

such, are generally much more robust than their non-covalent counterparts. Therefore, although non-covalent self-assembly enables the formation of highly optimized structures through a self-correcting process of bonds forming, breaking and reforming, the final products can be relatively fragile. To make more stable assemblies, therefore, the only realistic approach is to use covalent bonds. Moreover, covalent bonds offer another very significant benefit over non-covalent interactions — the possibility of efficient electron transport through the bond. If rationally constructed molecular electronic components are to be made in this fashion, then

covalent bonds offer the greatest chance of success.

So what is the next step forward for this area? Clearly this demonstration is limited to a single type of molecule and a single reaction pathway. However, there is no obvious reason why the approach described would be specific to this particular system, and thus this study opens up the possibility of a generic application for the synthesis of nanostructures from diverse molecular building blocks. The next step should be to build covalently bonded arrays in a surface environment from molecules encoded with a specific function, and, importantly, to demonstrate useful properties. It is clear that the strategy

described by Grill and co-workers for producing nanostructured arrays at the molecular level has many possible applications, not only in electronics, but also in magnetism, catalysis and even for the recognition and activation of biomolecules.

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## SCANNING TUNNELLING MICROSCOPY

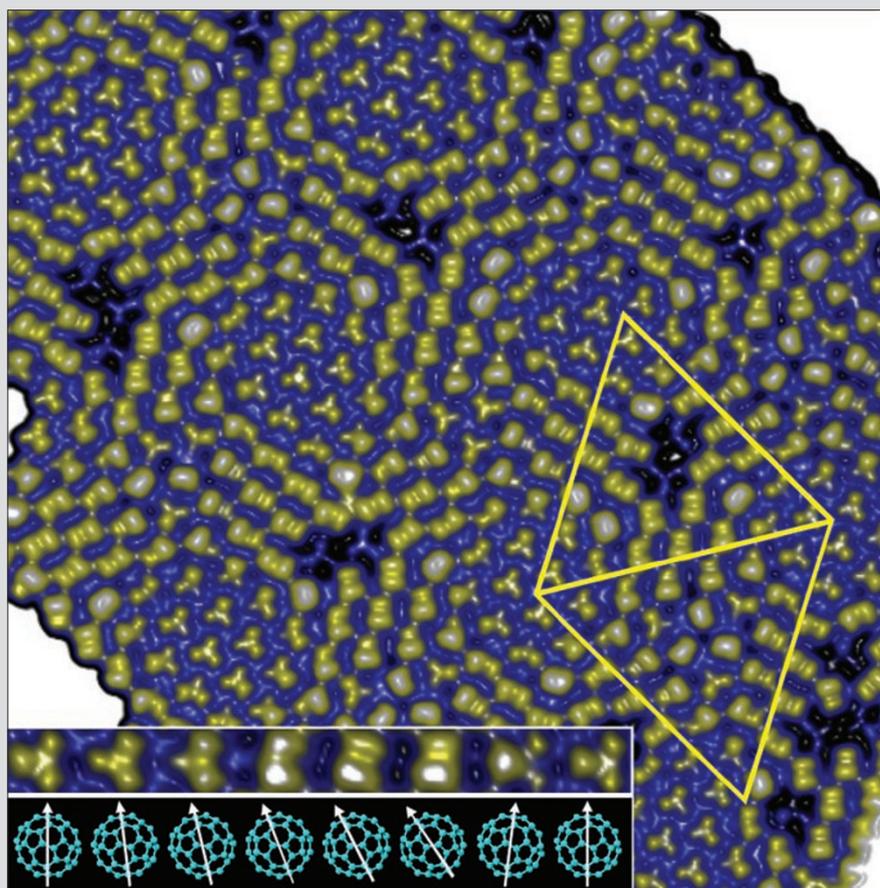
### Made to order

The ability of atoms and molecules to self-assemble into spectacular patterns on surfaces is clearly demonstrated in this scanning tunnelling microscope (STM) image taken by Guillaume Schull and Richard Berndt of Christian-Albrechts-Universität in Kiel, Germany, which was presented at the recent Trends in Nanotechnology conference in San Sebastian, Spain ([www.tnt2007.org](http://www.tnt2007.org)).

Schull and Berndt deposited approximately 0.2 monolayers of  $C_{60}$  molecules on a gold surface under ultrahigh vacuum at room temperature and then imaged the system with a low-temperature STM at 5.7 K. The image on the right, which is 20 nm across, shows that the  $C_{60}$  molecules (yellow and white structures) form a hexagonal lattice with a rhombus-shaped unit cell (yellow lines) that consists of 49 molecules.

The unit cell can be divided into a half that contains a defect and a half that is defect-free. Similar structures have been studied in the  $7 \times 7$  reconstruction of silicon surfaces for several decades.

Further analysis of the image reveals a layer of complexity that is not found when atoms, rather than molecules, self-assemble on a surface. Although  $C_{60}$  molecules are often compared to footballs, they are not perfectly spherical, which means that they have an orientation or direction (white arrows in inset). On some surfaces the  $C_{60}$  molecules are restricted to ‘pointing’ in



just one or two directions because of the strong interactions between the surface and the molecules, but 11 different orientations can be observed in this system, some of which are shown in the inset.

Moreover, as Schull and Berndt demonstrate, the orientations also display long-range order. The work will be published in *Physical Review Letters*.

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