

LIFE-CYCLE ASSESSMENT

Should graphene replace ITO?

J. Clean. Prod. <http://doi.org/4rn> (2015)

The current standard material for transparent electrodes in liquid-crystal displays for smart phones and other devices with transparent screens is indium tin oxide (ITO). Owing to the chemical instability of ITO, and the high cost and scarcity of indium, graphene has been proposed as a potential substitute. However, it remains unclear how such a substitution will impact energy use and metal resources. Rickard Arvidsson and colleagues at Chalmers University of Technology in Sweden have now shown that replacing ITO with graphene may be beneficial because energy use during graphene production could be lower than that during ITO production. The substitution may, however, bring about other effects.

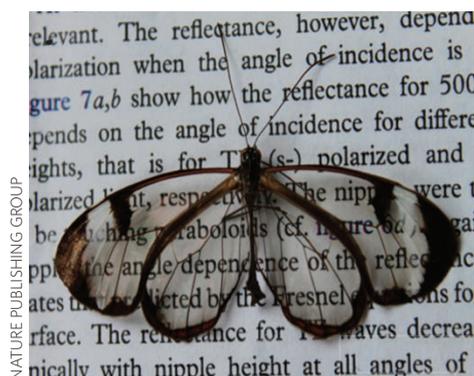
The researchers used the well-established life-cycle assessment method to examine the energy and scarce metal requirements of producing a graphene electrode by chemical vapour deposition and compared it with the production of ITO. During chemical vapour deposition, to form graphene on a catalytic surface such as copper, an excess of methane gas is heated, and the study found that methane use is the main contributor to energy consumption during graphene production. Comparing global reserves, indium and tin are likely to be scarcer than copper. The researchers suggest that while copper availability is unlikely to restrain graphene production — even though the use of copper during graphene production is about 300 times higher than the use of indium and tin in ITO production — current copper

consumption is unsustainable. Depending on whether replacement of ITO with graphene will increase the use of liquid-crystal displays or contribute to other new graphene-based technologies, net energy use in society may increase or decrease. *ALC*

BIOLOGICAL NANOSTRUCTURES

Transparent randomness

Nature Commun. **6**, 6909 (2015)



Some insects have photonic nanostructures on parts of their body that can, for example, produce structural colours or achieve transparency for camouflage. One such insect is the glasswing butterfly *Greta oto*, which has wings that are mostly transparent, with low reflectance of a few per cent across the visible spectrum and for viewing angles up to 80°. The regular arrangement and size of nanostructures on the surfaces of certain insect's eyes or wings is responsible for their antireflection properties. Hendrik Hölscher and colleagues at the Karlsruhe Institute of Technology have now revealed that the origin

of the transparency of the wings of *Greta oto* is instead linked to the irregular properties of nanopillars found on the wing surface.

The researchers found that the nanopillars are irregularly arranged with an average spacing of 120 nm and have random heights in the range of 400–600 nm. They proved that randomness in the arrangement and size of the nanopillars is the cause of the omnidirectional antireflection properties of this butterfly's wings by simulating the optical properties with an analytical model that includes a Gaussian distribution of the nanopillars' height. *ED*

NANOCRYSTALS

Surprise magnetism

Nano Lett. <http://doi.org/4qd> (2015)

For a material to be magnetic, it would be expected to have magnetic atoms inside. In nanostructures, however, magnetism can also arise from nominally non-magnetic atoms. For example, Anna Rodina of the Ioffe Physical-Technical Institute in St. Petersburg and Alexander Efros of the Naval Research Laboratory in Washington have now suggested that large magnetization can arise in CdSe nanocrystals due to the spins of atoms on their surface.

The optical properties of nanocrystals are not fully understood, and the observation of thermally activated light emission has not yet been fully explained. In a standard optical experiment, light excites electron–hole pairs, or excitons, which are divided into two categories. In bright excitons, the electron and the hole have opposite spins, and these can recombine and emit light. In dark excitons, the spins are parallel, and can only recombine and emit light if the spin of one of the charges is first flipped.

According to Rodina and Efros, it is the interaction of the dark excitons with the spin of dangling bonds on the nanocrystal surface that determines the temperature dependence of the light emission. Their theory shows that at temperatures higher than the observed critical value, the spins of the dangling bonds have a high thermal energy and are randomly oriented. Interaction with the dark excitons leads to a spin-flip event, so that dark excitons can contribute to light emission. Below the critical temperature, however, the spins of the dangling bonds align along the same direction. As a consequence, the spin-flip events are much rarer and the contribution of dark excitons to light emission is quenched. Furthermore, the alignment of all the spins creates a magnetic polaron — a collective magnetic state that is extended to the whole colloidal dot. *FP*

Written by Ai Lin Chun, Elisa De Ranieri, Alberto Moscatelli and Fabio Pulizzi.

METAL-ORGANIC FRAMEWORKS

A flexible recipe

Angew. Chem. Int. Ed. **54**, 6152–6157 (2015)

Metal-organic frameworks (MOFs) are three-dimensional highly porous solids composed of metal ions connecting short and mostly rigid organic linkers to form a crystalline network. The resulting porosity and high surface area of MOFs make them prime candidates for gas separation and sequestration. Seth Cohen and co-workers at the University of California, San Diego and the University of Florida have now added new flexibility to the design of MOFs.

Challenging common wisdom in MOFs architecture, the researchers managed to use linear, floppy polymers instead of rigid ligands and show that the final material — a polymer–MOF hybrid — is indeed crystalline. The polymer ligands are made of a polyether unit with methylene spacers of various lengths and an aromatic dicarboxylic acid strut. The carboxylic acid coordinates with zinc(II) ions to form a crosslinked porous framework. The porosity, surface area and hydrophobicity of the poly-MOFs can be controlled by varying the molecular weight of the polymer and the temperature of the reaction with zinc. From a polymer chemistry perspective, poly-MOFs demonstrate that linear polymers, usually associated with amorphous and non-porous arrangements, can form porous and crystalline solids through a coordination chemistry strategy.

Crystallographic data show that there are optimal conditions to prepare poly-MOFs, and although the fine mechanistic details still need to be worked out, the two best behaving poly-MOFs have pores of 7 Å and 9 Å — sizes that are favourable for CO₂ uptake. *AM*