Micro Machining Brittle Materials with Poly Crystalline Diamond Micro Tools

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Objectives: Precision micro machining of brittle materials with a precision polycrystalline diamond (PCD) micro tool fabricated using micro electro-discharge machining (EDM).

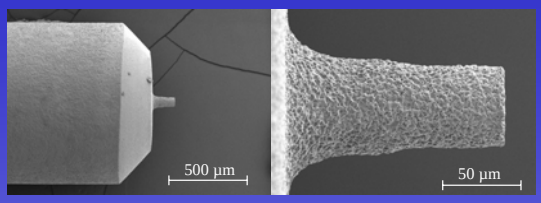

Figure 1. PCD Micro Milling Tool machined with micro EDM

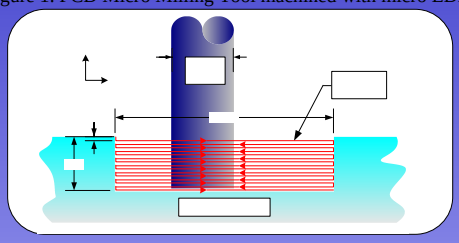
Figure 2. PCD milling geometry and tool path

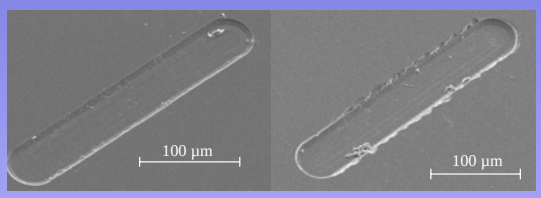

Figure 3. a) Groove machined in ULE glass with ductile mode grinding b) Groove machined in ULE glass with brittle mode grinding

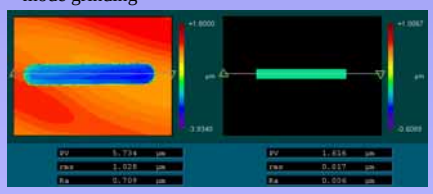
Figure 4. a) 3D surface measured with scanning white light interferometry b) bottom of the groove masked and filtered with a high pass filter with 10 µm wavelength

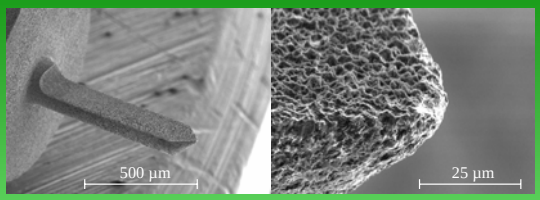

Figure 5. PCD Micro Drilling Tool machined with micro EDM

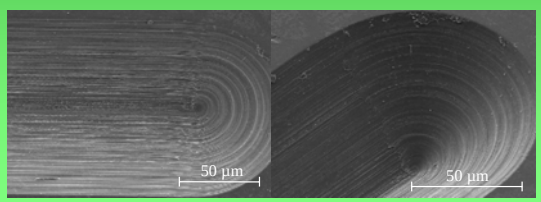

Figure 6. Vee-shaped groove machined in Soda-lime glass

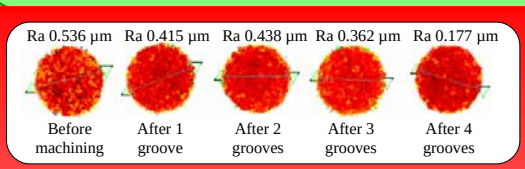

Figure 7. PCD Micro Milling Tool end-face wear during machining

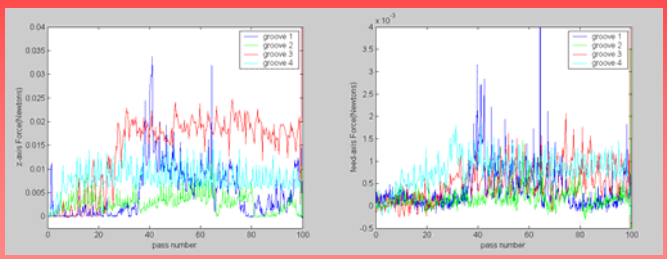
Figure 8. a) Plunge (Z) axis force measurements during the machining of four grooves b) Feed (X) axis force measurements

Project Summary: Micro machining is a flexible technique for producing 2½D and 3D microstructures, but cutting forces often restrict the workpiece to ductile materials with lower strength such as nickel and aluminum. To avoid this limitation, brittle materials, such as glasses and ceramics, and hard metals are usually micro machined without contact using lasers or micro electro discharge machining (µEDM). With the exception of lasers, micro machining processes generally suffer from tool wear, which degrades form accuracy if removing large volumes of material. Micro tools made of polycrystalline diamond (PCD), see Figures 1 and 5, offer a new alternative for micro machining hard and brittle materials. PCD consists of micrometer-sized diamond grains sintered under high temperature and pressure with metallic cobalt. The cobalt forms an electrically conductive network adequate for electro discharge machining. After shaping, the surface of a PCD tool contains protruding diamond grains that are randomly distributed. When the tool is rotated, the sharp protrusions act as hard and tough cutting edges for micro machining in a fashion similar to milling or drilling, see Figures 3 and 6. With precision control of the cutting depth and feed speeds, see Figure 2, the diamond grains are able to perform ductile mode grinding on brittle materials, such as, silicon, glass, tungsten carbide, and alumina. White light interferometry shows that the resulting surface finishes are on the order of a nanometer, see Figure 4. Analysis of the tool wear, see Figure 7, indicates that the tool "breaks in" during the machining of the first groove and the edges slowly dull during machining of subsequent grooves. Analysis of the cutting forces, see Figure 8, supports this hypothesis and shows that cutting edge is transitioning from the bottom of the diamond grain to the side.