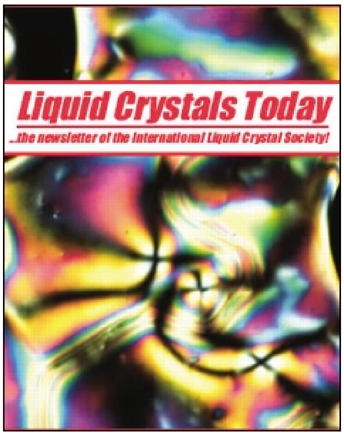

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The Contributions of Horst Stegemeyer to Blue Phase Research

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The Contributions of Horst Stegemeyer to Blue Phase Research

Remarks Made on the Occasion of His Retirement 14 October 1996

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The Early Years

Some of the most well known scientists in liquid crystal research investigated the blue phases at some time in their careers. In 1888 Friedrich Reinitzer described the pale blue colour occurring just as cholesteryl benzoate cools into the liquid crystal phase [1]. Otto Lehman detected a stable, optically isotropic phase different from the chiral nematic phase in 1906 [2]. Georges Friedel in 1922 noted the uniqueness of the isotropic to chiral nematic phase transition in his observations with a polarizing microscope [3]. In 1956 George Gray described many of these phenomena again [4] and in 1969 Alfred Saupe confirmed the optical properties noted by others and proposed a cubic model for the blue phase [5]. D. Coates and George Gray in 1973 reported the appearance of microscopic platelets whenever the blue phase was present [6]. Two years later S. Brazovskii argued theoretically that the transition from the isotropic phase to the liquid crystal phase should be accompanied by unusual behaviour in chiral systems [7] and one year after that David Armitage and Fraser Price presented dilatometry data providing evidence of phase transitions on either side of the blue phase [8].

In spite of all this work, the blue phase remained a relatively unknown phenomenon to workers in the liquid crystal field. I remember a conference in 1978 at which a small group of us were discussing the blue phase. One member of the group commented that the number of scientists who believed the blue phase existed probably numbered less than ten. Occasionally a poster on the blue phase was presented at a conference, but it drew little interest. There were no invited talks on the blue phase at conferences, let alone a session devoted to research on the blue phase. The reasons for this lack of interest were clear at the time: (1) the blue phase was reported to exist in a narrow temperature range less than a degree wide, (2) Saupe's model proposed a structure for the blue phase but no formal theoretical considerations were supplied, and (3) Brazovskii's theory of the transition to the liquid crystal phase in chiral systems was quite general in scope and contained little information on the structure of the unusual phase.

The 'Golden' Decade

The situation changed drastically with the publication of a series of four papers by a newly formed physical chemistry group directed by Horst Stegemeyer at the University of Paderborn [9]. During the period 1978–79, Stegemeyer and his co-workers explained the origin of the blue colour and provided calorimetric, optical, and thermodynamic evidence for two distinct blue phases. One year later, Stegemeyer and his student Karl Bergmann published pictures showing that a third, amorphous blue phase also existed in some compounds [10]. The publication of this work from Stegemeyer's laboratory caught the interest of a number of scientists working in the liquid crystal field and what followed was a 'golden decade' of blue phase research. Theoretical and experimental advances came at a rapid pace, with each one generating additional evidence that the blue phases were a unique phase of matter with remarkable properties. The excitement over this new knowledge even attracted workers from other fields of condensed matter chemistry and physics. Stegemeyer and his co-workers were among the leaders in this race for scientific understanding over the ensuing ten years and the University of Paderborn became the place to visit if one was at all interested in the blue phases.

In 1980 Saul Meiboom at AT&T Bell Laboratories performed optical transmission experiments indicating that more than one Bragg reflection may be present [11]. During that same year, David Johnson and Peter Crooker at the University of Hawaii detected four Bragg reflections from both the lower temperature (BP I) and higher temperature (BP II) blue phases [12]. One year later in 1981, Stegemeyer and his student Hermann Onusseit reported the observation of square, single crystals of a blue phase (see Fig. 1) [13]. I will never forget the excitement of this discovery when it was

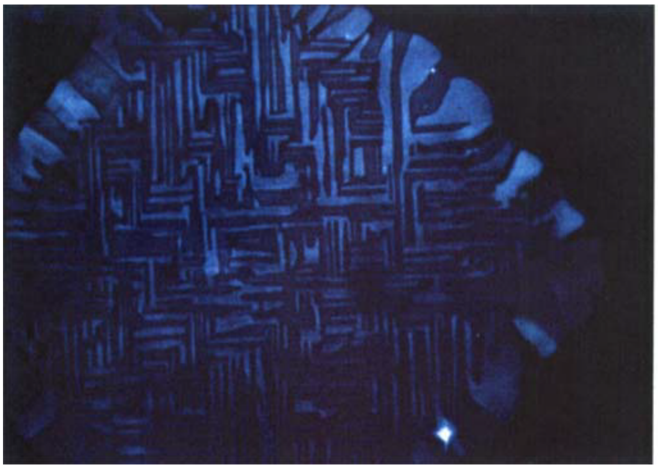

Figure 1. Single crystal of BP II after cooling into BP I (from [13]).

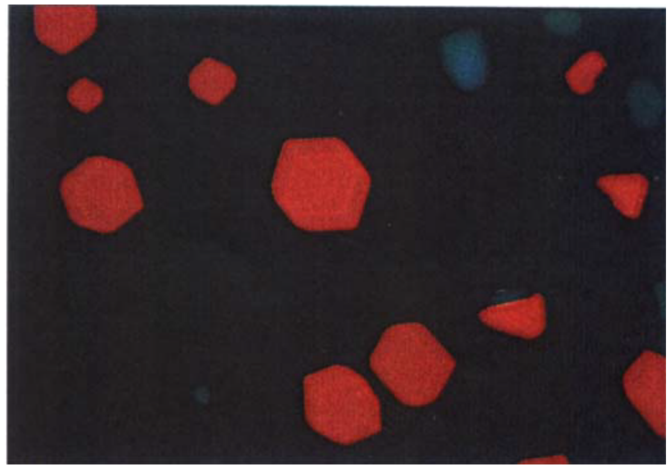

Figure 2. Single crystals of BP I growing from the isotropic phase (from [16]).

reported by Stegemeyer at a conference in the US. Every one of the hundred or so scientists in the room experienced a breathtaking sense of awe as Stegemeyer displayed photographs of these perfect single crystals made up of a fluid. It was at this conference that I decided to see if it might be possible to spend my upcoming sabbatical leave in Paderborn. We have a saying in the US to explain my reasoning; 'If you can't beat them, join them!'

Motivated by Stegemeyer's discovery of square, single crystals of the blue phases, during the period 1981–83 Richard Hornreich and S. Shtrikman at the Weizmann Institute of Science published a Landau theory for the blue phases based on cubic structures [14]. At about the same time, Stegemeyer and his co-worker Peter Pollmann reported that the viscosity of the blue phases was anomalously high [15]. During the period 1983–84, Stegemeyer and his student Thomas Blümel published pictures of three-dimensional single crystals of both BP I and BP II (see Fig. 2) [16], and in 1984 the first important results on the highest temperature blue phase (BP III) were reported. Working in Stegemeyer's laboratory, I used optical measurements to show that this phase was thermodynamically stable [17] and concurrently a group at AT&T Bell Laboratories utilized calorimetry to show the same thing [18].

At the same time the first work on the effect of electric fields on the blue phases was reported by Stegemeyer and his student Felix Porsch [19]. This was followed by important work from the University of Paris where P. Pieranski and his co-workers observed new blue phases stable only in an electric field [20]. The existence of new blue phases in an electric field was later confirmed by Stegemeyer's group [21].

Meanwhile, Stegemeyer and his students published temperature–chirality phase diagrams for the blue phases [22] and E. Demikhov at the Institute of Solid State Physics in Moscow observed selective reflection from the amorphous BP III [23]. In 1986 Pieranski's group utilized the Kossel diagram technique to analyse Bragg scattering from various blue phases [24]. Finally, Deng-ke Yang and Crooker in 1987 published the first phase diagrams showing the disappearance of BP II at high chirality [25].

Recent Developments

Investigation of the blue phases has continued, but at a significantly slower pace. In 1990 Hornreich and Shtrikman showed theoretically that a number of hexagonal phases were stable in an applied electric field [26]. In 1992 E. Demikhov, working in Stegemeyer's laboratory, and Stegemeyer reported that a new metastable blue phase, which they called BP S, sometimes existed [27]. In 1995 Paul Keyes at Wayne State University used light scattering measurements to show that the structure of BP III was macroscopically isotropic and suggested an analogy with the liquid–gas transition [28]. Shortly thereafter, Carl Garland and co-workers at MIT together with my group showed using both calorimetry and optical measurements that the BP III–isotropic transition line ended at a critical point [29]. Finally, just two years ago Thomas Lubensky and Holgar Stark at the University of Pennsylvania suggested a new order parameter for the BP III–isotropic transition and developed a theory with a liquid-gas critical point [30].

Personal Reflections

Patricia Cladis (AT&T Bell Laboratories) once showed a graph of the annual number of papers published on the blue phases as a function of time [31]. This graph is dominated by a huge and seemingly instantaneous increase in the number of papers around 1980. Horst Stegemeyer must take most of the credit for this explosion of scientific activity. Clearly he personally contributed to this flurry of papers, but much more important is the fact that his set of papers in 1978–79 woke up the liquid crystal community to the importance of investigating this fascinating phase of matter. Within the space of two or three years, conferences which had had at best one poster concerned with blue phase research now devoted entire sessions to the area. It is safe to say that if there was a spark that ignited this explosion of work, Stegemeyer was the one who provided it.

It is also important to note that theoretical work on the blue phases only began after Stegemeyer and his colleagues began to grow single crystals, and that the work done at Paderborn was crucial in confirming the theory. In addition, the existence of BP III was established due to work done in Stegemeyer's laboratory and understanding the effects of an electric field on the blue phases was aided significantly by the work of Stegemeyer and his co-workers. Due to the enormous impact he had on establishing blue phase research as an important and exciting area of condensed matter science and due to the leadership role he provided as advances were made at a dizzying rate, the name Stegemeyer and blue phase research will always be intimately linked.

I must end with a reflection concerning Horst Stegemeyer as a person. Anyone who has worked in his laboratory or discussed science with him will attest to the fact that he is a man of extremely high scientific standards. Experimental work must be done carefully and completely, difficult theoretical and experimental questions must be asked, different theoretical explanations must be explored, and new methods to obtain answers must be found. Yet behind this persona of intense scientific endeavor is one of the most kind and caring people I have ever met. He is deeply committed to the well-being of his co-workers and students, working with them not simply as scientific colleagues but as persons with day-to-day concerns and aspirations for the future. Horst Stegemeyer is always ready to help others with their work. He invites them to visit his laboratory to give lectures and even helps some of them find the funding for an extended stay in Paderborn. He gives freely of his time to help organize scientific conferences, edit and review scientific manuscripts, and provide leadership to both the German scientific community and his own university. If good things are supposed to happen to good people, then Horst Stegemeyer's career has been an excellent example of this. His scientific success has been matched by the wonderful influence he has had on all those who have had the privilege to know him.

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