of the University of Augsburg have shown that Landauer's principle — like the second law — needs to be generalized to apply at the nanoscale.

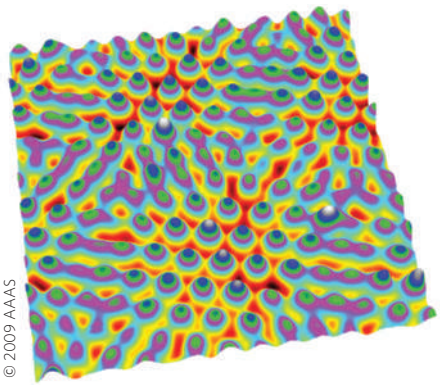
Using a double-well potential to model a single-bit memory, they calculate that full-bit erasure in small systems can be achieved with an entropy dissipation that is smaller than the standard Landauer limit. This breach of the Landauer limit is caused by thermal fluctuations that can be ignored on macroscopic scales, but become important at shorter length scales.

Dillenschneider and Lutz also propose an experiment to test their predictions: the use of fluorescence microscopy combined with real-time feedback to study the Brownian motion of a nanoparticle in a driven double-well potential. Similar experiments have already been performed on nanoparticles in static double-well potentials.

GRAPHENE

Reaching new levels

Science **324,** 924–927 (2009);
Phys. Rev. Lett. **102,** 176804 (2009)



When a magnetic field is applied to a two-dimensional (2D) electron gas, the electrons circulate in cyclotron orbits with well-defined energies called Landau levels. Moreover, these energy levels are equally spaced. Although the electrons in graphene are also confined to two dimensions, they differ in many ways from other 2D electron systems. In particular, they behave as though they do not have mass, which should lead to a distinctive zero-energy state and Landau levels with unequal spacings between them.

So far experimental evidence for these properties has been indirect, but now Philip First of Georgia Tech, Joseph Stroscio of the National Institute of Standards and Technology and co-workers have reported the first direct measurements of the unequally spaced Landau levels and the zero-energy state. Using samples containing about ten layers of graphene grown on a silicon carbide substrate, the team performed scanning tunnelling spectroscopy at 4.3 K in an ultrahigh vacuum. They found that the energy of the nth Landau level is proportional to the square root of the magnetic field and n.

Similar results, also based on scanning tunnelling spectroscopy, have been reported by Eva Andrei and co-workers at Rutgers University.

MICELLES

On target

Proc. Natl Acad. Sci. USA
doi: 10.1073/pnas.0903369106 (2009)

Atherosclerosis is a condition in which the walls of blood vessels are thickened with plaque owing to the accumulation of fatty materials like cholesterol. If the plaque ruptures it can lead to the formation of harmful blood clots, and elevated levels of thrombin — an enzyme involved in clot formation — in the blood vessel after injury can induce more clots. However, delivering anti-clotting agents can reduce the formation and expansion of clots. Researchers have now shown that a multifunctional micelle platform can be used to deliver drugs to atherosclerotic plaques to reduce clotting.

The individual monomers of the micelles made by Erkki Ruoslahti of the Burnham Institute for Medical Research and colleagues consist of an oily tail, a polyethylene glycol spacer and a head group that can be a fluorescent molecule, a drug or a peptide that binds to plaques. When micelles containing peptides were injected into atherosclerotic mice, they bound to the plaques and concentrated in areas prone to rupture, but they did not bind to healthy vessels. Micelles containing both the peptide and the drug also targeted the plaques, and the drug was able to reduce the activity of thrombin. Control experiments confirmed that the micelles themselves do not induce clotting, indicating that they may be a suitable platform for targeting and delivering drugs to atherosclerotic plaques to reduce clotting.

The ability of peptide-containing micelles to target plaques near the points of rupture means that it will be possible to deliver lower dosages of the drugs that can reduce clot formation at these sites.

The definitive versions of these Research Highlights first appeared on the *Nature Nanotechnology* website, along with other articles that will not appear in print. If citing these articles, please refer to the web version.

Top down Bottom up

Strength in numbers

Computational screening has turned up a fullerene derivative that might help fight the HIV virus.

Manthos Papadopoulos, the research director at the Institute of Organic and Pharmaceutical Chemistry in Athens, likes databases. Indeed, a recent paper on which he is the corresponding author is the result of a collaboration that began with a database search (*J. Chem. Inf. Model.* **49,** 1139–1143; 2009). Papadopoulos leads a team of theorists who calculate the properties of molecules. They ran through a database of over 100 fullerene derivatives and calculated that those with the highest binding affinity to the HIV virus were made by Andrew Baron and colleagues at Rice University, who agreed to provide samples. All that was left to do was to find someone to test their predictions: another literature search led Papadopoulos to recruit Claudiu Supuran of the University of Florence to the collaboration.

It has been known for more than a decade that fullerene molecules bind to the receptor pocket on the HIV virus, inhibiting its spread in the body. The measured binding affinity, however, was relatively low. Papadopoulos and co-workers in Athens predicted, and Supuran confirmed, that the binding affinity of the fullerene derivatives made by Baron's group would be three times higher than the strongest fullerene binder currently available. The research is an example of *in silico* drug design, which leverages modern computational power and large molecular databases to complement more traditional experiment-based approaches.

Although the collaboration was assembled from literature and database searches, it proved both fruitful and lasting. For Baron it represents a new direction: "We had performed research on the use of these molecules for treatment of cancer cells, but not in the area of HIV", he says. "We are very interested in continuing this joint work." For Papadopoulos the payoff was simple: "The most rewarding part was the confirmation of our prediction." His advice to other collaborations is equally simple: "Choose challenging topics and questions."