Illuminating the night with sunlight

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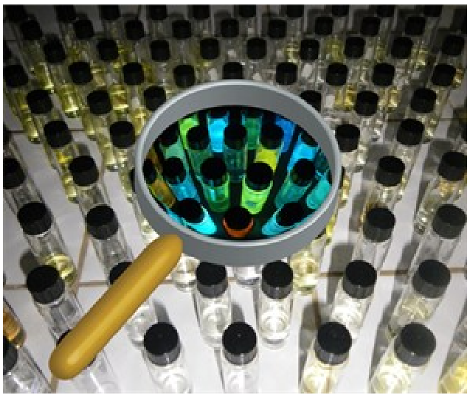


What would you do without artificial lighting? On beautiful summer days like we had recently, the question may be only rhetoric. However on gloomy winter days you may feel differently: ever tried not turning the lights on when you enter your office in the morning, or when you arrive home? Depressing, isn't it? It gets worse when you realise that your TV, computer screen, and smartphone all use an artificial lighting source. Try turning them off—it's easy to see how reliant we have become.

Even our *homo erectus* ancestors benefitted from the original artificial lighting—fire. Mastering fire allowed the illumination of caves and therefore the development of civilisation by enabling people to paint on the walls and stay up to tell stories and transmit knowledge. Illumination brings with it innumerable benefits, but it's easy to forget how prohibitive life without light is, and it's sad that there are still people in the world that can testify to that reality.

From a wood fire to the organic bulb

Skip forward a few hundred thousand years and the advent of electricity and the development of the incandescent light bulb, which took a century to reach commercialisation from the first demonstration by the English chemist Humphry Davy in 1802, marked an explosion in the use of artificial lighting during the 19th and 20th centuries. Nowadays, almost 20% of the worldwide production of electricity is solely used for lighting, which is about 9% of the global energy consumption. However, as an incandescent light source, most of the light produced with such bulbs is in the infrared, that is heat, and therefore not very useful for reading a book at night. As such, 90% of the energy used for lighting is directly wasted as heat; that's a staggering 8% of the global energy consumption wasted.

Improved efficiencies are achieved with fluorescent lamps at the expense of the quality of lighting (you would have experienced that "horrible lighting" feeling) and the safety of lighting (these lamps contain a significant amount of mercury). Even better efficiencies are obtained with electroluminescence (the conversion of electricity into light), which allows 100% internal efficiency. The principle is based on a semiconductor sandwiched between two electrodes: when the device is switched on, current flows through the semiconductor and electron and holes can recombine to form an exciton, which produces a photon when decaying. These Light-Emitting Diodes (LEDs) are based on inorganic semiconductor, but it is possible to replace the inorganic materials with an organic semiconductor, resulting in Organic LEDs, or OLEDs.

Advantages are numerous, mainly due to the possibility of printing such devices on lightweight and flexible substrates. Furthermore, OLEDs are flat light sources in contrast to the other aforementioned technologies which are point light source. This opens tremendous new opportunities for architectural design using discreet lighting panels instead of obtrusive bulbs.

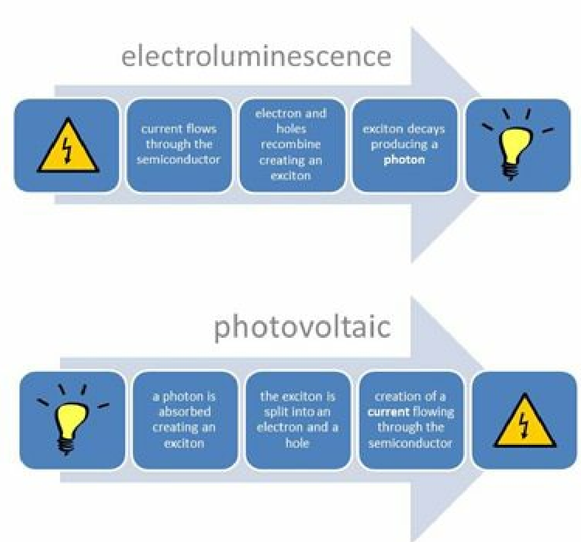
Whilst OLEDs are very successful for display applications, there are problems for indoor lighting. In particular the economic and energetic cost of fabrication is steep because of the use of a high vacuum deposition chamber and multilayer architecture, which thickness should be controlled to the nanometre on large areas.

A different electroluminescence technology is the Light-emitting Electrochemical Cell (LEC). Here a single layer of a semiconductor containing mobile ions is sufficient to produce light. The ions rearrange under an electric field and form *in situ* a multilayer architecture, meaning there is no need for complex and costly fabrication processes: LECs are considered a low-cost alternative to OLEDs, particularly suitable for large area lighting. Still, many issues concerning the practical stability and efficiency of the device have yet to be solved, and, as a chemist, this is where I have my part to play by designing, preparing, and providing new materials with enhanced properties, which hopefully will translate into devices with enhanced performances.

Harnessing nature

So what about the sunlight mentioned in the title? Besides developing more efficient devices to reduce our energy consumption, another aspect of the Energy challenge faced by human kind is to find renewable approaches to its production. The most obvious free source of energy is sunlight, which is already the primary source of energy used by Nature to sustain all life on Earth through its conversion to chemical energy by photosynthesis. And consider this: the amount of sunlight reaching Earth in ten minutes is equivalent to the annual worldwide consumption of energy. Photovoltaic technologies (converting light into electricity) have been developed to harness this virtually infinite energy source and transform it into electricity, but there is still some way to go.

Whilst electroluminescence turns electricity into light, photovoltaic processes do the opposite: absorption of a photon creates an exciton, which should be separated into an electron and a hole in turn collected at electrodes to create a current. The great similarity in principles between electroluminescence and photovoltaics makes research in both areas very complementary, almost symbiotic.



But of course there is a trick: one cannot directly illuminate the night sky with sunlight and it is necessary to store the photovoltaic energy produced during the day and distribute it at night. Thankfully there are many good people already working on these areas at the University of Birmingham, ensuring the lights remain on for our cities, homes and portable devices, making it possible to continue to tell stories, transmit knowledge, and ultimately advance civilisation as our ancestors did before us. Not quite such a humble bulb after all.

Further reading

In collaboration with scientists from Spain and Switzerland, Dr Baranoff published a paper in June 2013 discussing a critical breakthrough for electroluminescence with LECs enabling sustained high efficiencies at high luminance instead of peak high efficiencies at low luminance only. **Click here to read the paper (http://dx.doi.org/10.1002/aenm.201300284)** (please note, this is a pay-per-view journal).

For more details on OLEDs and Organic Solar Cells, **please follow this link (http://photonicswiki.org/index.php?title=Main_Page#Organic_Light_Emitting_Diodes)**.