UK Contributions to LCD Technology

Professor Peter Raynes, FRS, University of Oxford

The UK has an enviable reputation for its contributions to the development of liquid crystal displays to the pre-eminent position they hold as the display of choice for most articles of office and consumer electronic equipment. These contributions have been remarkably interdisciplinary, ranging through mathematics, physics, chemistry and engineering.

The first major contribution to emanate from the UK was the first ever patent for a liquid crystal display, written by B Levin and N Levin, and granted in 1936 to the Marconi company. The next major contributions, from academia, were made after some 20 years had elapsed and laid out the continuum theory of nematic liquid crystals. The static theory was developed by Sir Charles Frank in 1958, and in 1968 Frank Leslie transformed it into the dynamic theory. The continuum theory is the bedrock of the vast amount of numerical modelling of LCDs employed by the industry in the development and optimisation of the vast array of LCD modes currently available.

There then followed approximately two decades of discoveries and inventions from within a consortium of academia, industry and government laboratories which attacked the many issues with the early simple LCD technology, and laid the foundations for the multi billion dollar industry of today. This consortium was formed and guided by three wise and determined individuals: Cyril Hilsum at the Royal Signals and Radar Establishment, George Gray at Hull University and Ben Sturgeon at BDH Chemicals. The early liquid crystal materials were unstable, coloured and quite unsuitable for use in displays. In 1972 this changed dramatically when the cyanobiphenyls were invented at Hull University. These stable, colourless materials had excellent device properties and, once they had been formulated into wide temperature mixtures, they quickly became the material of choice of the LCD industry. Supplemented by the later addition of mixtures tailored for multiplexed displays, the cyanobiphenyls held dominance in the industry for more than a decade and resulted in two Queen’s Awards for Industry to the groups involved.

Two improvements of the basic twisted nematic device quickly followed from the consortium. The detailed optics of the device were understood and an equation derived which allowed the design of LC materials for thinner and superior TN devices. Secondly, early TN devices showed non-uniform contrast quite unacceptable to the consumer. The origins were traced to degeneracies in the liquid crystal alignment and techniques found to remove them. These techniques and the design of materials for the superior thin devices became industry standards still in use today.

Towards the end of the consortium two breakthroughs occurred which were key to the transformation of LCDs into the high information content displays so familiar today in mobile phones, computers and televisions. It had become increasingly obvious to all concerned that the electrode sharing technique known as multiplexing, did not work at all well for liquid crystals, and the prospects for using LCDs in phones, computers and televisions looked rather dim. The reason for this difficulty lay in the response of liquid crystals to electric fields; they respond to the root mean square of an applied field, making multiplexing and high information content displays virtually impossible. Within a short space of time two quite different ways forward were opened up and transformed the industry. The increase of the twist angle of the TN device produced a device with such a steep response that multiplexing became possible; this device attracted the name supertwist, or STN device. Secondly the long held view that electrical driving elements should be used to individually switch each pixel suddenly became a practical reality with the development of amorphous silicon thin film transistors at Dundee University. Although Dundee lay outside the consortium, the key development arose as input from within the consortium. At Dundee, Walter Spear and Peter LeComber had been developing amorphous silicon material technology, but saw the application to lie in solar cells. The consortium thought differently, and encouraged and financed the fabrication and testing of the world's first amorphous silicon TFT/LCD array. Both technologies are still in use by the LCD industry; the early dominance of the STN, which was easy to fabricate with existing technology, launched many new applications, but was soon replaced in many of these by the superior, but much more difficult to manufacture, amorphous silicon TFT technology.

Numerous developments subsequent to the consortium emanated from the UK. Chemists at Hull synthesised new LC materials which became used in the ever diversifying range of LCDs. The use of the difluorophenyl ring in the difluoroterphenyls and other materials has become widespread in LC mixtures designed for one of the LCD modes in widespread use in televisions, the Vertically Aligned Nematic, or VAN display, and its derivatives. Optical compensation films are universal additions to improve the optical performance of LCDs. Many optical compensation films incorporate materials which are derivatives of triphenylene discotic compounds with a negative optical birefringence. Ferroelectric LCDS, once seen as the white hope for high information content displays before the inevitable march of amorphous silicon TFTs, owe much to UK development. The chemists synthesised new FLC materials and the device physicists developed understanding of the devices and found ways of overcoming some key fabrication and driving issues. Recently there has been a resurgence in niche applications of FLCDs, such as projectors, SLMs and cameras.

Bistable displays which maintain an image long after the removal of driving signals had long been a goal of the LCD industry, and many options had been considered and rejected. Device physicists at RSRE, which by now had become DERA, and later QinetiQ, came up with a novel device configuration and switching mechanism known as the Zenithal Bistable Display, or ZBD. This device is truly bistable with a very attractive appearance; it is being trialled as supermarket shelf labels and has yet to reach its full potential.

Over the years the UK output of key contributions has been recognised by numerous SID awards. The lists of winners of the Karl Ferdinand Braun and Jan Rajchman Prizes, the Special Recognition Awards and SID Fellows and Senior Members contain many UK names, demonstrating the international recognition of the many contributions made by the UK to LCD technology.