Organic LEDs

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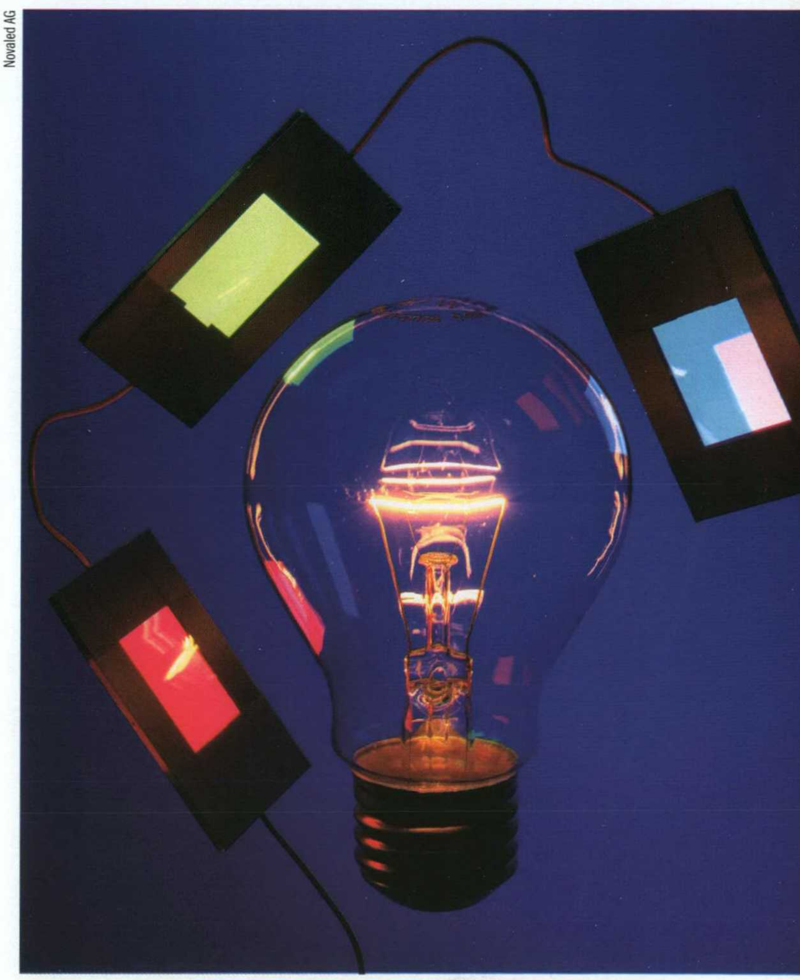
Modern times have us so accustomed to technological progress that we take it entirely for granted. Nevertheless, a real revolution in lighting technology now lies just around the corner

Born in a world where electric power is a natural part of everyday life, it comes as quite an unpleasant surprise when our power supply is suddenly cut off. Our civilization is so thoroughly dependent upon this energy source that occasional blackouts, sometimes depriving millions of people of power, are perceived as great catastrophes. Without a doubt, electric power was one of the greatest driving-forces behind the advance of civilization in the 20th century. Yet when someone enters a dark room and switches on the light nowadays, are they aware of the fact that people have only been performing such an operation for not quite 130 years? Humans have longed to overcome darkness since the dawn of time, but it has only been recently, in terms of the scale of mankind's history, that they have been able to battle darkness with any tool other than fire. Few people realize that the rivalry once underway between the formerly widespread gas-based lighting methods and the then emerging technology of electric lighting encouraged the development of a light-source model, which in turn led in the late 19th century to quantum theory and a revolution in physics, thus exerting an impact on every sort of technology we now use in our daily lives.

The light bulb as we know it today is the product of efforts made by several generations of researchers, above all in seeking the right filament material (Edison alone tested some 1,600 materials, and tungsten only came into use in 1890). Although it was understood from the outset that such bulbs are highly inefficient, the light generated accounting for only a few percent of all the electricity consumed and the rest being transformed into heat, they nevertheless brought mankind to a revolutionary turning point: being able, for the very first time, to generate light without combustion or fire. In the early 20th century, it was realized that light emission was a consequence of atoms or molecules switching from a higher to a lower energy state, and that every light source involves a mechanism whereby the atoms or molecules of the emitting substance are excited. Here the light bulb is not any different from combustion-based sources: in both cases, light is emitted by atoms or molecules that become excited by high-temperature thermal movement. Discharge lamps (such as fluorescent lamps) were the first technology to use a "cold" method of populating exited states, harnessing the energy of atom-electron collisions and making it possible to design much more efficient, lower-temperature lighting. Employing the recombination of solid-state charge carriers (initially in semiconductors) to populate exited states opened up new possibilities in light generation, offer-



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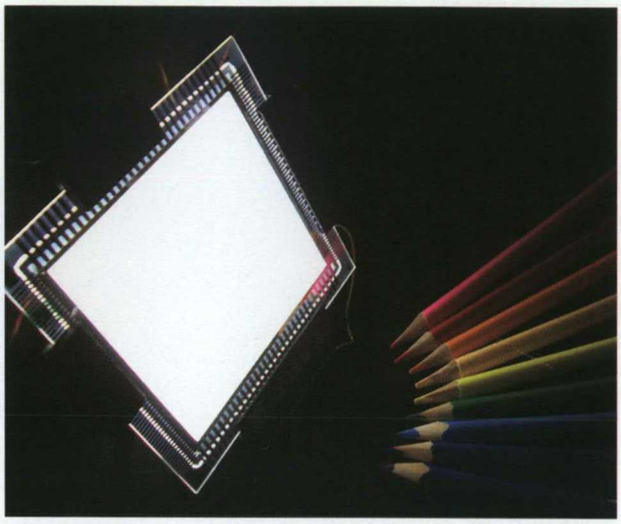
OLEDs can be made in every color, including warm and cold white. These flat and energy efficient devices are soon to replace our well-known light bulbs


Merck OLED Materials GmbH

Feedback from material and device tests is essential for the development and synthesis of new OLED materials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A white lab-scale OLED prototype measuring 7x7 cm^2

ing hope for low-voltage, high-efficiency lighting elements. Initially the main obstacle to the use of semiconductor diodes for producing light was the lack of diodes able to produce white light, but with time progress in creating light-emitting diodes (LEDs) overcame this barrier as well.

OLEDs – a revolution in the making

Yet a true explosion of new lighting devices with unprecedented properties and applications now lies just around the corner, with the emergence of organic light emitting diodes, or OLEDs. OLEDs are an attractive new class of light sources based on stable organic substances, where the flow of current gives rise to charge carriers (negative electrons and positively charged "holes") and light is emitted as a result of their recombination. The basic distinguishing feature of OLEDs is their spatial extensibility, which enables light sources to be created that have a very broad surface area, are flexible and resilient to mechanical stresses if a polymer base is used, and also offer a vast range of color choices.

OLED technology is currently a subject of intensive research in Europe, the US, and Japan. In view of the high costs involved, such research is being pursued under a handful of initiatives and programs that group together commercial companies and research institutions. Such concentrated, close-knit cooperation is essential for success, because the production of organic diodes requires very technologically advanced hardware, such as high-vacuum equipment for thin film deposition, which is only possessed by big companies such as Philips or Siemens.

In technical terms, an OLED diode represents a quite complicated system of many very thin layers of various materials situated between electrode layers (one of which is transparent); this system emits light when placed under electric potential. The type of material used as the light emitter determines the specific characteristics of such devices, and here OLEDs employ stable organic substances. The hue of the emitted light depends on the component materials employed. White light is obtained by mixing the light from three layers, each one emitting one of the primary colors: red, green, and blue. The mechanisms and principles of OLEDs operation have already been explored quite well, and the main research effort is now (like in Edison's era) being directed toward finding new materials to make devices more efficient and more universal. The rapid advance of organic chemistry and materials science over the past decade has given rise to a vast number of new functional materials produced with such new applications in mind. However, a single glance at the OLED field makes it clear that this is just the beginning, and that the future holds much in store. The history of technological progress teaches us how obstacles can be overcome.

Cooperation is the key

In recent yeas, OLED technology has reached such a level that we may already presume that organic diodes are destined to become the next light source to gain widespread use, after light bulbs, fluorescent lamps, and compact fluorescent lamps. For that to happen, further progress still needs to be made in improving their efficiency, durability (up to at least 10,000 hours), and brightness (above 50 lumens/watt). Also needed are white light sources of various hue temperatures, plus highly efficient OLED production processes. These are the objectives set for the integrated R&D project entitled OLLA (Organic Light Emitting Diodes for ICT & Lighting Applications), which brings together 24 leading European companies and research centers working with organic electronics, lighting materials and devices. The project's overarching goal is to develop, and to present by 2008, high-brightness white OLED segments intended for general lighting purposes meeting the technical parameters listed above.

The OLLA project encompasses all the fields that are essential for OLED technology, including studying the processes and materials used in organic diodes. Fundamental research under the project focuses on several methods for generating white light. The applied research being pursued in parallel aims to tailor the technological development to better meet the needs of future users. Another separate set of measures, encompassing training programs and efforts to popularize awareness of OLEDs as a potential light source, are directed towards lighting designers, architects, and others.

OLLA is one of the world's largest joint research projects for developing white OLEDs, and is partially funded under the IST (Information Society Technologies) priority of the Sixth EU Framework Programme. Having the most technologically advanced lighting manufactures involved in the same program together with front-running research institutions in the field paves the way for parallel progress in terms of work on developing new materials, new devices, and mass production technology, as well as laying the groundwork for transforming OLEDs into a commercially viable lighting technology. The OLLA project dovetails with similar initiatives and programs being pursued on other continents, such as the Next-Generation-Lighting Initiative in the United States and the Lighting 21 program in Japan.

From the scientific point of view, the most crucial elements of OLEDs are the organic substances capable of emitting light when placed under electric potential. Aside from a large number of organic molecules, potential emitters are also being sought among metal complexes from the lanthanide and platinum groups, as well as complexes of boron and zinc, cadmium, copper silver, aluminum, and gold ions. Metal ions are usually surrounded by carefully selected ligands - chemical compounds from the group of heterocyclic derivatives. Several research groups within the OLLA project are working with metal ions of the lanthanide and platinum groups. The sole Polish team involved in the project, led by Assistant Professor Marek Pietraszkiewicz from the Laboratory of Spectroscopy and Photochemistry, Institute of Physical Chemistry, Polish Academy of Sciences, is investigating the synthesis and spectroscopy of light-emitting complexes involving europium. These complexes ensure the transfer of energy from the excited state of the ligand to trivalent europium ions, which emit red light within several narrow spectral bands. The significant challenge that lies ahead for those researching the chemistry and physical chemistry of europium complexes is to obtain the highest possible light emission within the red zone - something that represents no easy task. It requires the design of organic ligands whose electron energy levels ensure the optimal flow of absorbed energy from the ligand to the emitting energy level of the europium ions. While other red light emitters, such as organic iridium complexes, display significantly stronger light emission than europium complexes, they are relatively unstable and significantly more expensive than europium compounds, and moreover they do not emit monochromatic light. Besides this, their emission spectrum stretches into the near infrared range, which entails a loss of energy in the form of emitted heat.

The OLLA project is administered by a team of managers from Philips. Aside from the project website (www.olla-project.org), which acts as the communications hub of the project and offers a lot of publicly accessible information, the free flow of information among project participants is facilitated by the groove.net environment, which enables work to be carried out online, as if everyone was together in the same office. Report paperwork has been simplified and does not constitute a great burden. This style of management is worthy of emulation for other projects as well.

The OLLA project also encompasses intensive educational and training efforts, including workshops for consortium members, working visits, and also conferences and summer schools. The latter are likewise accessible to participants from outside the project. In September 2005, the Institute of Physical Chemistry of the Polish Academy of Sciences, organized the first of three successive summer schools schelduled for 2005-2007. The next, devoted to what are called triplet emitters from the platinum group, was held in Kutryn on 26 May - 2 July 2006 (http://ichf.edu.pl/summer_school2006/index.html). The topic of the third OLLA summer school, to be held on 18-25 June 2007, will be thin molecular films and their technological applications. ■

Further reading:

www.olla-project.org
summerschool.olla-project.org

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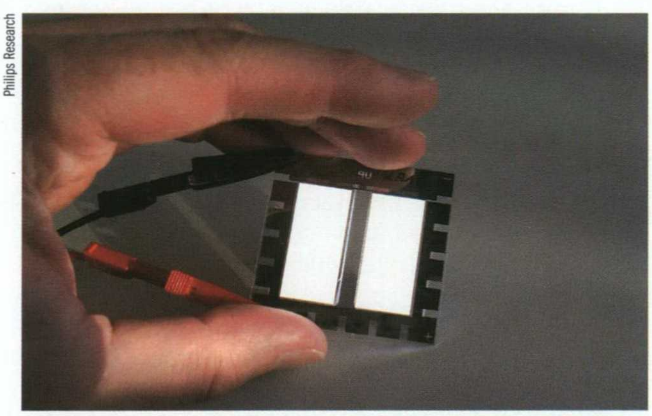

**Optics are playing a major role in OLED efficiency.
Only 25% of the light generated is coupled out in the forward direction if no outcoupling enhancement is used**