Are electron tweezers possible? Apparently so

November 9 2011

(PhysOrg.com) -- Not to pick up electrons, but tweezers made of electrons. A recent paper by researchers from the National Institute of Standards and Technology (NIST) and the University of Virginia (UVA) demonstrates that the beams produced by modern electron microscopes can be used not just to look at nanoscale objects, but to move them around, position them and perhaps even assemble them.

Essentially, they say, the tool is an electron version of the laser “optical tweezers” that have become a standard tool in biology, physics and chemistry for manipulating tiny particles. Except that electron beams could offer a thousand-fold improvement in sensitivity and resolution.

Optical tweezers were first described in 1986 by a research team at Bell Labs. The general idea is that under the right conditions, a tightly focused laser beam will exert a small but useful force on tiny particles. Not pushing them away, which you might expect, but rather drawing them towards the center of the beam. Biochemists, for example, routinely use the effect to manipulate individual cells or liposomes under a microscope.

If you just consider the physics, says NIST metallurgist Vladimir Oleshko, you might expect that a beam of focused electrons—such as that created by a transmission electron microscope (TEM)—could do the same thing. However that’s never been seen, in part because electrons are much fussier to work with. They can’t penetrate far through air, for example, so electron microscopes use vacuum chambers to hold specimens.

So Oleshko and his colleague, UVA materials scientist James Howe, were surprised when, in the course of another experiment, they found themselves watching an electron tweezer at work. They were using an electron microscope to study, in detail, what happens when a metal alloy melts or freezes. They were observing a small particle—a few hundred microns wide—of an aluminum-silicon alloy held just at a transition point where it was partially molten, a liquid shell surrounding a core of still solid metal. In such a small sample, the electron beam can excite plasmons, a kind of quantized wave in the alloy's electrons, that reveals a lot about what happens at the liquid-solid boundary of a crystallizing metal. "Scientifically, it's interesting to see how the electrons behave," says Howe, "but from a technological point of view, you can make better metals if you understand, in detail, how they go from liquid to solid."

"This effect of electron tweezers was unexpected because the general purpose of this experiment was to study melting and crystallization," Oleshko explains. "We can generate this sphere inside the liquid shell easily; you can tell from the image that it's still crystalline. But we saw that when we move or tilt the beam—or move the microscope stage under the beam—the solid particle follows it, like it was glued to the beam."

Potentially, Oleshko says, electron tweezers could be a versatile and valuable tool, adding very fine manipulation to wide and growing lists of uses for electron microscopy in materials science. "Of course, this is challenging because it requires a vacuum," he says, "but electron probes can be very fine, three orders of magnitude smaller than photon beams—close to the size of single atoms. We could manipulate very small quantities, even single atoms, in a very precise way."

More information: V.P. Oleshko and J.M. Howe. Are electron tweezers possible? *Ultramicroscopy* (2011) doi:10.1016/j.ultramic.2011.08.015

Provided by National Institute of Standards and Technology