

environmental chemistry and toxicology of nano-Ag remain largely unknown. This means that the huge scientific and technological progress in the development and application of nanoparticles also leads to many open and interesting questions in environmental chemistry and toxicology.

Mueller and Nowack show that with a consistent quantitative framework, as is seen in the material flow analysis and the environmental fate models used, first estimates of environmental concentrations and risks can be obtained. These results can then serve as a starting point for more comprehensive investigations later on. Because the current empirical database is insufficient, environmental fate models are essential tools for preliminary assessments even though they are based on generic assumptions that may or may not be accurate. Using these models, it is possible to quantitatively estimate mass fluxes between environmental media and the levels in these media, and to consistently compare different materials (Fig. 1).

The question then is: are nanoparticles so different from chemicals that chemical risk assessment methods from the past 30 years cannot be applied to them? Existing methods from chemicals assessment should certainly be used as a starting point for assessing nanoparticles. In environmental fate models (Fig. 1), substance properties such as the organic-carbon-to-water partition coefficient (K_{oc}) and the half-life for aerobic biodegradation are used to describe individual transport and degradation processes. The K_{oc} , for example, is used to quantify a chemical's absorption into suspended particles and its subsequent deposition to the sediment with the settling particles. Therefore, the key question to ask before applying the same models to assess nanomaterials is: do engineered nanoparticles have the same properties as those stipulated in current environmental fate models used to assess chemicals? If not, how can we modify the process descriptions in the models, which yield quantitative estimates of mass fluxes (indicated by

the arrows in Fig. 1) based on substance properties, so that they reflect the specific properties of the nanoparticles? Can we characterize the environmentally relevant properties of nanomaterials such as partition coefficients and timescales of agglomeration, transformation and degradation so that more reliable estimates are possible?

Depending on the composition, size distribution and surface treatment of the nanoparticles, these questions will have different answers for different nanomaterials. Whereas Mueller and Nowack have examined three different nanomaterials in one study, tailoring the risk assessment methods to the types of nanoparticles will be needed. Being on the nanoscale is not really a unifying property of the many different nanoparticles so the actual diversity of the materials needs to be captured in risk assessments.

References

1. Mueller, N. & Nowack, B. *Environ. Sci. Technol.* doi:10.1021/es7029637 (2008).
2. Blaser, S. *et al. Sci. Total Environ.* **390**, 396–409 (2008).

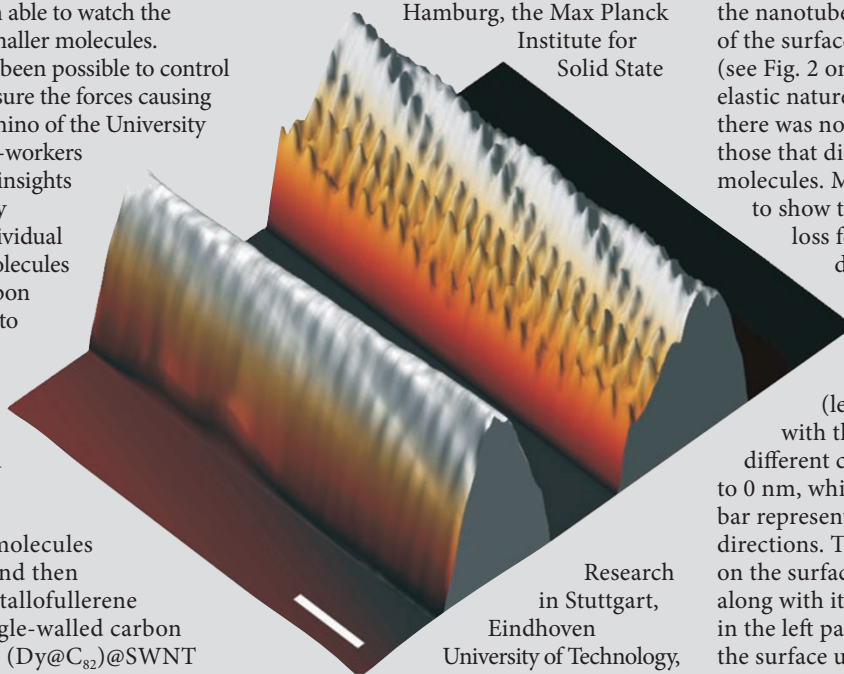
FORCE MICROSCOPY

Looking at molecules within molecules

Researchers have been able to confine small molecules inside larger molecules for a number of years and, more recently, they have even been able to watch the movement of the smaller molecules. However, it has not been possible to control this motion or measure the forces causing it. Now, Makoto Ashino of the University of Hamburg and co-workers have provided new insights into such systems by measuring how individual metallofullerene molecules confined inside carbon nanotubes respond to the tip of an atomic force microscope (see page 337).

Ashino and co-workers started by encapsulating dysprosium atoms inside carbon-82 molecules to form $Dy@C_{82}$, and then inserting these metallofullerene molecules into single-walled carbon nanotubes to form $(Dy@C_{82})@SWNT$ 'peapod' structures. These molecules within molecules were then deposited onto an insulating surface and probed with dynamic non-contact atomic force microscopy.

In addition to studying the surface topography of these peapods, Ashino and his co-workers — who are based in Hamburg, the Max Planck Institute for Solid State



Research in Stuttgart, Eindhoven University of Technology, the Hong Kong University of Science and Technology, and Nottingham University — also simultaneously measured the energy lost by the vibrating tip of the AFM as it moved over the

surface of the $(Dy@C_{82})@SWNT$ structures. Not surprisingly, the presence or absence of a $Dy@C_{82}$ molecule inside the nanotube influenced both the shape of the surface and the energy-loss images (see Fig. 2 on page 338). The highly elastic nature of nanotubes meant that there was no energy-loss signal for those that did not contain any smaller molecules. Moreover, the team were able to show that the maximum energy loss for filled nanotubes occurred directly above the sites of the $Dy@C_{82}$ molecules.

The image here shows the surface topography of an empty nanotube (left) and a peapod structure, with the height represented by different colours (black corresponds to 0 nm, white to 2 nm), and the scale bar representing 1 nm in both horizontal directions. The atomic-scale corrugations on the surface of the empty nanotube, along with its helicity, can be clearly seen in the left part of the image, whereas the surface undulations (which have an amplitude of 56 ± 5 pm in the vertical direction) caused by the $Dy@C_{82}$ molecules are clearly visible for the nanotube on the right.

Peter Rodgers