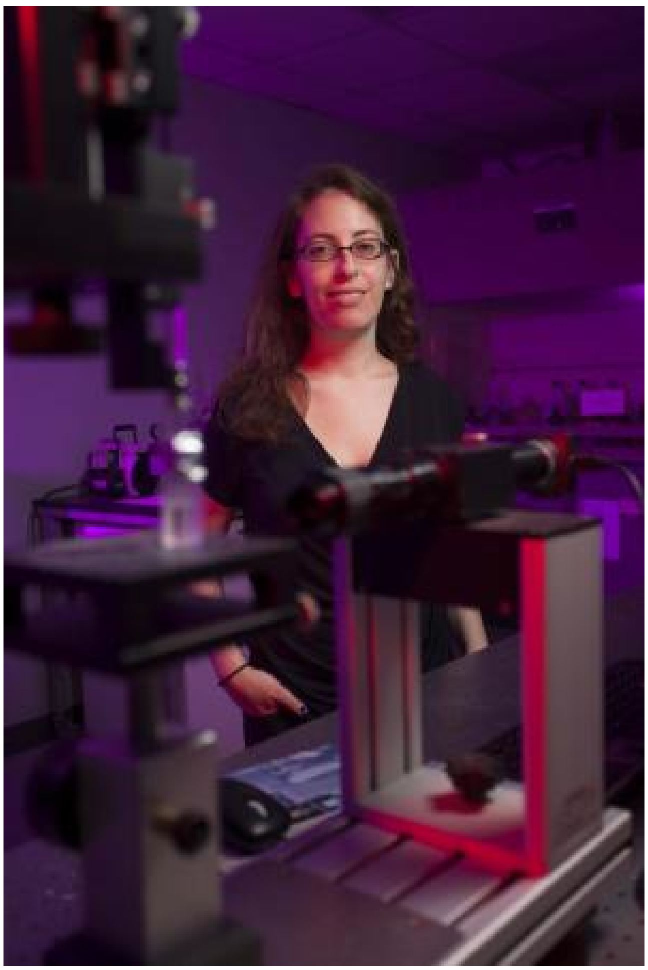
UH chemical engineer makes device fabrication easier

July 2 2014



University of Houston chemical and biomolecular engineer Gila Stein received a $279,411, three-year grant from the National Science Foundation to build models that can explain the complex physical and chemical reactions that take place in lithography systems used for device fabrication. Credit: UH Cullen College of Engineering Office of Communications

Have you ever wondered how the tiny components and devices inside your cell phone are made? The devices inside your phone and computer, such as integrated circuits, microprocessors and memory chips, are made in a process called lithography that, in Greek, translates quite literally to "writing on stones."

In the semiconductor industry, lithography is used to print two-dimensional patterns onto silicon wafers using a light-sensitive polymer called a photoresist. Patterns are transferred into the silicon wafer with different unit operations, like deposition or etching, to build up the conductors, insulators and circuits that form the final device.

Though the lithography process might sound simple, it requires a variety of very complex physical and chemical processes in the photoresist to form the pattern. The semiconductor industry relies on the lithography process to produce nearly all electronic device components – yet, very little is understood about the physics and chemistry underlying the complex chemical reactions required for semiconductor patterning.

But Gila Stein, Ernest J. and Barbara M. Henley Assistant Professor of chemical and biomolecular engineering at the University of Houston Cullen College of Engineering, is looking to change all of that thanks to a $279,411, three-year grant from the National Science Foundation (NSF). With this award, Stein will be working to build models that can explain the complex physical and chemical reactions that take place in lithography systems used for device fabrication.

Specifically, Stein will be researching materials called chemically amplified resists, which are systems wherein a polymer is blended with a catalyst and then a chemical reaction is used to form the patterns for semiconductor devices. Her collaborator on this project is Manolis Doxastakis, a materials scientist and simulations expert at Argonne National Laboratory.

"These are the materials that are used to pattern semiconductor devices, like the chips in your computer. As computers become faster and faster, it's because you're shrinking the size of all the little devices that go into those integrated circuits, like the microprocessors and memory chips," Stein said. "So, if you want to be able to pattern things that are very, very small, you need to have really good control over the reactions that create those patterns."

The bulk of Stein's research will involve performing very simple experiments with chemically amplified resists, interpreting the results of those experiments, and then building models to predict how those same materials will perform under much more complex circumstances, such as at the industrial scale. Having such a model in place would be a homerun for the semiconductor industry, as the time needed to evaluate materials and optimize their processing would be vastly reduced.

This latest study is a spinoff of previous research Stein published in the *Journal of Physical Chemistry C* in 2012, in which her team outlined a very simple model that can be used to predict a broad range of experimental data. "To our knowledge, that had never been done before," Stein said. "Now we're trying to understand why that model works so well."

Luckily, Stein said she and her team already have some predictions as to why such a simple model might work so well in accurately predicting complex chemical reactions. The general hypothesis, Stein explained, is that their simple model reflects three important factors that she and her research team believe to play a role in determining the outcome of these chemical reactions.

The first factor, Stein explained, relates to the complex dynamics of the polymer itself that, when blended with a catalyst, affects the way the catalyst moves and, therefore, how the reaction moves.

The second factor supposes that the temperature might not be constant throughout the reaction. Each chemical reaction that takes place releases heat, and the heat might not dissipate quickly enough to keep the temperature constant.

The third factor accounts for the possible plasticizing of the polymer film while the reaction is taking place, which could affect the outcome of the reaction. The byproducts of a chemical reaction might slightly melt the polymer film in which the reaction is taking place, making the film more liquid than solid. When the film changes from a more solid to a more liquid state, the movement of the small catalyst inside the film also changes, since small molecules move much faster inside liquids than in solids.

Through designing and conducting simple experiments, Stein's group will test these hypotheses to determine how any or all of the three factors play a role in these chemical reactions, and to what extent. "After completion of these tests, we expect to have an idea of which one is relevant – or if all are – and then move onto the next step, which is to refine our model based on what we learned," Stein said.

After refining their model, Stein's research team will begin nanopatterning tests to observe the same reactions at the nanoscale. This portion of the research will take place at the University of Houston's Nanofabrication Facility, a state-of-the-art cleanroom research facility equipped with an extensive toolset for nano- and micro-device prototyping and characterization. Once this portion of the research is completed, Stein said she hopes her team can then link what they observed in their experiments back to the underlying physics of the polymers used in these reactions.

If all goes perfectly to plan, Stein said this model could be implemented into semiconductor manufacturing processes immediately, taking out much of the guesswork with semiconductor patterning at the nanoscale. However, she noted that there is much work to be done before this dream becomes a reality.

"There are a lot of steps that need to happen before we can prove that the models we have can predict what happens in these systems rather than just describing what happens, but our hope is that this is something that could translate easily into manufacturing and could be dropped right into an industrial process simulator," Stein said.

Provided by University of Houston

Citation: UH chemical engineer makes device fabrication easier (2014, July 2) retrieved 27 April 2024 from https://phys.org/news/2014-07-uh-chemical-device-fabrication-easier.html