Nano World: Roadmap for nano-imprinting

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Scientists could soon easily fabricate electronics and other structures only nanometers or billionths of a meter in size by stamping them out, following a new strategy that could help guarantee results, experts tell UPI's Nano World.

Nanoimprint lithography acts much like a miniaturized rubber stamp, essentially pressing a mold into a soft polymer to create detailed patterns with features down to nanometers in size. It does not rely on expensive and cumbersome optics and lasers, making it simple and cheap. In 2002 Motorola became the first large semiconductor manufacturer to test a nanoimprint tool, and companies are racing to commercialize nanoimprinting, such as EVG, Molecular Imprints, Nanonex, Obducat and SUSS MicroTec.

"Users of nanoimprint lithography typically have a very good idea of the nanostructures that they wish to manufacture. However, they usually have no idea about how to exactly get there without trial and error. Our research gives them a roadmap to get to where they want to go," said researcher William King, a mechanical engineer at the Georgia Institute of Technology in Atlanta.

Quality issues plagued nanoimprint lithography. These were caused by unpredictability in how polymers flowed against the mold pressing into them. Earlier research into this complicated process often produced conflicting recommendations, forcing manufacturers to pursue costly trial and error.

King and his colleagues meticulously combined experimental data with computer simulations to analyze dozens of possible variable that might come into play in nanoimprinting, such as the viscous flow during the filling in the cavities in stamps of varying sizes and shapes. Certain variables carried different import depending on the scale involved. For instance, high-pressure gradients could exist inside the imprinting tools at the nanoscale "that are almost ridiculously high compared to what you would expect at the macroscale," King said.

"A lot of papers published on this topic actually disagree with each other. This is not because everyone was wrong with their theories, but rather they looked in a very narrow design space rather than look at the entire field. Our study was comprehensive, explaining phenomena seen by every single published study in this field," King said.

Nanostructure designers can now "consult our roadmap and then be directed as to how to achieve what they wish to achieve. They can plug in the size of their nanostructure, the material properties, and various process parameters such as time and temperature, and they can calculate exactly how their nanostructures will evolve and what they will look like," King said.

"Engineers that are using nanoimprint lithography to manufacture nanostructures now have rational guidelines to design their process. Before our research, they used ad-hoc methods and had no overarching rational engineering strategy for process design. It is now possible to engineer the nanostructures instead of just trial and error," he explained.

The researchers are improving their design rules to extend below 50 nanometers. "Right now they are very accurate from 1 millimeter down to 50 nanometers, and work only fairly well down to about 10 nanometers," King said. He added two large semiconductor firms and a number of smaller companies and startups are consulting with the research team regarding their nanoimprint lithography roadmap.

This research could "make life considerably easier for designers and production engineers," said condensed matter physicist Graham Cross at Trinity College in Dublin. "Although the King group has made a good start at comparing their theoretical predictions to the existing experimental data, further laboratory work of a more comprehensive nature will be needed to verify the hypotheses put forward. We are actively engaged in this process in our lab now."

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