Gerhard H. Buntz (Patent Attorney, European Patent Attorney, Physicist, Basel), "Twisted Nematic Liquid Crystal Displays (TN-LCDs), an invention from Basel with global effects", Information No. 118, October 2005, issued by Internationale Treuhand AG, Basel, Geneva, Zurich. Published in German.

By the end of the 1960s the management of F. Hoffmann-LaRoche AG (Roche) decided to diversify into several new areas of research and technology, among them medical technology.

The appointed head of R&D of this field identified several points of focus for future research and development activities. One topic was the improvement of displays for medical devices, e.g. by the use of liquid crystal displays. These had recently become the object of applied research by some major manufacturers of electronic components.

Liquid crystals (LCs) are organic substances combining the physical properties of liquids with those of solid crystalline materials. Unlike "real liquids", the elongated liquid crystal molecules are not totally disordered; the long axes of the nearest neighbors are ordered with respect to each other. As a result they exhibit e.g. anisotropic optical properties of "real crystals", such as optical birefringence and dielectric anisotropy, etc.

This hybrid nature of liquid crystals attracted the attention of research already in the nineteenth century. The significance of liquid crystals beyond their mesomorphic behavior (e.g. between the phases) and the potential benefits from their unusual material properties for practical applications were not realized for many decades to come. However, the rapid development of low voltage, low power consuming digital electronics and the related search for a compatible display technology started to draw attention to liquid crystals end of the 1960s.

All display devices with liquid crystals (i.e. liquid crystal displays, LCDs) share the same basic construction: a thin layer of liquid crystal material is sandwiched between two flat glass plates which are coated with electrodes for the application of an electric field. These substrate plates are either both transparent or one is transparent and the other reflective.

In 1970 the most advanced state of development of a liquid crystal display was based on an effect called *dynamic scattering* (DS). The occurrence of *dynamic light scattering* in an otherwise clearly transparent liquid crystal layer with negative dielectric anisotropy is due to molecular turbulences induced by a current flow through the layer upon application of a voltage to the display electrodes. The development of the DS effect was advanced by the US company RCA, the leading company in the field of LCD research at that time.

Even though LCDs based on the dynamic scattering effect were the first to enter a niche market, e.g. as digital displays for electronic clocks, the drawbacks of this effect for many applications were obvious. Poor optical contrast, limited life-time, energy consumption and long response times were some of the drawbacks of the DS effect.

The only potential LC alternative to the DS effect at the time was the so-called *guest-host* field effect, i.e. an effect which is not based on current flow. In this effect dichroic dye molecules (guest) which are blended into the liquid crystal material (host) change the optical appearance of the display upon application of a voltage. However, also the optical contrast of guest-host displays was insufficient.

In this situation many electronics manufacturers around the globe eagerly started to search for better display devices based on liquid crystals and other electro-optical materials. Apart from improving DS-LCDs, research for new electro-optical effects and new liquid crystal molecules started in a category of liquid crystals known as *nematic*.

In about September 1970 the researchers Wolfgang Helfrich and Martin Schadt, then working in the physics department of Roche, for the first time operated an LCD that was based on a new effect which they had just invented. This effect, which later became known as the *twisted nematic effect* is based on a layer of positive dielectric nematic liquid crystals which are uniformly aligned on both display substrates by suitable treatment of the respective surfaces. The respective uniaxial directions of molecular alignment on the two plates exhibit an angle of 90°. This induces a continuous rotation of the long axes of the liquid crystal molecules across the thickness of the LC layer, similar to spiral staircases or corkscrews. The polarization direction of linearly polarized light traveling through such a twisted LC-configuration follows the rotation of the long molecules axes and thus, the light leaves the LC-cell with the direction of polarization rotated by 90°. When such a layer is placed between two crossed (linear) polarizers we observe the following: the light which is linearly polarized by the first polarizer is rotated by the LC-cell and can therefore pass the second (crossed) polarizer. Inversely, a pair of parallel polarizers with the twisted LC-layer in between blocks the light, whereas without the LC-cell in between, light would be transmitted.

This rotary power of liquid crystal molecules for light as described above was known since 1912. Unknown, however, and discovered by Schadt and Helfrich was the electro-optical behavior of a twisted LC-layer consisting of positive dielectric nematic molecules under the action of electric fields, i.e. when a voltage is applied between the two electrodes. They realized that the capability of the twisted liquid crystal configuration to rotate the polarization direction of light (off-state) can be abolished already at voltages around 2V. Considering again a twist configuration between crossed polarizers, but now with a voltage (> 2V) applied, the light is blocked (on-state of TN-LCD). This situation is analogous to the case of two crossed polarizers without a twist configuration in between which appear black. Inversely, an activated twist configuration (voltage > 2V) is transparent when placed between two parallel polarizers, whereas without the twist configuration in between, light would be transmitted. The optical contrast of a TN-LCD between off and on-state is very large and is basically determined by the quality of the polarizers.

Therefore, a twisted LC-layer sandwiched between two substrates that are coated with transparent electrodes and placed between two polarizers acts as an electro-optical switch whose transmission can be electrically controlled. Applying a small voltage to a TN-LCD switches the cell from transparent (off) to black (on), or vice versa.

An important finding was that this effect occurs at voltages far below those required for complete unwinding of the helical LC structure. The experiments showed that it was sufficient to electrically deform the central layer of the helical molecular structure to suppress the rotation of the polarization direction of light in the helix. This finding was highly surprising and not predictable at the time.

This liquid crystal cell, Roche-internally named "Drehzelle" (twist-cell) was also being tested by Schadt in the laboratories of the company Brown Boweri Cie. (BBC) in Baden using new equipment available there. At that time there was a contract of cooperation between Roche and Brown Boveri in the field of medical technology. His results with the new equipment confirmed that the novel type of liquid crystal display featured impressive electro-optical properties while avoiding virtually all known drawbacks of DS-cells.

During the period in which Schadt and Helfrich worked on the TN-LCD a liquid crystal researcher from Kent State University (Kent, Ohio) visited the BBC labs. This visiting scientist was informed by BBC about the TN-experiments and, being a renown expert in the field himself, it was easy for him to immediately recognize the possible impact of the new electro-optical effect for liquid crystal displays. One of his colleagues in Kent, J. L. Fergason, also a well known expert in the field of liquid crystals, had established a company some months previously for the development and production of liquid crystal displays under the name of ILIXCO (International Liquid Xtal Company). In view of the commercial interests of this company the leakage of information about the new LCD being developed at Roche was most threatening.

Right after Schadt and Helfrich heard of the information leak - and since it seemed possible that ILIXCO would attempt a patent application itself - they asked the Department of Intellectual Property at Roche to prepare and deposit a patent application for the protection of the novel liquid crystal cell in a minimum of time. Within two weeks a patent application (nr. 17937/79) was finalized and filed at the National Swiss Patent Office in Berne on December 4, 1970.

Since patent applications are disclosed at the earliest 18 months after filing it was unclear for about two years which of the two parties could claim the earlier priority date. As it turned out later, Fergason had indeed filed a patent application for the identical invention in the USA, however, with the filing date of April 22, 1971.

Several days after the deposition of their patent application, Schadt and Helfrich submitted a short paper to *Applied Physics Letters* in which they introduced the new liquid crystal cell. This paper was published on February 15, 1971 and received highest attention among experts in the field (M. Schadt and W. Helfrich, Voltage Dependent Optical Activity of a Twisted Nematic Liquid Crystal, Appl. Phys. Lett. vol. 18, 127, 1971). As it turned out, this publication was for years one of the most cited papers in the scientific literature.

Before expiration of the one-year priority period, Roche filed a range of corresponding patent applications in the twenty industrial nations that were considered the most important in those days. Among them were the USA and Japan, not, however, Korea and Taiwan. In Hongkong and Singapore the granted British patent was later revalidated.

Since the examination processes of the Roche TN-patent in the different countries started at different times, a calmer period in the patenting process followed. After publication of the TN-effect many articles on the new field-effect liquid crystal display were published in professional journals, but at first, no breakthrough of the new TN-LCD technology occurred on the market.

In some countries all patent applications are disclosed and published after a period of 18 months. Among these countries were Germany, the Netherlands and Japan. For the Helfrich/Schadt patent application this was around June 4, 1972. Several days after this date Roche was contacted on behalf of a Japanese company with an offer to purchase the industrial property rights for the TN-invention. As it became known later, the company was the Seiko-Group. This unforeseen interest came as a surprise to the Roche management who had difficulties estimating the commercial value of the industrial property rights. The offer was given attention by the top-management level but a decision was postponed.

The notes of periodically meeting of the Licensing Commission of Roche of July 27, 1972 stated that the company was not interested in utilizing the invention and that the property rights could therefore be licensed. Also mentioned in the notes was the interest of the Japanese company and that "the value of the invention is difficult to assess because it is very close to the state-of-the-art." Between the lines this meant that the commission did not believe in the patenting potential of the invention.

Soon after this meeting another party expressed interest in licensing the invention. As it turned out, it was the company ILIXCO. Mainly because of a highly unpleasant visit of Fergason with his lawyer in Basel, this contact was also put on hold.

Somewhat later a first official notice was received from the US-patent office. The examiner stated that the claimed invention lacked novelty. The invention, he said, had already been described in an article by Fergason in Electro-Technology, issued in January 1970. This article does include a suggestion for improving the known guest-host effect. The article was published in the context of a review of the state of the art of electro-optical effects in liquid crystals at that time.

This supposed improvement would consist of twisting a liquid crystal layer containing (guest) dye-molecules by about 90°. This measure was supposed to better absorb arbitrarily polarized incident light by the dye-molecules within the liquid crystal layer than in the classical guest-host cell. In this way, according to Fergason, the light-absorbing input polarizer required by the classical guest-host display would be made redundant.

The examiner claimed that an expert in the field, starting from this idea and reversing the conclusion, could - simply by omitting the dyes and adding a second output polarizer – end up with the invention.

In the mean time especially the Japanese watch and electronics industries had started manufacturing TN-LCDs. Therefore, the Patent Department of Roche decided to give the twist-cell patent top priority. A range of measures was decided in order to accelerate the patenting procedure and to obtain a better assessment of the chances for successful patent protection world-wide. It was decided to immediately initiate the examination of the patent application in all countries with delayed examination procedures (i.e. DE, NL, JP). It was also decided to exploit all options for research of hitherto unknown documents describing the state-of-the-art. As it turned out, the Fergason article cited by the US examiner remained the closest documented state-of-the-art.

Highest importance was given to the response to the pending official notification of the US examiner. To this end legal, patent and scientific experts from Basel provided on-site support to the local legal representatives and visited the examiner in Washington for technical discussions. As a result, the examiner was convinced of the patentability of the application which itself could be advanced to the level of possibly being granted. At this stage the examiner declared the so called "interference" with the application of Fergason which – as mentioned above - was filed at a later date but had in the mean time resulted in a granted US patent.

The interference procedure is the result of a peculiarity of the US American patent law. In the USA a patent is not granted to the one who has filed first, as is the case in most other countries, but it is granted to the one who has first made the invention. In the case of two applications for the same patent it has to be determined who of the two applicants made the invention first. This investigation is conducted during the interference process.

Foreign applicants are at a disadvantage in this interference process because they are not entitled to resort to evidence that originates from a date prior to the day of their first application. In the present case Roche could therefore only resort to its first filing date, i.e. December 4, 1970, while Fergason had his earlier laboratory notes and the testimony of his employees at his disposition as evidence for an earlier date of the invention.

In the course of the interference process records from April 1970 emerged which indeed could be interpreted, with plenty of goodwill, to hint at a twisted liquid crystal structure and its electrical activation. Moreover, there were witness accounts stating that he had talked to his employees about such a liquid crystal cell as early as December 1969. However, there are powerful arguments against this version. Above all, Fergason would never have published that fatal article in Electro-Technology if he had really had the TN-cell in mind at that moment in time. Nevertheless, the American attorneys of Roche came to the conclusion that Roche would probably lose in an actual interference action. Based on this opinion and following the advice of the attorneys, the US American application for the Schadt-Helfrich cell was withdrawn.

However, in the USA this decision did not have any practical relevance for Roche anymore. During the interference process the economic status of Fergason's ILIXCO had changed for the worse, and he was forced to sell his US patent, which Roche could secure in an out-of-court settlement. Roche now owned both TN-patents that were competing in the interference process and could therefore renounce in the US the one with the lesser legal chances.

Roche had now a granted patent in the USA. With respect to manufacturers of LCDs in the USA this was of limited importance because most of the relevant companies had given up the production of LCDs via-à-vis the rapidly developing TN-LCD industry in South-East Asia, especially in Japan. But from a commercial point of view and because getting the Helfrich-Schadt patent granted in Japan was expected to take many years, the US patent was of eminent significance for immediate licensing negotiations between Roche and especially Japanese companies. Furthermore, the US patent served to control the import of LCDs into the US market from countries such as Korea or Taiwan were Roche did not yet have patent protection and, at the same time, as a basis for licensing to companies from these countries.

In the mean time the examination process of the Helfrich/Schadt patent had started in other countries. Among the first official notifications from countries with "substantial examining procedures" Germany, Japan and the Netherlands stated similar reasons for rejection as those of the USA. In these countries, however, Roche succeeded in convincing the examiners that a patent should be granted.

Subsequent to the patent examination follows the period of objection during which third parties, i.e. basically competitors, have the opportunity to file arguments the patentability of an invention (as outlined above, this did not hold for the US). The number of objections filed in the present case was unusually large: eight in Germany, seven in Japan and four in the Netherlands.

In Germany and Japan the Roche patent applications which had initially been successfully examined were declined during the opposition proceedings. Roche filed complaints against all rejections. In the Netherlands, the patentability was eventually acknowledged during the opposition proceedings. However, the claims were so severely restricted that the Dutch patent would have been useless. For this reason and due to the lack of another level of appeal and despite a protest by Roche this basically positive ruling had to be accepted. The Dutch application was abandoned.

The opposition proceedings extended over a period of many years, in Germany until 1977, in Japan until 1979 and in the Netherlands until 1980. The ensuing appellant processes lasted another four years in Germany and Japan and three years in the Netherlands. The ruling was against patentability in all three opposition proceedings. In the Netherlands this signified the end of legal options.

Unlike in the Netherlands the opposition level in Japan does not represent the highest authority. The case was therefore transferred from this level to the Tokyo High Court where Roche was finally successful and was granted the Helfrich/Schadt patent in 1985.

The most unconventional path to obtaining a granted patent was taken in Germany. After refusal by the notorious 21st Senate of the German Federal Patent Court (the chief judge was carried away during the hearing commenting that it could not possibly be an invention if he was able to understand the underlying physics) efforts were made to forward the case first to the German Federal Court and then finally to the Federal Constitutional Court, however, without success.

Roche envisaged a second chance in Germany thanks to an evidently unique situation in the former German patent law. As mentioned above, the intellectual property rights were acquired from Fergason. Among them was an application in Germany with US priority date. For this application the right for a delay of initiation of the examination was enlisted for a period of six years. After six years had expired an application was deposited to suspend examination of this application with the argument that the other case was still pending. As a consequence the examination was resumed only after conclusion of the other case.

As anticipated, already the first examiner rejected the application. Roche filed a complaint against this rejection. In the mean time, responsibilities had changed at the German Federal

Patent Court. Instead of the 21st Senate the 15th Senate was now responsible for the case. With this Senate the complaint was successful and Roche was finally granted the patent in Germany. This happened as late as 1992, i.e. after expiration (20 years) of the TN-patent. Nevertheless, the fact that a German TN-patent was granted was commercially significant because it provided retroactive justification for the license fees paid by German TN-LCD manufacturers to Roche.

The history of the patent of the twisted nematic liquid crystal display, which was often qualified as the 'invention of the century', illustrates how simple and obvious an invention may seem in retrospect. It's patent history also demonstrates that the benefits of such an outstanding achievement can be harvested only if strong efforts are made to achieve adequate intellectual property protection. The case also shows that applicable patent laws are hardly adequate to handle such an extraordinary situation. The case also shows that the enormous dedication and efforts that were required to eventually achieve patent success could not have been borne by a small enterprise and even less so by an individual inventor.

References

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http://www.itag.ch/fileadmin/remaco/Information/Nr_118_TNLCDs.pdf