European Commission

Science for Environment Policy

Making nano-scale manufacturing eco-friendly with silk

Nanolithography — a way of making finely detailed patterns or structures, such as those found in advanced computer microchips, uses toxic and corrosive chemicals. Researchers have now shown that these could be replaced with eco-friendly silk proteins and water, eliminating the need to use and dispose of hazardous chemicals, while achieving similar levels of detail to conventional methods.

In nanolithography, an underlying base, such as silicon, is coated with a polymer, called a 'resist'. A design is then 'drawn' on the resist, typically using a narrow beam of light or electrons. This changes the properties of the resist and reveals the design by allowing a solvent to either dissolve the drawn area (positive resists) or the area around it (negative resists).

Conventional nanolithography uses toxic resist materials and volatile organic compounds (VOCs) to create designs on the resists. The resulting toxic and VOC waste products are a hazard to both those handling them and the environment. As such, there is a growing need to develop safer, eco-friendly resists and solvents, especially as new production techniques move from small labs to large manufacturing plants.

Researchers are now turning to the natural world in search of green solutions, one of which may be silk. Silk proteins have a natural tendency to self-assemble into different structures under different conditions. Silk dissolves in water under some conditions, but is insoluble under other conditions. This suggests it may be possible to produce both positive and negative silk resists by controlling how they are made.

Additionally, without using harsh chemicals it may be possible to produce resists with enhanced properties. Biological components, such as enzymes, could be added to form biosensors, for example.

The researchers in this study coated silicon and quartz slides with silk proteins to produce both positive and negative resist types. They then used an electron beam, at different strengths, to draw a design on to the resists. They found that areas of water insoluble silk proteins (the positive resists) were degraded when exposed to electron beams, making them soluble. Higher strengths of electron beams could also change the soluble silk proteins of the negative resists into water insoluble forms.

This allowed them to create positive and negative resists, respectively. Using this approach, the researchers found they could produce structures with a resolution of 30 nanometres (nm), which is similar to existing techniques. They believe that this resolution could be improved with further development and optimisation.

The researchers also added chemical and biochemical substances, such as 'quantum dots' and enzymes, to silk solutions. They found that silk proteins can preserve the function of these substances, such as the ability of an enzyme to trigger a colour changing reaction in the presence of a chemical.

The results demonstrate that silk proteins may be a viable alternative to conventional techniques for nanolithography, avoiding the use of toxic chemicals and generation of environmentally hazardous toxic waste products. The researchers note that their technique did require higher strengths of electron beam than is typical in conventional approaches.

Importantly, the results have also shown that it is possible to encapsulate functional molecules in silk protein resists. This could potentially benefit a wide range of different applications. For example, it could lead to biosensors capable of identifying and measuring environmental contaminants, or in diagnosing disease using extremely small samples of blood or other biological fluids.

February 2015
Thematic Issue 48

Nanomaterials' functionality

Source: Kim, S., Marelli, B., Brenckle, M. a, *et al*. (2014). All-water-based electron-beam lithography using silk as a resist. *Nature Nanotechnology*. 9(4): 306–10. DOI:10.1038/nnano.2014.47

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