Advanced Manufacturing Choices

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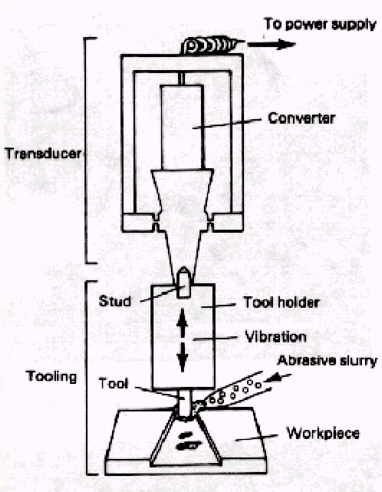
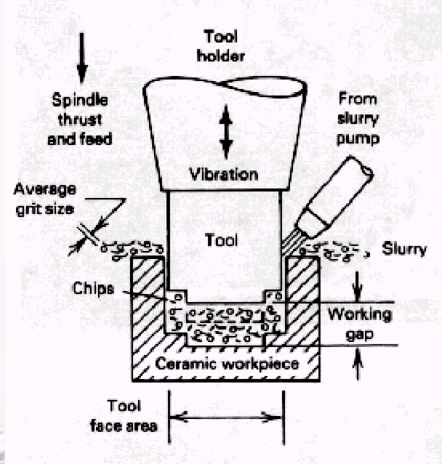
Ultrasonic Machining

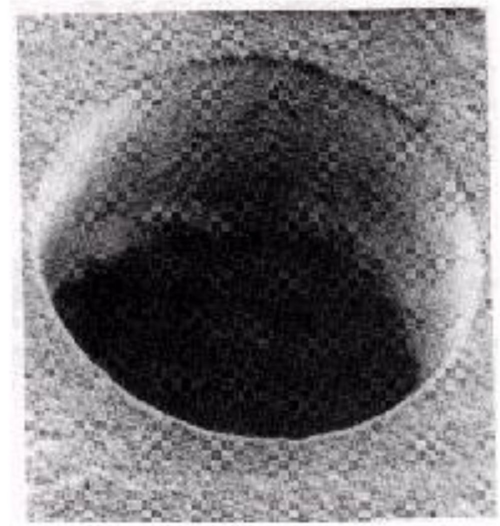
- In ultrasonic machining (USM), also called ultrasonic grinding, high-frequency vibrations delivered to a tool tip, embedded in an abrasive slurry, by a booster or sonotrode, create accurate cavities of virtually any shape; that are, “negatives” of the tool.
- Since this method is non-thermal, non-electrical, and non-chemical, it produces virtually stress-free shapes even in hard and brittle work-pieces. Ultrasonic drilling is most effective for hard and brittle materials; soft materials absorb too much sound energy and make the process less efficient.





Ultrasonic Machining

- Almost any hard and brittle material, including aluminum oxides, silicon, silicon carbide, silicon nitride, glass, quartz, sapphire, ferrite, fiber optics, etc., can be ultrasonically machined.
- The tool does not exert any pressure on the work-piece (drilling without drills), and is often made from a softer material than the work-piece, say from brass, cold-rolled steel, or stainless steel and wears only slightly.
- The roots of ultrasonic technology can be traced back to research on the piezoelectric effect conducted by Pierre Curie around 1880. He found that asymmetrical crystals such as quartz and Rochelle salt (potassium sodium titrate) generate an electric charge when mechanical pressure is applied. Conversely, mechanical vibrations are obtained by applying electrical oscillations to the same crystals. Ultrasonic waves are sound waves of frequency higher than 20,000 Hz.

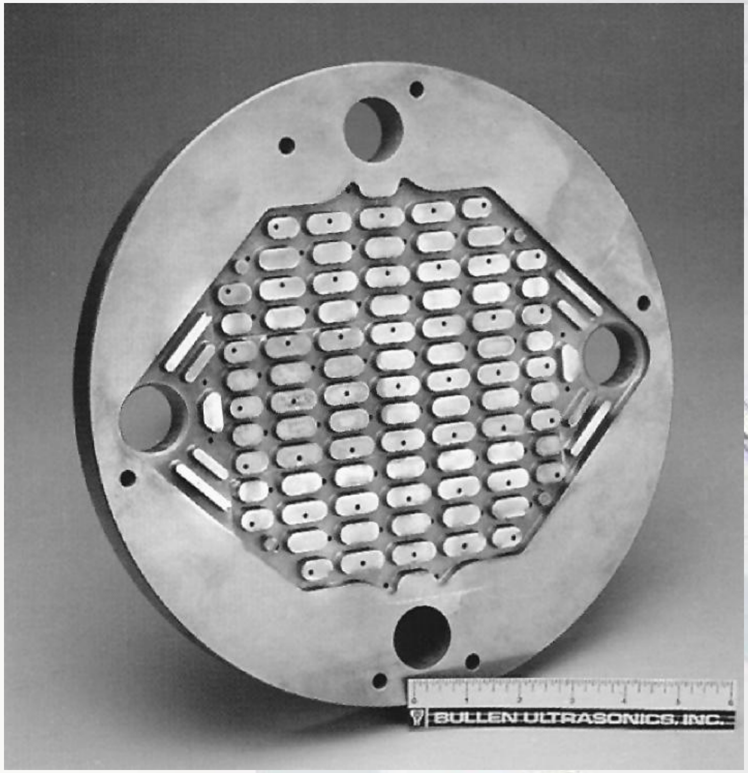


640µm hole by ultrasonic drill

Ultrasonic Machining

Channels and holes ultrasonically machined in a polycrystalline silicon wafer.

- The tool, typically vibrating at a low amplitude of 0.025 mm at a frequency of 20 to 100 kHz, is gradually fed into the work-piece to form a cavity corresponding to the tool shape.
- The vibration transmits a high velocity force to fine abrasive grains between the tool and the surface of the work-piece. In the process material is removed by micro-chipping or erosion with the abrasive particles.
- The grains are in a water slurry which also serves to remove debris from the cutting area. The high-frequency power supply for the magneto-strictive or piezoelectric transducer stack that drives the tool is typically rated between 0.1 and 40 kW.



Ultrasonic Machining

Coin with grooving carried out with USM

- The abrasive particles (SiC, Al_2O_3 or BC d= 8~ 500 μm) are suspended in water or oil.
- The particle size and the vibration amplitude are ususally made about the same.
- The particle size determines the roughness or surface finish and the speed of the cut.
- Material removal rates are quite low, usually less than 50 mm^3/min.

Ultrasonic Machining

- The mechanical properties and fracture behavior of the work-piece materials also play a large role in both roughness and cutting speed. For a given grit size of the abrasive, the resulting surface roughness depends on the ratio of the hardness (H) to the modulus of elasticity (E). As this ratio increases, the surface roughness increases.
- Higher H/E ratios also lead to higher removal rates: 4 mm^3/min for carbide and 11 mm^3/min for glass.

ultrasonic machining can be used to form intricate, finely detailed graphite electrodes.

Ultrasonic Machining

- Machines cost up to $20,000, and production rates of about 2500 parts per machine per day are typical.
- If the machined part is a complex element (e.g., a fluidic element) of a size > 1 cm^2 and the best material to be used is an inert, hard ceramic, this machining method might well be the most appropriate

900 watt Sonic-mill, Ultrasonic Mill

Ultrasonic Machining

Advantages and disadvantages of ultrasonic machining.

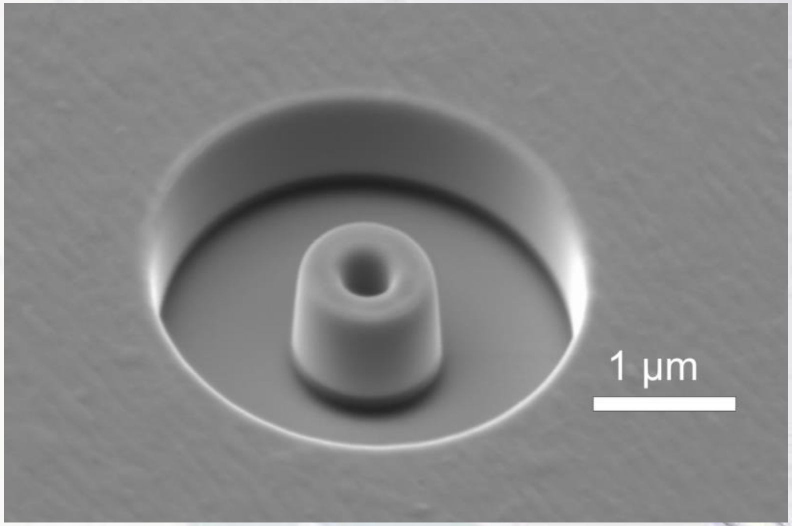
Advantages	Disadvantages
Machining of any material regardless of conductivity	Low material removal rate
Precision machining of brittle hard materials	Tool wears fast
Does not produce electric, thermal or chemical defects at the surface	Machining area and depth are quite restricted
Can drill circular or non-circular holes in very hard materials	
Less stress because of its non-thermal nature	

Focused Ion Beam Milling (FIB)

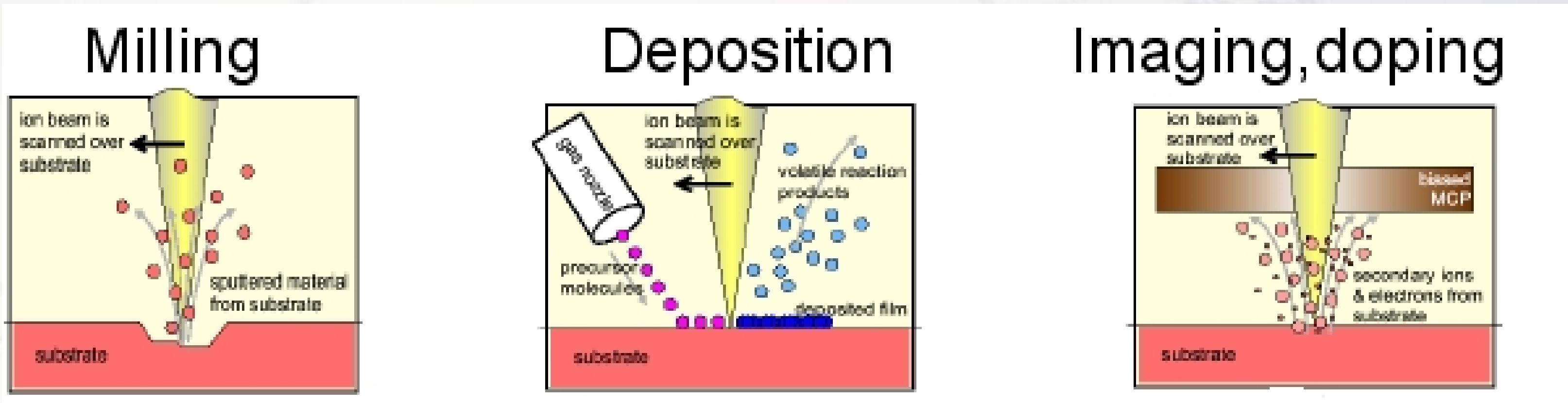
- Focused ion beam, also known as FIB, is a technique used particularly in the semiconductor and materials science fields for site-specific analysis, deposition, and ablation of materials.
- The FIB is a scientific instrument that resembles a scanning electron microscope. However, while the SEM uses a focused beam of electrons to image the sample in the chamber, a FIB instead uses a focused beam of ions.
- Gallium ions are accelerated to an energy of 5-50 keV (kiloelectronvolts), and then focused onto the sample by electrostatic lenses. A modern FIB can deliver tens of nanoamps of current to a sample and can image the sample with a spot size on the order of a few nanometers.

Focused Ion Beam Milling (FIB)

- Because of the sputtering capability, the FIB is used as a micro-machining tool, to modify or machine materials at the micro- and nanoscale. FIB micro machining has become a broad field of its own, but nano machining with FIB is a field that still needs developing.
- The common smallest beam size is 4-6 nm. FIB tools are designed to etch or machine surfaces, an ideal FIB might machine away one atom layer without any disruption of the atoms in the next layer, or any residual disruptions above the surface.



Focused Ion Beam Milling (FIB)



http://www.youtube.com/watch?v=VV90xM3QTcM