MATERIAL WITNESS

SMART TIPPING

The first atomic-resolution images of carbon nanotubes taken by a scanning probe microscope caused great excitement. Here at last was a direct view of what electron diffraction had previously disclosed: the hexagonal carbon framework. Or was it? Some experiments seemed to reveal the chicken-wire mesh of graphitic carbon[1,2], but other experiments showed not a hexagonal honeycomb but a trigonal array of bright spots[3]. It might depend on the type of microscope used — the scanning tunnelling microscope (STM), say, which images electronic structure, or the atomic force microscope (AFM) and its variants, in which contrast depends on tip–sample forces. Or it might depend on the nature of the tip, or the separation between tip and sample.

This was no surprise. Ever since the earliest days of the STM and AFM in the 1980s, the issue of what was being imaged was hotly debated. The temptation to regard these regular arrays of bright blobs as atoms on a crystal surface was, for the most part, assiduously resisted in the knowledge that, especially for the STM, the imaging mechanism did not by any means guarantee a simple topographic map.

Indeed, graphite itself supplied a cautionary tale. It was used as a substrate for some of the earliest STM images, which showed the trigonal rather than honeycomb pattern[4].

The standard interpretation invoked differences between two types of carbon atom in the surface layer: some (C_α) have a near neighbour in the second layer directly below, whereas others (C_β) sit directly above the central void of a six-membered ring. Only the latter were predicted to register as bright spots at low bias voltages between tip and sample. Yet experimentally the trigonal pattern predominates for high bias too, though the honeycomb was occasionally seen even for low biases.

To add to the puzzle, AFM images might be expected to show a honeycomb because they supposedly report more directly on the arrangement of atoms — but the trigonal pattern is often seen here too[5]. So what is governing these images of graphitic carbon?

That's what Ondráček *et al.* have set out to clarify[6]. Using first-principles calculations to predict both tip–surface forces and electronic tunnelling currents between graphite or single-walled carbon nanotubes and a variety of scanning probe tips, they rationalize the diverse results found in experiments.

The outcome depends on the tip–sample distance, the bias (for STM) and the chemical nature of the tip. For example, a pure silicon (111) tip has an atom at its apex with a dangling bond, making it capable of changing the hybridization of a carbon atom and

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forming a chemical bond, changing the contrast mechanism for force microscopy. That effect is even more pronounced for a tungsten tip. But at greater separations, Pauli repulsion dominates the interaction, as it does with more inert tips even close up — and then the force maxima occur over the hexagonal ring centres, giving the trigonal pattern.

For the STM, the C_β sites do give larger currents for typical separations, but the ring centres produce the bright spots in near-contact mode, reversing the contrast. Thus, inert tips are generally the safest option for imaging carbon nanostructures. ❐

References

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CELL MECHANICS

Moving under peer pressure

Collective cell motion in a continuous tissue is found to be guided by cooperative intercellular forces.

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Cells in the tissues of our bodies, thankfully, do not move much. The collective motion of cells in a multicellular tissue is of great interest, however, because it occurs during embryo morphogenesis and in unhealthy circumstances such as wound healing and cancer metastasis[1]. Although it is known that there are biochemical signals that guide the direction of motion — a process called chemotaxis — it is less clear what role mechanical forces play in organizing collective cellular motion. Writing in *Nature Materials*, Tambe *et al.* report an analysis of the coupling between cellular motion and mechanical forces in a continuous two-dimensional cell culture *in vitro*[2]. They generate high-resolution