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Etching of micro-channels in fused quartz for novel device applications

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ABSTRACT

Glass and fused-quartz are commonly used in microfluidic and optical sensor devices due to their chemical inertness and optical transparency. This study focuses on the etching of glass and fused-quartz using chemical etching and electrochemical discharge machining (ECDM) techniques. The aim is to compare their effectiveness and identify the most suitable technique for micro-channel formation. Chemical etching with hydrofluoric acid /Buffered hydrofluoric acid solution is commonly used for deep etching in silicon dioxide, but becomes challenging for long etching periods beyond 100 μm depth. There are primarily two problems: a) the integrity of the mask used for defining micro-channels; b) undercut below the mask edges. These two problems seriously limit the chemical etching process beyond 100 μm depth. A mask made of evaporated Au/Cr has been found effective in protecting borosilicate-glass during etching to a depth of 148 μm. However, etching of fused-quartz is much slower than borosilicate-glass while the mask integrity remains the same. Hence obtaining micro-channels beyond 100 μm depth is extremely challenging in fused-quartz. This study compares our results of chemical etching and ECDM of fused-quartz, concluding that electrochemical discharge machining is the effective and reliable technique for micro-channel formation on fused-quartz. The results showed a significant enhancement in surface quality as proven by UV–vis transmission data obtained after well-optimized BHF treatment on ECDM samples. Specifically, this treatment involved subjecting ECDM etched fused-quartz samples to a 1:1 BHF treatment for duration of 5 min. Following this optimal BHF treatment, the UV–vis transmission data showed an increase from 36% to 44% thereby meaning the surface roughness caused by ECDM has been smoothened during 5 min 1:1 BHF treatment. These findings provide valuable insights into the etching processes, masking materials, and techniques for micro-channel fabrication, with potential applications in microfluidics and optical sensing devices.

1. Introduction

Fused quartz and glass, due to their unique properties such as transparency, corrosion resistance, temperature resistance, and hardness[1], find widespread applications in microelectromechanical systems (MEMS), microfluidics, and lab-on-chip devices. To define patterns in glass and fused quartz, controlled etching in HF-based etchant is commonly employed [2,3]. Chemical etching and electrochemical discharge machining are known as superior techniques for etching glass and fused quartz. Notably, recent studies have investigated the machining of fluidic channels on borosilicate glass using grinding-aided electrochemical discharge engraving (G-ECDE) and process optimization methods [4]. The integration of such innovative approaches enhances the capabilities of glass machining, opening up new avenues for advanced microfluidic device fabrication. Electrochemical discharge machining (ECDM) has been proven to be a successful method of fabricating micro features in fused silica and glass substrates. Electrochemical machining (ECM) and electro-discharge machining (EDM) are combined in ECDM. Material removal happens by thermal melting, anodic dissolution and vaporization in the ECM and EDM processes,

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