaneous polarisation in ferroelectric LCs [11], the observation of Kossel lines in colloidal crystals [14] and in blue phases [24–32], precise control of temperature gradients [20–24,27,61], acoustic experiments [47,49], the application of AFM to LCs [37–41], the inclusion of particles in LCs [50], the development of a new sphere rheometer [8], the precise control of humidity [53–61,63] as well as the generation of umbilics by flow and their stabilisation by magnetic fields [68].

Using such new experimental methods, Pieranski elucidated unknown structures, for example: the structure of the blue phase (BP) modifications BP1 [20] and BP2 [28], and found experimental evidence for new phases, such as the three-dimensional hexagonal blue phase BPH$^{3d}$ [22,27,31], the tetragonal blue phase BPX [24,26], the two-dimensional hexagonal blue phase BPH$^{2d}$ [32] and a new lyotropic phase [57].

Pawel Pieranski’s activities are very versatile. Prima facie, a list of his research topics may look like the directory of a textbook on liquid crystals and soft matter: Nematic LCs, convection and instabilities, colloidal crystals, blue phases, dislocations, anchoring, phase transitions, free-standing films, crystal facets. However, there is always something special, a detail that was overlooked previously, a new point of view, or even a seminal progress: the cherry on the cake! For example, thermal convection is induced by heating from above [5]; colloidal crystals are grown as two-dimensional layers or in a confined geometry or [13,16–18]; the work on blue phases is extended to studying facets [20–23] and diffraction patterns [24–31] or applying AFM [37]; for dislocations, Brownian motion is observed [27]; instead of static uniaxial anchoring, multistability and anchoring transitions are analysed [33–36]; for phase transitions, finite size effects are investigated [17,42]; free-standing films are studied in a vacuum to study their undamped vibrations [44–50] or free-standing films are made of lyotropic LCs [52]; the analysis of crystal facets is extended to soft crystals and lyotropic LCs [40,41,53–61].

In addition to these extras, Pieranski often discusses how quite different fields in science are related to each other, for example, smectic films to quantum billiards [46] and localisations in fractal drums [50] or LCs in general to problems in physics and mathematics [66]. He emphasises, how the recognition gained from LC experiments can be transposed to other fields through universal aspects of LCs [67].

**Pawel Pieranski’s teaching**

Pawel Pieranski is a brilliant teacher, both on the level of classroom experiments and on the academic level [75–77]. In his lectures and publications, he invites us to perceive nature with all of our senses. Most evidently, his presentations are a feast for the eyes, owing to their beautiful images and drawings (Figure 4). Not surprisingly, Pieranski received the Luckhurst-Samulsky-Prize 2014, recognising the best publication published in the journal Liquid Crystals in 2013 [68]. However, he also encourages us to use our sense of hearing through his acoustical experiments, for example, when he raises the question ‘Can one hear the shape of a drum?’ [47,49]. He also inspires our tactile sense, when he compares the cantilever of an AFM to the fingertip probing a surface, when describing its function in a popular scientific context. Last, but not least, Pawel Pieranski discloses a delightful sense of humour, for example, when he describes the unexpected visit of a longhorn (reduvius personatus) in his lab [69]. Often, reading his articles is like enjoying a thrilling novel about magical creatures and fantastic beasts, when we learn about frustrated liquids [25], diabolical points [45], self-tuning behaviour [44], the magic spiral [48], the devil’s staircase [53] or peculiar effects like thermopermeation [60], centrophobic behaviour [52], hygrophilic behaviour [52], the chirogyral effect [62], or rheotropism [72].

Pawel Pieranski also enjoys the reputation of being an inspiring, unreserved academic host. In addition to teaching and supervising his students and Ph. D. candidates in Orsay, he often invited and trained students, Ph. D. candidates and postdoctoral researchers from other countries. Some of his former visitors are, for example, John Bechhoefer [35], Christian Bahr [47], Roland Meister [38,39], Evgenii Demikhov [42], Tobias Plötzing [56,58] and Heinz Kitzerow, the author of this article [29–31].
Alfred Saupe and Paweł Pieranski – some mutualities

Summarising, Paweł Pieranski – like Alfred Saupe – performed outstanding pioneering work on many subjects within the field of liquid crystal research. However, there are additional mutualities between Alfred Saupe and Paweł Pieranski. These two researchers shared joint interest in several areas, for example, an interest in LC order, defects and topology, in lyotropic liquid crystals, in atomic force microscopy and also in blue phases. As a matter of fact, Alfred Saupe was the first who suggested a cubic superstructure in order to explain the coincidence of cholesteric-like selective reflection and missing birefringence in blue phases [78]. Later, Pieranski and his coworkers confirmed this hypothesis and determined the space groups describing BP1 and BP2 [20,28]. Both Saupe and Pieranski are liquid crystal experts of international renown, spending a major period of their academic career outside of their respective country of birth. Also, both of them spent the academic year 1989 as invited fellows at the Wissenschaftskolleg zu Berlin [79], thereby cultivating a vicinity to liquid crystal research in Germany.

Alfred Saupe ceremony 2019

The Alfred Saupe Medal was handed over to Paweł Pieranski at the 46th German Liquid Crystal Conference (Arbeitstagung Flüssigkristalle) held in Paderborn, 27–29 March 2019. In his lecture 'Physics of the i-Land', Paweł Pieranski (Figure 5) discussed the generation, motion, interaction of defects in a system.

Figure 4. (a) Free-standing film observed by polarising optical microscopy (POM). (b) Frames of different shapes for freely suspended smectic or lyotropic films. (c) Array of magnets and (d) POM image of umbilics stabilised by these magnets. (e) POM image of a nematic dowser texture subject to flow. (f) An unexpected visit in Paweł Pieranski’s lab, reported in Ref. [69]. With kind permission by the respective publisher, the figures are reproduced from the following references: (a), (f) Figure 1 from Ref. [69]. (© EDP Sciences); (b) Figure 4 from Ref. [52]. (© MDPI (Basel, Switzerland)); (c), (d) Figure 22 from Ref. [68]. (© Taylor&Francis); (e) Figure 12 from Ref. [72]. (© EDP Sciences).

Figure 5. Paweł Pieranski, giving his speech 'The Physics of the i-Land' at the 46th German liquid crystal conference on 28 March 2019 in Paderborn (Photo: Bingru Zhang, Paderborn University).
where the order is given by a phase $\varphi$ and described by an order parameter $\exp(i\varphi)$. In extension of recent works [71–73], he showed beautiful microscopic pictures of defects in the dowser texture, pointed out their analogy with vortices of the vector potential in type II superconductors and emphasised that the liquid crystal facilitates the generation of defects with opposite topological charge, which can annihilate each other (‘dowson collider’). In principle, the mutual annihilation of defects in superconductors is not forbidden, but the generation of vortices of the vector potential with opposite handedness, i.e. magnetic flux lines with antiparallel magnetisation, may be very hard to achieve experimentally. In his speech, Paweł Pieranski recognised the work by Alfred Saupe and memorised the friendship with some of his research companions.

Congratulations to Paweł Pieranski, Alfred-Saupe-Prize laureate 2019!

Acknowledgement

During the late 1980s, the author of this article (HK) enjoyed research visits in Paweł Pieranski’s lab at the Laboratoire de Physique des Solides in Orsay. Learning the Kossel diagram technique at this time facilitated identifying and separating different electric field effects in blue phases, which was a major breakthrough in HK’s Ph. D. work. HK will not forget these exciting and extremely fruitful research visits and would like to express his gratitude to Paweł Pieranski for the magnificent support, hospitality and friendship received in Orsay.

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