On a roll with inorganic LEDs

An international team of researchers claims to have overcome the limitations of creating printed interconnected arrays of ultrathin and ultrasmall inorganic light-emitting diodes (ILEDs) for deformable and semitransparent lighting displays.

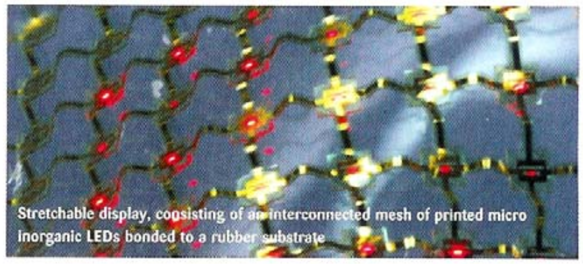
They say their epitaxial growth and printing techniques could pave the way for combining the performance of ILEDs with the thin film production techniques used for organic devices on bendable substrates such as glass, plastic and rubber.

Professor John Rogers at the University of Illinois, USA (one of the institutions involved), explains, 'Inorganics are very bright, efficient and long lived, however, they are currently produced using wafer sawing, robotic assembly and bonding with bulk wires. These procedures are cumbersome for systems that require a large number of LEDs – they are unsuitable for small and/or thin devices'.

The team has achieved arrays of gallium arsenide LEDs with thicknesses of about two micrometres and lateral dimensions of 10x10µm (100 times smaller than conventional devices).

The production steps involve building epitaxial semiconductor multilayers on a wafer, with a 'sacrifical layer' underneath. When ILED fabrication is complete, a wet chemical etchant removes this film, leaving the ILEDs undercut, each anchored to the wafer by polymeric structures. An automated printing tool brings a rubber stamp, which is embossed with corresponding relief features, into contact with the wafer at selected points. This fractures the anchors and lifts a large number of LEDs for application onto the chosen substrate. The latter is coated to ensure adhesion.

By repeating the stamping process, ILEDs can be transferred to other locations on the same material, creating dense arrays or positioning them far apart for near transparent panels. Interconnection is achieved by conventional deposition of metal films, eliminating the need for bulk wire bonding. Ohmic contacts are established for improved performance through metallisation and annealing. Over 90% of the pixels function, which is potentially suitable for applications such as biomedical imaging devices and wearable health monitors.


Stretchable display, consisting of an interconnected mesh of printed micro inorganic LEDs bonded to a rubber substrate

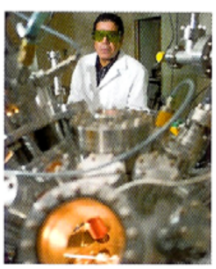
The structures created can bend to a radi of ~7mm, with no fracturing of the active materials or degradation of properties, claims the team.

Furthermore, 'anchoring, as we refer to here, is totally new', says Rogers. The anchors are engineered to hold the LEDs in their defined locations during undercut etching and drying, but are also fragile enough for removal for printing. They contrast to anchors used for transistors and solar cells that are usually made from the edges of the devices themselves.

Gareth Jones, Chief Technology officer at Enfis, a designer and manufacturer of LED light engines, based in Swansea, UK, says the work is 'ground breaking. If [it] can be extended to gallium-nitride (GaN)-based LEDs, then it could lead to ultra-low cost, wide-area lighting to compete with organic LEDs, given the expected improvement to the cost of ILED emitters over the next three to five years. Likely limitations will be ensuring that heat can be conducted away from the chip efficiently for higher luminous flux applications'.

The technology is being applied to GaN devices, with attempts to make the LEDs smaller and to integrate drive electronics on the same substrate. It has been licensed to a venture-based startup for commercialisation. 'The ability to distribute lots of small LEDS and interconnect them all at once, using a type of planar processing, are key to the low cost,' explains Rogers.

Rupal Mehta


Nuclear engineer Ahmed Hassanein at the Purdue University Laboratory, USA

Nanofabrication gets a boost

- **The methods used to create thin plasma lines in fusion energy are being adapted for nanolithography. Nuclear engineers at Purdue University and Argonne National Laboratory, both in the USA, are working to improve the efficiency of two plasma-producing methods – one using a laser and the other a discharge-produced method that employs an electric current – as only one to two per cent of the energy spent is converted into plasma. This research could solve the design problems of creating 'extreme ultraviolet light' with a wavelength of 13.5nm, less than one tenth the size of current lithography.**
- **The Nanofabrication Centre at the University of Southampton, UK, is open for business. The team behind it believes the facility could enable manufacture of high-speed and non-volatile universal memory devices for industry within five years.**
- **A so-called 'nano pen' could provide a quick and convenient way of laying down patterns of nanoparticles for electronics. Inventor Ming Wu and colleagues at the University of California, Berkeley, USA, say their instrument overcomes the slow speed of previous techniques. It makes use of photoconductive surfaces, and manufacturers can adjust the size and density of the patterns by varying the voltage, light intensity and exposure time applied.**

Patterning carbon nanotubes on polymer substrates

Direct and controlled assembly of single-walled carbon nanotubes (SWNTs) on polymeric substrates has been achieved, say researchers at Northeastern University, USA. They believe this is the first wafer-scale process, and could open up applications in interconnects, transistors and sensors. The scientists exploit the surface energy differential between a plasma-treated hydrophilic parylene-C surface and a hydrophobic photoresist to create microscale patterns of SWNT networks using dip coating. The advantage of the parylene-C substrate is that once treated with oxygen plasma, it maintains its hydrophilic property long enough for patterning. This overcomes the low surface energy of other polymeric substrates, which have traditionally made direct assembly on a hydrophobic substrate difficult.