Quasicrystals

Dendrimers break the rules and open the way to new photonic materials

Due to their unusual crystallographic symmetry, quasicrystals have attracted considerable interest in recent years. Quasicrystals are materials that defy the rules of conventional crystallography by possessing rotational symmetry other than the allowed 2, 3, 4 and 6-fold symmetry. These materials are usually metal alloys. Micropatterns with quasicrystalline symmetry have been etched to obtain photonic band gap arrays. 2-dimensional quasicrystalline lattices are able to widen the photonic band gap, enabling them to prevent light within a specific range of wavelengths from propagating in any direction, and a 1-dimensional quasicrystalline lattice has been found to slow down light.

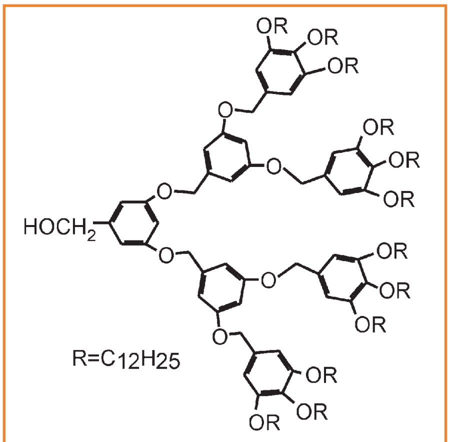

Figure 1: *Structure of the dendron investigated*

For a photonic quasicrystal to have a band gap that is within the visible light region the materials lattice must have spacing between neighbouring lattice points of a few hundred nanometers. Metal alloys, traditionally the source of quasicrystals, have spacing between the metal atoms of typically only a few angstroms.

A group based in the Department of Engineering Materials at the University of Sheffield have increased the spacing of neighbouring lattice points in a quasicrystal by using supramolecular dendrimers. The team, headed by Goran Ungar and Xiangbing Zeng, are interested in creating nano-arrays in 2 and 3 dimensions. They have worked from the principle that many compounds can self-organise into bulk phases that show periodicities on the 10^{-8} – 10^{-6} m scale. Compounds, both synthetic and natural, such as thermotropic liquid crystals, block co-polymers and lyotropic systems, are able to organise themselves as a result of their molecular shape and amphiphilic nature. The periodicity that these systems develop can be 1, 2 or 3-dimensional. Until now all the 2 and 3-dimensional phases identified for such systems have obeyed the rules of crystallography and possessed a symmetry that could be described by the 17 crystallographic plane groups or 230 crystallographic space groups. For the first time, Ungars group demonstrate that these self-organising systems can defy crystallographic rules and form quasiperiodic structures as with some metal alloys. This fortuitous discovery represents a new mode of organisation in soft matter.

The team investigated a dendritic compound, formed from the dendron illustrated in **figure 1**. The compound formed an unknown phase X.

Phase X forms directly from the liquid which enabled the team to grow it in mono-domains. The team used small-angle X-ray single-crystal diffraction to investigate the symmetry of the material. The x-ray pattern obtained showed a 12-fold symmetry which is a much higher degree of symmetry than normal crystalline materials and characterised the phase as quasicrystalline. Ungar says that this 12-fold symmetry is higher than that of any crystal and that this is the main advantage to their approach. The Sheffield group is continuing in this field of research, collaborating with Virgil Percec's group at the University of Pennsylvania to produce dendrons that have larger periodicities. Ungar feels that there will be an upper limit to what is achievable using dendrons so is currently considering new approaches to producing self-assembled quasicrystaline photonic materials.

Supramolecular dendritic liquid quasicrystals. Xiangbing Zeng, Goran Ungar, Yongsong Liu, Virgil Percec, Andre´s E Dulcey & Jamie K Hobbs. *Nature.,* 2004, Vol 428, 157-159.

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