EDITORIAL

Different and More Powerful, Not Just Smaller, Faster, Cheaper

A major driving force behind the development of new tools and techniques in nanoscience has been the ability to produce electronic devices and circuits with smaller dimensions, faster processing times, and cheaper production costs.[1] While "smaller, faster, cheaper" has become a mantra for the semiconductor industry and has motivated further development of established nanofabrication tools and methods, new capabilities are being enabled by chemical methods of nanofabrication and the resulting creation of nanoscale chemical patterns.[2−9] Likewise, a plethora of clever alternative methods for patterning at the nanoscale are being developed.[1,2] These creative methods are being used in areas far beyond device electronics, encompassing chemical, biological, medical, and other applications.

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These ideas were highlighted throughout the symposium on "Chemical Methods of Nanofabrication" at the Spring ACS National Meeting, organized by YuHuang Wang, Chad Mirkin, and So-Jung Park, and are described in their Nano Focus article in this issue.[2] The three-day symposium included more than 25 speakers delivering research talks spanning the range of techniques and applications in this field, from expanding the limits of traditional lithography, to the development of entirely new tools operating on fundamentally different principles from photolithography. Other presentations focused on bottom-up methods, including the use of biologically active molecules or diblock copolymers for templated nanomaterial synthesis and assembly.[10] The progress that has been made in synthesizing materials having smaller dimensions and assembling them into patterns with higher density is an indication that bottom-up methods will play important roles in device manufacturing and in not yet imagined applications.

Nanoscale chemical patterns can be made in arbitrary forms. Here, octadecanethiol has been patterned on a gold substrate using dip-pen nanolithography. Image courtesy Andrew Senesi and Chad Mirkin, Northwestern University.

Nanopatterning is an enabling step in many biomedical technologies, including biosensors, therapeutics, diagnostics, and tissue engineering. Two examples are described in this issue, both using patterned nanomaterials but applied to different bioengineering problems. Björn Reinhard and co-workers use a combination of electron-beam lithography and template-assisted assembly of nanoparticle cluster arrays to engineer substrates suitable for surface-enhanced Raman spectroscopy (SERS).[11] The patterned arrays show SERS signal enhancement and can discriminate between bacterial pathogens; this could provide an alternative to costly and laborious PCR-based diagnostic methods.

Regenerative applications, including neural tissue engineering, have also benefited from the use of nanopatterned substrates since neurite growth can be controlled and guided based on micro- and nanopatterned substrates presenting grooves or protrusions to cells. Younan Xia (also a speaker in the symposium) and co-workers examined neurite outgrowth on electrospun nanofibers oriented in three-dimensional networks and found that neurites could be directed based on the orientation and controlled alignment of electrospun fibers.[12] The three-dimensional nanofiber networks are systems that mimic the extracellular matrix and thus could be useful as simple scaffolds in nerve regeneration and repair.

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Increasingly, the nanofabrication and chemical patterning communities are taking cues from one another and even merging. This was evident at the ACS meeting. At major nanofabrication meetings, such as the International Conference on Electron, Ion, and Photon Beam Technology and Nanofabrication (EIPBN, or "Three Beams"),[13] chemical patterning is being highlighted. Merging the ideas and approaches of these communities will no doubt yield new opportunities and advances.

Finally, word just came to us that one of the leaders of this field, George Whitesides of Harvard University, has been awarded the inaugural Dreyfus Prize in the Chemical Sciences for "revolutionizing the chemistry of soft matter." Whitesides has been a key adviser, editorial advisory board member, and contributor to *ACS Nano*. We congratulate both him and all those in the field of chemical methods of nanolithography for being honored in this way.

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