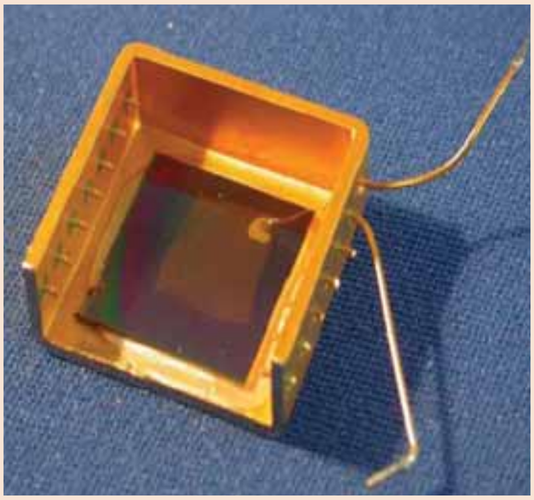
Nanocrystal diodes for medicine

NANOTECHNOLOGY

Considerable research time has been dedicated to designing light-emitting diode (LED) devices that can be applied in biomedical diagnostics and medical devices; the holy grail has been to produce them cheaply and so that they can be integrated into existing technologies. Now a new study, by scientists at the Los Alamos National Laboratory and colleagues at the University of Milano–Bicocca in Italy, has pushed back the boundaries of nanocrystal science by producing a new glass-based, inorganic material that can emit light in the ultraviolet spectrum and be integrated onto silicon chips common in most electronic technologies.

The team, whose work has been published in *Nature Communications* [Brovelli *et al.*, *Nature Comms* (2012) doi: 10.1038/ncomms1683], developed a process for creating such nanocrystal LEDs that produce light in the ultraviolet range and have the potential to become implantable products. It is hoped that the devices could be fabricated cheaply and robustly, and be sufficiently scalable for use in activating specific light-sensitive drugs to improve medical treatment, as active components of wearable health monitors and even for identifying fluorescent markers in medical diagnostics.



The nanocrystal device.

The new synthesis strategy allows for the production of the LEDs through a wet-chemistry approach involving simple chemical reactions, and which emits in the ultraviolet range due to how the nanocrystals are embedded in the glass. The devices have both chemical inertness and the mechanical stability of glass, as well as having electric conductivity and electroluminescence, allowing them to be utilized in difficult environments, including in bodily implants and immersion into physiologic solutions.

With regular LEDs, the light emission occurs at the interface between two semiconductors; however, with this design the material is produced to act as an ensemble of semiconductor junctions distributed in the glass, with the active part consisting of tin dioxide nanocrystals that have been overlaid with a shell of tin monoxide embedded in standard glass. When the thickness of the shell is tuned, the electrical response of the whole material can be manipulated. Incorporating the tin dioxide nanocrystals in silica has been useful for the research, and required the design of new synthesis routes starting from molecular precursors. This was achievable because the solubility of tin in silica is so low that the use of conventional melting processes results in the complete precipitation of tin. The group therefore designed a modified sol–gel synthesis procedure that allows for the controlled segregation of tin oxide nanocrystals in a glass matrix.

The next task is to optimize the material and device structure, crucial to moving from proof of principle to practical application, and they are also looking to exploit the other features of the nanostructured glasses, such as its photorefractivity. The team feels that the oxide-in-oxide motif is only a small part of its potential, and plan to explore how the concept can also be applied to other materials of different structure and composition.

Laurie Donaldson

Refuting the Shuttleworth equation

SURFACE SCIENCE

For over 60 years it has been believed that there is excess surface tension on a solid material in a similar way to that on a liquid, as described by the Shuttleworth equation. However, in 2009, two Finnish scientists, Lasse Makkonen and Kari Kolari, and a British colleague, David Bottomley, presented a paper in the journal *Surface Science* that claimed the long-held equation about the relation between surface tension and surface energy on an unstrained solid wasn't actually compatible with thermodynamics, which provoked a fair amount of controversy in the field.

Now Lasse Makkonen, a researcher at the VTT Technical Research Centre of Finland, has published a study in *Scripta Materialia* [Makkonen, L., *Scripta Mat* (2012) doi: 10.1016/j.scriptamat.2012.01.055], which has returned to the subject to revise our understanding of surface tension on solids, claiming that this finally closes the debate on the applicability of the equation. His new study has mathematically shown that the Shuttleworth equation reduces to the definition of surface tension derived from mechanics, and that surface tension on a solid material is unconnected to the energy needed to create a new, unstrained surface. Consequently, the excess surface tension on a solid does not really exist as we usually understand the concept.

In showing mathematically that the Shuttleworth equation reduces to the definition of mechanical surface stress, Makkonen argues instead that the existence and nature of surface tension on a solid should only be assessed by molecular dynamics at the surface layer.

As a geophysicist by background, Makkonen originally came across the Shuttleworth equation in a book on applied surface thermodynamics in 1998, thinking then that there was a potential problem with the equation. He returned to the problem in a 2002 study and then again later when he realized that he was not the only one to have doubts about the veracity of the equation. As he points out, his new paper is intended to "remove from people's mind the false analogy between the surface tension of a solid and that of a liquid. In fact, in the traditional sense, surface tension does not exist on a solid, and this is important to understand conceptually."

Makkonen hopes that this development will be useful in achieving a better understanding of phenomena in micromechanics and electrocapillarity, and perhaps lead to new interpretations of some microelectronic measurements, thus improving the measurement technology in that field. He now expects to leave such problems of surface stress to others, and return to his usual role in researching the use of thermodynamics in modeling micro- and nanoscale phenomena.

Laurie Donaldson