

look-ahead



By Alan Richter, Editor

THIS MONTH

Cutting Tool Engineering covers:

- A nanoscale mechanical machining technique; and
- Tap development using advanced computer simulation.

NANOMACHINING

Fabricating nanoscale parts has been typically seen as a process that requires a bottom-up approach, where material is added—possibly atom by atom, according to Dr. Xiaodong Li, a professor at the University of South Carolina's Department of Mechanical Engineering who heads the school's Nanostructures and Reliability Laboratory. "People tried to throw away the traditional top-down approach of removing material to fabricate nanoscale devices and components," he said.

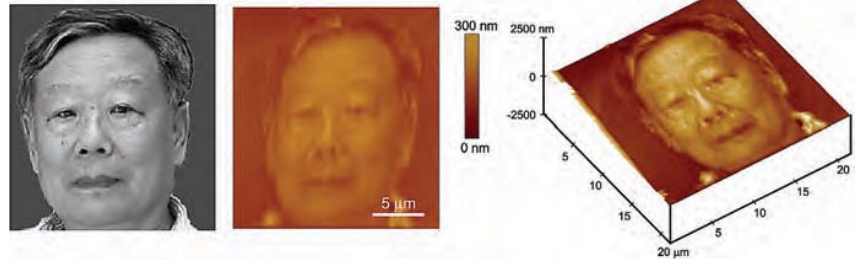
To demonstrate the feasibility of designing a nanodevice using CAD software and then applying traditional mechanical machining techniques to produce nanoscale parts and features, Li and researchers from the Harbin (China) Institute of Technology integrated a piezo closed-loop nanoscale-precision stage and an atomic force microscope. Although an AFM is designed for small-scale imaging and not machining, combining it with a piezo closed-loop stage overcomes the AFM's range and resolution limitations in its three axes for mechanical machining, according to professor Shen Dong, head of the Harbin Institute of Technology's group.

"You need feedback, so this is called a closed-loop system," Dong said. "It can precisely move the stage from one location to another with nanometer resolution." The stage is from PI (Physik Instrumente) GmbH & Co. KG, Karlsruhe, Germany, and the AFM from Veeco Instruments Inc., Santa Barbara, Calif., but other commercially available equipment is also suitable, he noted.

To demonstrate the capabilities of the stage and AFM device, the researchers

mechanically machined a 3-D human face with a frame size of $20\mu\text{m} \times 20\mu\text{m}$ and a peak-valley height of 120nm in a polished aluminum disk sample with a 9.8nm R_a . A single-crystal diamond tip with a 30nm radius mounted on the AFM's stainless steel cantilever scratched and plastically deformed the workpiece surface, mimicking a conventional CNC machine.

In addition to metal, the system can also machine polymers and semiconductor materials.



University of South Carolina

A digital picture of Shen Dong (left), a coauthor of the paper about nanoscale mechanical machining and a professor at the Harbin (China) Institute of Technology's School of Mechatronics Engineering, and the corresponding 2-D (center) and 3-D nanomachined images of his face machined in an aluminum workpiece.

There are three material-removal modes for the process: ploughing, wedge formation and cutting with chip formation. The feed rate plays an important role in determining the mode, and cutting is desired to achieve a fine surface finish, according to the researchers. The surface roughness of the machined nanostructures can be as fine as 4nm R_a . Cutting at a 200nm feed produced uniform grooves, whereas as the diamond tip was not always in a cutting state at feeds of 50nm and 100nm. Features machined in the Z-axis direction can be in the nanometer range, and those in the X- and Y-axis direction can be from 0.5 μm to 100 μm , Li noted.

The face took about 10 minutes to machine, which is too long for a commercially viable process, according to Li. He added that the team is attempting to realize high-volume batch processing.

For that, there are two approaches: having multiple tips on one cantilever to machine multiple parts simultaneously and machining a mold, or stamp, to perform high-volume nanoimprinting.

The team also plans to combine the top-down and bottom-up approaches, such as growing nanowires on a machined surface, to take advantage of both approaches and open up opportunities for fabricating active nanodevices and nanostructures. "For years, people in the community said, 'we cannot rely

on one method alone. We need to combine them,'" Li said. "We're making this dream come true."

For more information, contact the University of South Carolina's Nanostructures and Reliability Laboratory, Columbia, S.C., at (803) 777-8011 or www.me.sc.edu/research/nano.

TAPPING SIMULATION

Developing taps using physical prototypes is costly and time consuming, and creating them with static simulation software has its own set of drawbacks. Those include not providing information about edge temperatures, chip formation, temperature at the chip/rake face and other interfaces, maximum shear stress, and stresses at the cutting edges, minor diameter and OD, according to Anders Theorin, design engineer

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