Nanoclusters Battle Second Law
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**4 billion** Number of transistors that would fit on a postage stamp today

light-sensitive monomer made the new approach possible. The scientists added two ingredients: an initiator that reacts with blue light and an inhibitor that reacts with UV light. When the scientists project the blue light through the lens onto the monomer, the liquid absorbs the light and releases radicals hungry to bond. And bond they do, creating a solid polymer wherever the blue light hits.

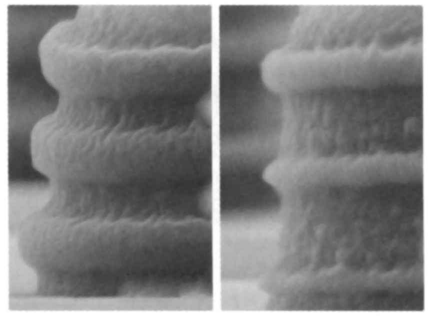
The UV light then acts as the eraser, the team reports. Around the pinpoint of blue light, the scientists created a doughnut of UV light, stimulating the chemical inhibitor in the monomer. This process also produces radicals, but these snatch up other radicals, preventing polymerization. So a fine line is created by sweeping the periphery with UV light.

John Fourkas of the University of Maryland in College Park and colleagues report a similar approach: An activating laser beam gets polymerization going, and a de-activating beam keeps the polymerization contained.

Sculpting with light may allow these researchers to craft tiny gears for tiny machines or finely detailed screens for controlling where light hits a material.

In a third paper, Rajesh Menon of MIT and his colleagues describe a technique that also uses two different wavelengths of light. But the researchers blocked light instead of erasing it.

The team placed light-sensitive film over the material to be patterned. Upon exposure to UV light, the film becomes transparent, allowing the scientists to "cut" a window wherever desired. Light of another wavelength can be shone through the stencil to etch the material beneath.



**New studies show thinner rings are possible with a two-laser approach (right). Other methods yield bulkier rings (left).**

The studies aren't likely to revolutionize the semiconductor industry, says Robert Allen, also of IBM. But "what they have done with very long wavelengths of light is spectacular."

# Nanoclusters battle second law

## In simulations, collisions can increase velocity, reduce entropy

**By Laura Sanders**

Nobody's above the law. But tiny clusters of colliding atoms may duck below the second law of thermodynamics. In simulations, researchers in Japan found that in rare cases, tiny clusters of atoms ricochet off each other faster than their approaching speeds. The results, in the March *Physical Review E*, seem to violate the second law's requirement that any work squanders a little bit of energy in the form of waste heat, leaving a system with higher entropy.

In collisions big enough to see, like those between a tennis ball and a gym floor, the speed of an object's approach is always faster than its speed after impact. A ball dropped against the floor bounces a little slower and comes up shorter on each bounce because a small amount of the ball's energy is siphoned as heat.

In the nanoworld, though, normal rules do not always apply, the results suggest.

Researchers Hisao Hayakawa of Kyoto University and Hiroto Kuninaka of Chuo University in Tokyo developed a computer program to model head-on collisions of squishy collections of several hundred atoms called nanoclusters. At speeds around 5 meters per second, most of the clusters in the simulation stuck together like two candied apples in the sun. Others just bumped into each other and moved away at a slower rate than their approach.

**Nanoclusters sometimes gained speed after colliding in simulations, seeming to defy the second law of thermodynamics.**

But about 5 percent of the time, the colliding nanoclusters sped up after bumping, exhibiting what the researchers call a super rebound. In these rebounds, the outgoing energy exceeded the incoming energy, meaning that the system overall lost entropy, an apparent violation of the second law.

"It's an interesting observation. For me, it was also counterintuitive," comments Jörn Dunkel, a theoretical physicist at the University of Oxford in England.

This superbounce comes from the random fluctuations of motions of the atoms that make up each nanocluster, the researchers say. Depending on the exact motions, some fluctuations can give the collision an extra boost, like an extra springy trampoline.

"Nanoscale physics involves such unexpected events," Hayakawa says.

But this extra boost works only in tiny systems. When the researchers increased the size of each nanocluster in the simulation to over 1,000 atoms, the superbounce disappeared entirely. "In order to see a violation of the second law, you need a very small number," Dunkel says.

These clusters evade the second law on a statistical technicality: The average speed of all the outgoing nanoclusters is less than the approaching speed. Even though individual nanoclusters appear to violate the second law occasionally, the average behavior of all the nanoclusters falls in line with the law's constraints.

FROM TOP: FOURKAS ET AL./SCIENCE/AAAS; KUNINAKA ET AL./PHYSICAL REVIEW E