Proceedings of the Canadian Society for Mechanical Engineering International Congress
32nd Annual Conference of the Computational Fluid Dynamics Society of Canada
Canadian Society of Rheology Symposium
CSME-CFDSC-CSR 2025
May 25–28, 2025, Montréal, Québec, Canada

Precision machining of glass in the submillimeter scale using thermochemically-assisted grinding

Guillaume Villeneuve[1], Jean-Philippe Leclair[1], Rolf Wuthrich[2], Lucas A. Hof[1]
[1] Department of Mechanical Engineering, École de technologie supérieure, Montréal, Canada
[2] Department of Mechanical and Industrial Engineering, Concordia University, Montréal, Canada
guillaume.villeneuve.1@ens.etsmtl.ca

Abstract

The mechanical, optical, and thermal properties of glass make it well-adapted for use in Micro-Electromechanical Systems–, optics, and microfluidics. However, micromachining glass and other SiO_2-based materials poses significant challenges due to their hardness and brittleness. Mechanical, thermal, and chemical machining processes face constraints related to processing speed, feature precision, and high costs. Additionally, the demand for glass microsystems is growing, and there is a lack of processes adapted to small-batch production and rapid prototyping of sub-millimeter scale glass parts.

Spark-Assisted Chemical Engraving (SACE), or Electro-Chemical Discharge Machining, is a hybrid machining process combining chemical and thermal effects to remove material. A tool-electrode applies electrochemical discharges near a nonconductive workpiece submerged in an electrolytic solution, accelerating the chemical etching through localized heating. This process removes material with minimal damage. Additionally, surfaces cut using SACE are immediately suitable for glass-to-glass bonding as no redeposition of material occurs around the machined zones.

While SACE is suitable for creating features ranging from 100 micrometers to 1 or 2 millimeters, processing times become very restrictive for larger feature sizes, i.e. a few millimeters. In the past years it was proposed to use abrasive tool-electrodes for simultaneous material removal through electrochemical discharges and mechanical grinding, improving material removal rates, while conserving the advantages of SACE, such as the absence of material redeposition and good surface quality. While some studies demonstrate the synergy between grinding and thermochemical etching, understanding the underlying mechanism of this hybrid machining process remains limited. This work aims to better characterize the interactions of the two material removal mechanisms and thus define a range of operating parameters to improve processing speed, reliability and cutting quality.

Borosilicate glass workpieces were submerged in 27% (wt.) potassium hydroxide (KOH). The tool-electrode, a 0.8 mm diameter diamond-coated grinding bit with cobalt binder, was used to grind and apply electrochemical discharges to create 0.8-mm wide channels in the workpiece. The effects of varying machining voltage, tool rotation speed, feed rate and depth of cut were studied. The measured response parameters were machining force, surface roughness and frequency of chipping of the material. Different cutting regimes were identified based on the relative intensity of the mechanical and chemical attacks.

It was found that the proposed thermochemically-assisted grinding process produces better surface quality with less chipping than grinding alone, while offering higher processing speed than SACE, highlighting potential for economically viable manufacturing of millimeter-scale glass parts in small batches.