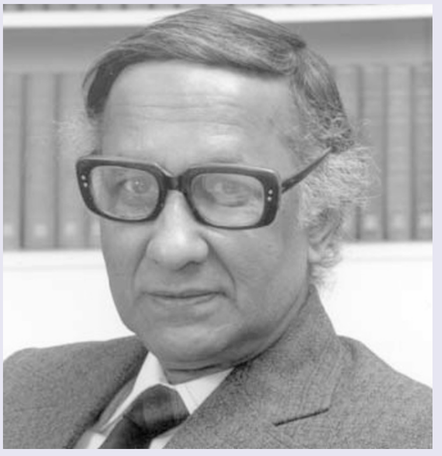
Obituary

Sivaramakrishna Chandrasekhar (1930–2004)



Discoverer of discotic liquid crystals

Liquid crystals have become the quintessential molecular materials of the modern era, used in displays that range from the size of a fingernail to wide-screen televisions. They are both liquid and crystal: their molecules have some positional and orientational order typical of a crystal, but they also behave as fluids. The development of research into liquid crystals has been due in no small measure to the pioneering work of Sivaramakrishna Chandrasekhar, known affectionately as 'Chandra', who died on 8 March.

More than 40 years ago, after postgraduate studies at the University of Cambridge in Britain, Chandra joined the University of Mysore, India, with the remit to create a school of physics. At the time, very few people, very few scientists even, were aware of the existence of liquid-crystalline materials. Chandra himself later admitted that "my knowledge of these intermediate phases was, at that time, limited to the brief accounts I had come across as a student more than ten years earlier in books published in the 1930s". Nevertheless, he was determined to change his field of research from the solid state to liquid crystals.

After a further sojourn in Britain, at Cambridge and University College London, Chandra and a few of his pupils moved in 1971 to the Raman Research Institute in Bangalore. There he established a liquid-crystals laboratory that soon became one of the outstanding schools of research in the field. It was during his time at the Raman Research Institute that Chandra made lasting contributions to research in self-organizing systems. Probably the best known was his prediction and discovery in 1977 — with two of his students, B. K. Sadashiva and K. A. Suresh — of the self-organization of disc-like molecules to form 'discotic' liquid crystals. These materials were an entirely new class of liquid crystal, quite different from the classical liquid crystals formed by rod-like molecules that had been known since they were observed by Friedrich Reinitzer in 1888. The disc-like molecules spontaneously form one-dimensional stacks, which in turn order themselves on two-dimensional lattices; the third dimension has no translational order — that liquid-like characteristic.

Chandra's discotic liquid crystals were hexaalkyl esters of hexahydroxybenzene — materials that had been around since the 1930s but whose liquid-crystal behaviour had never been recognized. It was his insight that at last illuminated the observations, and he pipped his French competitors, led by Pierre-Gilles de Gennes and J. Billard, to the post: the Bordeaux group published their work on discotic phases of hexa-substituted triphenylenes shortly afterwards.

Chandra's discovery triggered a flurry of activity in laboratories throughout the world. Since then, around 2,000 new discotic compounds have been synthesized — and a similar number of papers have been published on the physics and chemistry of such systems. Discotic liquid crystals have many unusual properties, including 'negative uniaxial birefringence' — their refractive index is different along one axis than along the other two — which makes them particularly suitable as coatings for displays. Their photoconductivity (increased electrical conductivity when photons are absorbed) has proved useful in many light-related applications: for high-resolution light scanning and xerography, solar cells, ferroelectric switches and optical storage devices, to name but a few. Light-emitting diodes constructed from discotics are characterized by a very low onset voltage for the emission of light. The onset voltage depends on the orientation of the columns, as electron mobility is much greater along the columns than perpendicular to them.

Chandra and his colleagues also made pioneering contributions through experimental studies of the effect that pressure has on the properties of liquid crystals. They uncovered a host of new phenomena — for example, pressure-induced liquid-crystal behaviour in materials that are not liquid crystals at atmospheric pressure; and, conversely, the suppression of liquid-crystal behaviour by the application of pressure. This remarkable phase of matter, between liquid and solid, was also found to have triple points in the phase diagram of single-component systems; there are gas–liquid-like critical points, tri-critical points, even multi-critical points, and critical end points.

Chandra's research also proved fruitful in the study of optically active liquid crystals, and of chiral nematic materials in particular (similar to the materials used in colour-change thermometers). He studied the propagation of light through self-organizing helical media as a function of helical pitch length, sample thickness and birefringence, and discovered a remarkable effect — the optical analogue of the Bormann effect. The Bormann effect is associated with an anomalous increase in the transmitted X-ray intensity when an absorbing crystal is set for Bragg reflection. Chandra established the existence of a similar optical effect in an absorbing chiral nematic medium in the vicinity of the reflection band.

In 1983, Chandra was elected a Fellow of the Royal Society of London, and in 1994 he won the society's Royal Medal for his discovery of discotic liquid crystals. The string of awards and medals he received throughout his career are too numerous to mention. The citation for his Niels Bohr–UNESCO Gold Medal in 1998 is typical of many, recognizing Chandra's "outstanding contributions to the development of liquid crystals, the advancement of science in developing countries and the teaching of physics".

Chandra was a great player on the international stage. He was very active in the creation and development of the International Liquid Crystal Society, which gave this multidisciplinary research community a focal point. In 1990, he became the society's first president. Today, the International Liquid Crystal Society includes chapters from 56 countries, representing more than 1,000 members. But Chandra never ceased to promote science in India. In 1991, he founded a new Centre for Liquid Crystal Research in Bangalore, which was inaugurated by K. R. Narayanan, then vice-president of India.

Those of us who knew him are saddened by his passing, but will remember him fondly. Young scientists will be introduced to his work afresh, particularly through his classic monograph on the complex subject he held dear, called simply *Liquid Crystals*.

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