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Scaled-down: new nano device can weigh single molecules

A tiny resonating beam, just 10 millionths of a meter in length, can measure the mass of a molecule or nanoparticle in real time.

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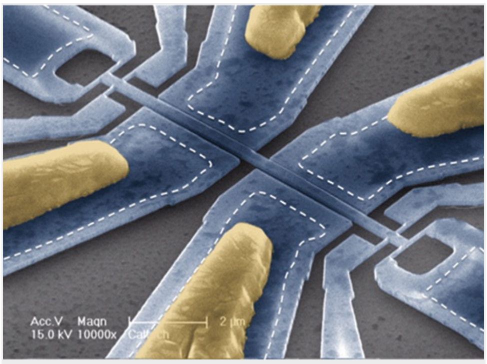
An article from Scientific American.



Caltech/Scott Kelber and Michael Roukes

The diagonal resonating beam can detect the presence of single molecules and determine their mass.

Dieters and exercise buffs might feel better about their progress if they tracked their weight loss in daltons. Even a short jog can help you shed a few septillion daltons, a unit of mass often used in biochemistry that is equivalent to the atomic mass unit. (Of course, no weight-conscious individual would want to know their full weight in this unit—the average American male weighs approximately 5 X 1028 daltons.)

Even the megadalton, or one million daltons, is a tiny unit of measure—a gold particle five nanometers across weighs in at just a few megadaltons. (One nanometer is a billionth of a meter.) But researchers at the California Institute of Technology and CEA–Leti, a government-funded research organization in Grenoble, France, have built a scale that weighs single objects even lighter than a megadalton, including nanoparticles and human antibody molecules. The device is the first of its kind to determine the masses of individual molecules and nanoparticles in real time, the researchers reported in a study published online August 26 in *Nature Nanotechnology*.

The heart of the device is a nanoelectromechanical resonator—a tiny beam of silicon vibrating at two tones simultaneously. "It's like vibrating a guitar string at the fundamental and a harmonic," says study co-author Michael Roukes, a Caltech physicist. "We're continuously strumming it with an electrostatic excitation." The beam runs diagonally across the photo (above); it measures 10 microns long and 300 nanometers wide. (A micron is one millionth of a meter.)

Tiny arms connecting the ends of the beam to the rest of the device convert the resonator's vibrations into an electrical signal via a phenomenon known as the piezoresistive effect. "The smallest pieces there are flexed slightly, and when they're flexed their resistance changes," Roukes says. "And so we can read out the motion as a change in resistance." A single molecule landing on the beam shifts the frequency of the two tones downward, and from the accompanying change in resistance the researchers can deduce both the mass of the particle and where it landed along the beam.

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More from *Scientific American*.

The device's sensitivity to single molecules allowed the researchers to perform mass spectroscopy—identifying the various particles in a mixture by their masses—on collections of gold nanoparticles five and 10 nanometers in diameter, as well as on the antibody molecule immunoglobulin M, which weighs just under one megadalton. (The natural molecules proved much more consistent in their construction than did the man-made nanoparticles, whose masses fluctuated by a factor of five or so from particle to particle.)

Roukes notes that past resonators were capable of measuring molecular masses, but only after hundreds of identical molecules had been deposited onto the beam. "We couldn't actually know molecule by molecule what their mass was," he says. The new, more sensitive version should allow researchers to perform mass spectroscopy to identify the various particles within a mixed sample. For instance, researchers could analyze a biological specimen to look for a telltale biomarker with a known mass. "If we can do it one by one, now we can start looking at arbitrarily complex mixtures of different things," he says.

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References

1. Hanay, M. S. *et al*. *Nat. Nanotech.* doi:10.1038/nnano.2012.119 (2012).