C O N T E N T S

Cover: Millimeter thin organic light-emitting diodes could revolutionize the lighting market of the future. Schott has started a development project that is set to investigate the potential (see article page 2).
Photo: Studio Rinner

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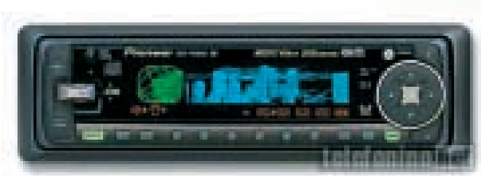
Efficiency wit

Thin, flexible, durable and energy-saving – these are the top features of high-grade lighting elements based on organic light-emitting diodes. The technological foundation for the production of large area components is being investigated in Schott research labs.

OLED – "Organic Light-Emitting Diodes" – is a relatively young technology. Although the subject of research in the display industry for some years, OLEDs have only now begun to attract attention for lighting applications. Currently the lighting market is dominated by conventional products such as incandescent light bulbs and fluorescent lamps. Where particularly bright light is required, halogen lamps are used, while neon tubes are popular for special and effect lighting. For colored lighting applications, inorganic light-emitting diodes (LEDs) are most commonly used. These offer very high efficiency and an extremely long service life, but manufacturing costs still make them expensive. They are, therefore, restricted to special applications, such as traffic lights, where reliability is of the utmost importance. The latest technologies for the manufacture of flat lighting elements with thin organic light-emitting layers provide an interesting basis for new products. Yet, to date, there are still no companies commercially active in the market segment for organic flat lighting.



One of the first commercially available products with an OLED display: a car stereo by Pioneer.

Highly Promising Technology

In 1979, while working on solar cells, the Kodak scientist Ching Tang noticed a blue emission from the organic materials he was using. Eight years later, together with his colleague van Slyke, he was able to demonstrate for the first time electroluminescence on very thin organic multilayers at low voltages of less than 10 volts. As a consequence, intense research activities were started worldwide, which resulted in the discovery of electroluminescence in polymers and led to the first applications within ten years. The display industry is showing great interest in OLEDs especially as this technology does not produce any reflections or color distortion. There are now more than 100 companies intensively involved in developing OLED technology – ranging from global players such as Sony and DuPont to Universal Display, a small company with 35 employees. "With OLEDs, the sense that a display is not just adequately functional, but also beautiful, is within grasp for the first time," says Les Polgar, president of an Eastman Kodak Co. display subsidiary in Walnut Creek, California.

Project Throws Light on Potential

Research has focused on issues relevant for displays, such as high resolution, high switching speed and a broad color range. It also appears that the technology can be used with ultra-thin large area displays. It offers light weight, flexibility, wide viewing angles, potentially low manufacturing costs and long service life, as well as a high luminous efficiency combined with relatively low energy consumption.

Partially backed by government funds, Schott has started a joint project with partners from industry and science to carry out research into the fundamentals of manufacturing flat and thin lighting elements using conductive light-emitting layers with thicknesses in the nanometer range. The researchers will

h Electroluminescence

OLED-Displays

Obvious benefits:

- Flexible, especially for polymers
- Lightweight
- Efficient/energy-saving
- Large-area lighting
- Ideal emission characteristic (virtually 180°)
- Any color can be achieved
- No color distortion with change of viewing angle
- Transparent if required
- Potentially low manufacturing costs
- Very bright
- Long-life

Schott components which illustrate the typical OLED properties for displays and lighting systems.

also investigate materials and combinations of materials for higher efficiency and longer service life while looking into the feasibility of the technology base itself.

Implementation of the research results could very well improve the technology to such an extent, that it could also be used for traditional lighting products, thus significantly expanding the market volume for OLEDs. However, the individual process steps still need to be investigated intensively before the attractive market potential can be tapped. The project is scheduled for three years. Depending upon the technological results, a business plan and production on a pilot scale will follow.

Coating Technology Decisive

The one-dimensional compactness of the lighting technology represents a considerable competitive advantage compared to conventional solutions. Very thin organic layers (polymers) in the nanometer range are applied to large area substrates. The coating process therefore plays a key role in the technology. The research will look into achieving a high material yield while using recyclable materials to the extent possible.

A further advantage of OLED applications for large area lighting is the possibility of manufacturing components with higher efficiency. Although efficiencies already exceed those of incandescent light bulbs, alternative materials are to be

Equipment for the investigation and use of the new technology. The processes are carried out under clean room conditions and in an inert gas atmosphere.

investigated intensively. It appears that the OLED technology could reduce energy usage to a third of that required with classical lighting.

The organic materials are produced by the German-based companies Covion and Bayer.

Schott's broadly faceted research and development activities build a solid foundation for the joint project. The company possesses extensive knowledge on substrates, structuring and cleaning as well as processes for the coating of large areas. Schott is experienced in applying inorganic coatings using a very wide variety of techniques such as dipping, spin coating, screen printing and various PVD and CVD processes. With this know-how, a large number of product developments have been achieved in the lighting and photonics fields, leading to increasing market shares for Schott in these areas. Schott is also very capable in encapsulation, test and analysis procedures. Staff with expertise in OLED technologies has recently been hired to broaden the company's technology base, with plans for future expansion. To pursue these R+D activities, Schott set up a clean room laboratory on an IBM site in Hechtsheim, a suburb of Mainz. At that site it is possible to coat large areas with organic matter under inert gas atmosphere.

Promising Future

The prognoses for OLED displays are highly promising, although there are only a few products currently on the market. Pioneer has marketed a small display for car stereos on a trial basis and Motorola has introduced a cellphone in the United States with OLED displays manufactured by Pioneer. Sony has announced that it will be launching a 15" OLED display in 2003. Despite the relatively small number of current products, sales figures of 5 billion dollars in 2005 are already being forecast for the OLED-based "new display" technology (Source: Stanford Resources and Handelsblatt Feb. 27, 2001).

Detailed research into the OLED lighting market is not available. At the beginning of 2001 the United States Display Consortium (USDC) of San José, California included lighting with OLEDs in its OLED road map. Discussions with possible customers have shown that there is a great deal of interest in this innovative idea. An increase in market acceptance is foreseeable, says Schott project manager Dr. Klaus Bange, who expects further increases in efficiency, coupled with a reduction in the material costs for the organic substances as well as the development of coating processes which use materials more economically. On the basis of these assumptions the market volume for the OLED lighting sector for 2005 is estimated at some 100 million euros ■

Competent Partners

The investigation and use of the OLED technology is highly complex and calls for partners with very varied capabilities. The joint project incorporates companies and universities with complementary qualifications and know-how.

Schott: Thin-glass substrate and lighting know-how, large area coating processes, analysis, measurement.

University of Potsdam: Electro-optical properties of conjugated polymers, polarized electroluminescence.

LMU Munich: Organic π-conjugated materials for photonics, OLEDs with crosslinked hole injection and hole transport layers.

Max Planck Institute for Polymer Research: Assembly of ultrathin organic and polymer films with controlled supramolecular architecture, development of linear, non-linear and integrated optical techniques.

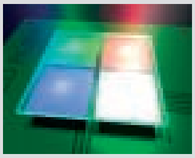
Technical University Braunschweig: Organic semiconductors, small molecule based OLEDs.

Bayer AG, Leverkusen: Baytron P, a conductive polymer for hole injection, small molecule based transport materials and emitters.

Covion Organic Semiconductors GmbH, Frankfurt: Only plant worldwide for the manufacture and formulation of organic semiconductors for display applications.

In the manufacture of components the solutions (above) are applied by spin coating on ITO coated glass substrates (right). The films deposited in this way have thicknesses in the nanometer range.

Light-emitting Polymers



An OLED consists of a substrate, a transparent electrode, one or more thin organic layers and a counter-electrode. This structure is protected through encapsulation, since both the organic layers and also some of the electrode materials are very sensitive to oxidation and react adversely with moisture. The substrate is glass as a rule but plastic films and glass/plastic laminates are also conceivable. A good diffusion barrier against oxygen and moisture is important here too. The transparent anode is ITO (Indium Tin Oxide) or similar oxide compounds.

An OLED functions much like an inorganic LED and is based on injection electroluminescence. The four elementary processes in an OLED are: the injection and transport of electrons and holes, the formation of electron-hole pairs and the radiative recombination of the charge carriers. When the applied voltage between the electrodes is high enough, charge carriers are injected into the organic layer. Under the influence of the electrical field, the injected charge carriers move to the opposite electrode. If electrons and holes meet, an electron-hole pair (exciton) can be formed, which can recombine radiatively and emit light. The emission spectrum and thus its color are determined by the energy of the exciton and thus by the organic material used. The spatial extension of the recombination zone depends on the mobility, the diffusion length and the energetic conditions, such as for example internal barriers. For high efficiency OLEDs the processes mentioned above must be synchronized with each other ■