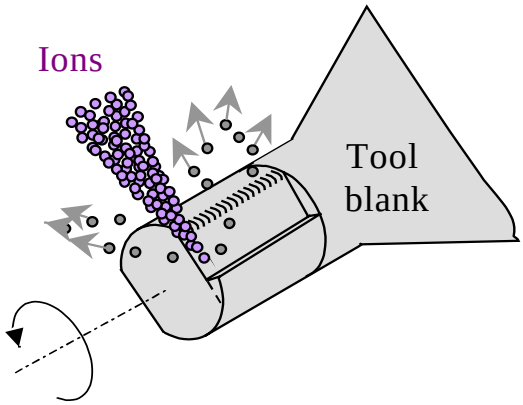
Ion Beam Manufacture of Microscale Tools

Manufacturing Technologies

Researchers at Sandia National Laboratories have developed techniques for manufacturing microscale tools. Items fabricated to date include machine tools and materials testing tools such as indenters. The techniques involve ion beam sputtering. Material is precisely removed from a solid object by bombardment with an energetic, focused beam of ions. The beam of ions can be guided to trace simple or complex geometric patterns, and may also be controlled in space and time to cut three-dimensional shapes, or profiles.

The ion beam manufacture of microscale machine tools developed from a desire to prototype mini- or micro-structures using conventional machining techniques, rather than lithographic methods.

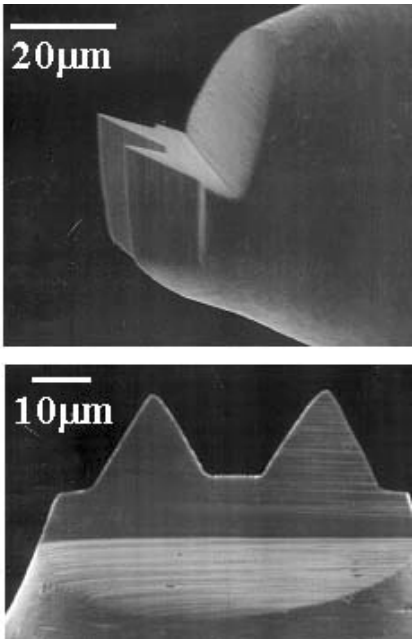


Schematic of ion beam sputtering technique

Capabilities and Applications

The technology can create custom-shaped, micron-size machine tools in materials such as diamond, tungsten carbide and tool steel. Techniques have been developed that establish cutting edge radii of curvature less than 100 nanometers.

Ion beam shaped diamond tools can create features in products that have a very specific surface geometry or an ultra-smooth surface finish. The specialized products can help the precision engineering community in their effort to make sub-micron production possible by ultra-precision machining. Milling tools and lathe tools have been made and tested by ultra-precision machining polymers, aluminum, brass and steel. Excellent pattern transfer is found on machined workpieces.



Two prong turning tool made of high speed steel

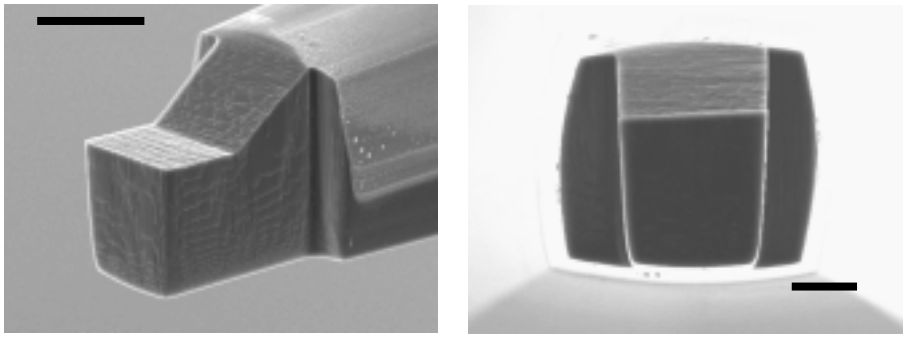
The ion beam technology can also create specifically shaped hardness testers (indenters) and nanoscratch tools, and could be used to manufacture microsurgical manipulators.

Features

The technology has many beneficial features including:

- shaping of most solid materials
- fabrication of a large range of geometric shapes in two and three dimensions
- tool dimensions from 100 microns to sub-micron
- dimensional resolution in the sub-micron region
- a relatively simple process to set up and control

The ion beam technology is unique. The material removal process does not heat the object being shaped. Furthermore, there are no large forces on the tool during ion shaping; material is removed at the atomic scale. In addition, the object that is being sculpted is observed during the manufacture, and the process can be altered if needed. Chemical assist can accelerate the rate of material removal.



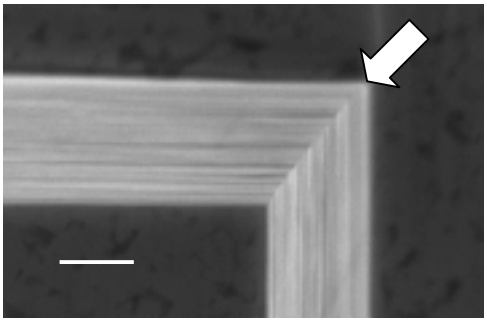
Single crystal diamond microtool shaped by focused ion beams

Accomplishments

- Fabrication of lathe tools having dimensions down to 5 microns.
- Fabrication of multi-tip lathe tools having dimensions of 10-50 microns.
- Fabrication of turning tools having triangular, trapezoidal, and other nonrectilinear cross-sections.
- Development of techniques for tailoring microtool rake and relief angles.
- Fabrication of single crystal diamond turning tools.
- Successful tests of micro-end mill tools and micro-turning tools on a wide range of materials and workpiece geometries.
- Fabrication of microindenters using focused ion beam sputtering.
- Development of a mechanical-based Damascene process for fabricating thin film microcoils on nonplanar substrates.

Contact
David Adams
505-844-8317
dpadams@sandia.gov

Michael Vasile
505-844-1858
mjvasil@sandia.gov



End view of microtool showing sharp cutting edge