New method monitors semiconductor etching as it happens -- with light

Eurekalert!

CHAMPAIGN, Ill. — University of Illinois researchers have a new low-cost method to carve delicate features onto semiconductor wafers using light – and watch as it happens.

"You can use light to image the topography and you can use light to sculpture the topography," said electrical and computer engineering professor Gabriel Popescu. "It could change the future of semiconductor etching."

Chip makers and semiconductor researchers need to very precisely control the dimensions of their devices. The dimensions of the components affect performance, speed, error rate and time to failure.

Semiconductors are commonly shaped by etching with chemicals. Etching errors, such as residual layers, can affect the ability to further process and etch as well as hamper device performance. Thus, researchers use time-consuming and costly processes to ensure precise etching – for some applications, to within a scant few nanometers.

The Illinois researchers' new technique can monitor a semiconductor's surface as it is etched, in real time, with nanometer resolution. It uses a special type of microscope that uses two beams of light to very precisely measure topography.

"The idea is that the height of the structure can be determined as the light reflects off the different surfaces," said electrical and computer engineering professor Lynford Goddard, who co-led the group with Popescu. "Looking at the change in height, you figure out the etch rate. What this allows us to do is monitor it while it's etching. It allows us to figure out the etch rate both across time and across space, because we can determine the rate at every location within the semiconductor wafer that's in our field of view."

(See a video of Goddard narrating a real-time recorded etching at http://www.youtube.com/watch?v=6tIJqNrV20s&feature=plcp [1])

The new method is faster, lower in cost, and less noisy than the widely used methods of atomic force microscopy or scanning tunneling microscopy, which cannot monitor etching in progress but only compare before and after measurements. In addition, the new method is purely optical, so there's no contact with the semiconductor surface and the researchers can monitor the whole wafer at once instead of point-by-point.

"I would say the main advantage of our optical technique is that it requires no

contact," Popescu said. "We're just sending light, reflected off the sample, as opposed to an AFM where you need to come with a probe close to the sample."

In addition to monitoring the etching process, the light catalyzes the etching process itself, called photochemical etching. Traditional chemical etching creates features in steps or plateaus. For curved surfaces or other shapes, semiconductor researchers use photochemical etching. Usually, light shines though very expensive glass plates called masks that have distinct patterns of gray to let light through by degrees. A researcher must purchase or make a mask for each tweak of a pattern until the correct pattern of features is achieved.

By contrast, the new method uses a projector to shine a grayscale image onto the sample being etched. This allows the researchers to create complex patterns quickly and easily, and adjust them as needed.

"To create each mask is very expensive. That's impractical for research," Goddard said. "Because our technique is controlled by the computer, it can be dynamic. So you can start off etching one particular shape, midway through realize that you want to make some change, and then change the projector pattern to get the desired outcome."

The researchers envision this technology applied beyond etching, to real-time monitoring of other processes in materials science and life science – for example, watching carbon nanotubes self-assemble, or error monitoring during large-scale computer chip manufacturing. It could help chip manufacturers reduce costs and processing time by ensuring that equipment stays calibrated.

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