NIST Testing Method Quickly Tells Whether Thin Films Are Strong Enough for the Job

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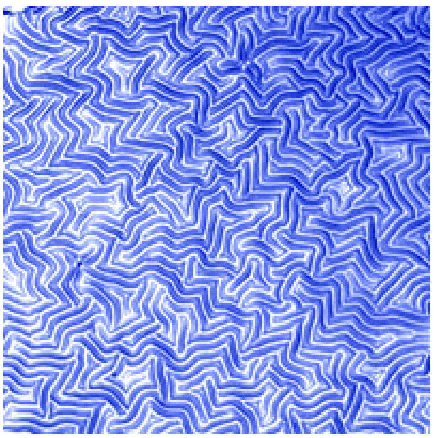

The challenge of determining whether thin films—some no thicker than a single molecule—are strong enough for a growing number of important technology jobs just got easier and quicker thanks to an inexpensive testing method reported in the upcoming issue of Nature Materials by a team led by researchers at the Commerce Department's National Institute of Standards and Technology (NIST).

Useful for evaluating all types and combinations of materials, the new method measures and analyzes the strength and stiffness of a thin-film sample in about 2 seconds, as compared with several minutes for indentation and other conventional approaches. In addition, the NIST-developed technique accommodates high-throughput testing, so that hundreds or even a few thousand systematically varying samples can be tested in rapid succession.

Accelerated testing could spur progress in a large variety of existing and emerging technology areas that rely on thin-film advances for improved performance or enhanced protection. Examples include semiconductors, solar cells, fuel cells, coatings, magnetic storage devices and prospective nanotechnology devices.

For films less than 1 micrometer thick, mechanical-property measurements made with existing tools often yield relative values, which can blur predictions of how different films will perform. In contrast, the new method yields quantitative measurement results that permit definitive comparisons between samples.

In the article,* NIST and IBM collaborators report on how they used the innovative "measurement platform" to assess the strength of polymer and ceramic films ranging from a few nanometers to a micrometer in thickness. One pilot-tested film was a ceramic material dotted with nanometer-scale pores. Such nanoporous films are being developed to insulate devices and layers on future-generation integrated circuits.

While the nanopores in the so-called low-dielectric-constant (low-k) films improve their effectiveness as electrical insulators, the tiny holes also can compromise the films' strength. A major concern is whether the nanoporous films can withstand the rigors of the chemical mechanical polishing process used to smooth each layer in a chip.

Using the desk-top testing platform, smaller than a box of tissues, the team evaluated a battery of low-k films that varied in porosity, from samples with no pores to samples in which pores made up half the volume. After comparing the results with those obtained with the widely used nanoindentation method, the team concluded that the NIST-developed approach “provides an inexpensive, fast, and highly effective technique” for evaluating new varieties of low-k materials.

“We expect that this technique will find application in addressing a variety of questions ranging from fundamental materials science to applied discovery in the field of films and coatings,” they write.

Christopher Stafford, a NIST polymer scientist, suggests other applications include evaluations of new photoresist masks that will be used to print chips with the smaller-wavelength ultraviolet light sources that the semiconductor industry is now implementing. It also should be useful for assessing the mechanical properties of nanotechnology devices made with still-experimental methods, such as nanoimprint lithography in which nanometer-scale features are stamped into a substrate.

“This simple technique can provide invaluable information concerning the mechanics of nanostructured materials and ultrathin polymer films,” said Stafford.

Called SIEBIMM (for strain-induced elastic buckling instability for mechanical measurements), the new method builds on the science of buckling, which for most of its 400 years has been concerned with crumbling buildings or crumpling of the Earth’s crust.

The method entails mounting a postage-stamp-sized assortment of incrementally varying thin films on a strip of silicone rubber about the size of a Band-Aid. The combination of sample array and soft substrate are placed on a custom-built stage that can be stretched or compressed.

Subjected to a gradually increasing force that stretches or squeezes, a sample becomes unstable and buckles, wrinkling like a piece of corrugated cardboard. Situated beneath the stage, a laser beams through the sample and a camera captures the light scattered at this critical point of instability.

From the resulting diffraction pattern, the buckling wavelength, or distance between the peaks of adjacent wrinkles, is determined. Through a series of mathematical calculations, the buckling wavelength can be related directly to the elastic modulus of the sample, which corresponds to the strength of the material.

The SIEBIMM method was developed at the NIST Combinatorial Methods Center (www.nist.gov/combi), which develops rapid, high-throughput technologies to accelerate the discovery and application of new materials.

As a non-regulatory agency of the U.S. Department of Commerce's Technology Administration, NIST develops and promotes measurement, standards and technology to enhance productivity, facilitate trade and improve the quality of life.

The original press release can be found here.