New patterning technique produces faithful reproduction of grayscale images down to micrometer level

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A scanning-electron micrograph of the 'Lena' image. © 2011 American Vacuum Society

In his 1959 lecture There's Plenty of Room at the Bottom, the US physicist Richard Feynman asked the question: "Why cannot we write the entire 24 volumes of the Encyclopaedia Britannica on the head of a pin?" Since then, scientists have made great advances in the nascent field of nanotechnology — and among them, the reading and writing of features at the atomic scale.

Current techniques for patterning features at the atomic scale, however, have been limited by their ability to replicate colors or grayscale information. Joel Yang at the A*STAR Institute of Materials Research and Engineering and co-workers have now developed a patterning technique that produces a faithful reproduction of grayscale images with accuracy down to tens of micrometers.

Conventional micro-patterning techniques typically build on halftone printing, whereby the brightness of the image is generated by varying the density of monochromatic elements. Yang's technique considers these elements as 'nanoposts' — posts of only ten nanometers in size — that are arranged in one of 17 possible patterns or 'shades'. It then produces faithful reproductions of grayscale images using these 17 shades in hand.

As a proof of principle, the researchers replicated the patterns of a test image (pictured) onto an area of 40 square micrometers. In the densest region, the separation between individual dots was a mere 10 nanometers.

The halftone technique had been used before to create grayscale optical micrographs. However, Yang and colleagues have now pushed the approach into the realm of electron microscopy: "Our technique utilizes an electron-beam-lithography method with one of the best resolutions, allowing us to create grayscale images that are highly miniaturized," explains Yang. "The method should be useful for creating images that can be seen under an optical microscope and may open up new avenues to adding colors to images."

Yang and his team envisioned several uses of the miniaturized images, for example, in anti-counterfeit features to nanophotonic devices. "But above all, these are striking images," says Yang. Indeed, one of the images — a 4000-fold miniaturization of M. C. Escher's mezzotint Dewdrop — has won last year's Grand Prize Award of the International

Conference on Electron, Ion, and Photon Beam Technology and Nanofabrication (EIPBN) conference. "Winning that award was a thrilling experience especially as it was presented by a community of nanofabrication experts", says Yang. "One who stares enough into the screen of a scanning electron microscope would appreciate the intrigue and aesthetic beauty of these micrographs. It is rare to see a scanning-electron-microscope image of a photo-realistic person staring back at you from the nanoworld."

More information: Yang, J. K. W., et al. Miniaturization of grayscale images. *Journal of Vacuum Science and Technology* B 29, 06F313 (2011). dx.doi.org/10.1116/1.3660790

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