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Precision Glass Microstructure Fabrication Using Femtosecond Laser Induced Chemical Etching (FLICE)

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1. Introduction

Femtosecond laser induced chemical etching (FLICE) is a novel technique that allows versatile micro-production of 3D structures in silica glass, allowing a range of lab-on-chips providing rapid analysis for bio/chem samples to be fabricated.

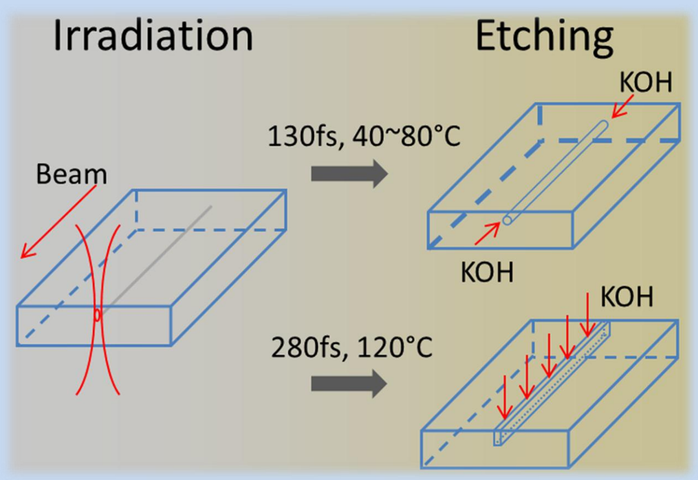
2. Objectives

HF acid is widely used in etching but is accompanied with low etching selectivity, depletion in deep tunnels and a high toxicity. KOH is a better alternative that overcomes these obstacles. Upon the optimisation of laser and KOH etching process, it is envisaged a versatile, high-throughput, high precision and safe process would be established.

3. Methods

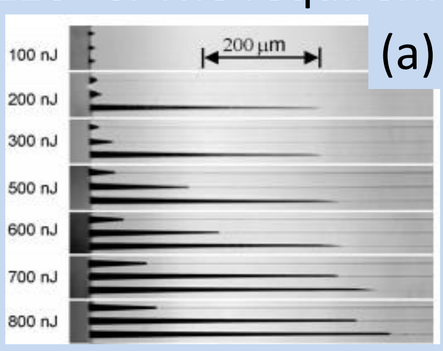
Two lasers were used to process fused silica plates mounted on a CNC stage with their parameters listed below. Beams were circularly polarised and focused by an objective (f=12.7mm). Samples were then etched in 10M KOH aqueous solution at different temperatures.

Laser model	Wavelength	Duration	Repetition rate	Beam ϕ	M^2
Spectra-Physics, *Hurricane i*	800nm	130fs	1-5kHz	5mm	2
Amplitude Systèmes, *Satsuma*	1030nm	280fs	1-2000kHz	2.2mm	1.1

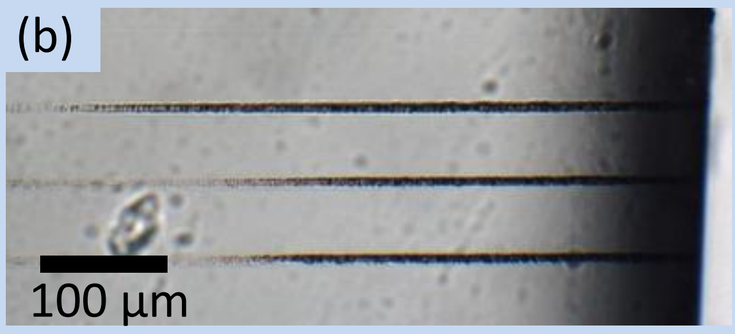


4. Results and discussion

Laser disrupted the glass structure, generated Si-rich nanoplanes in the affected zone and boosted its etchability to KOH. Two fabrication routes were established: in-bulk fabrication utilised irradiation with 130fs laser and etching in 10M KOH heated to 40~80° C, and surface fabrication used 280fs laser and etching at 120° C. The requirement for selectivity (20000:1) or raw glass removal rate (9.5μm/h) could be fulfilled.



(a)



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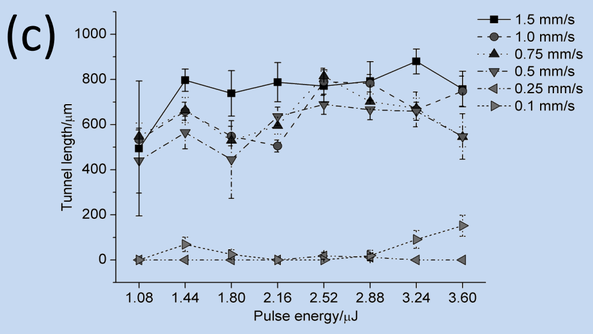

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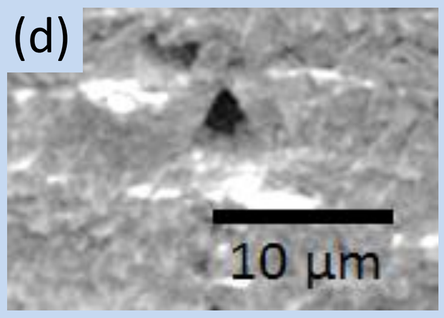

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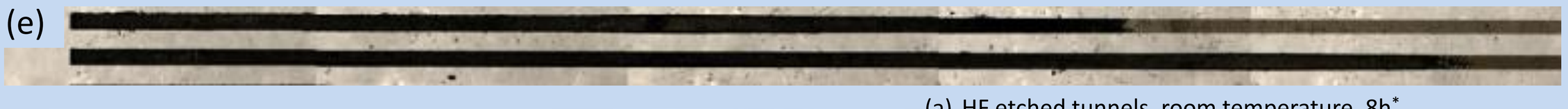
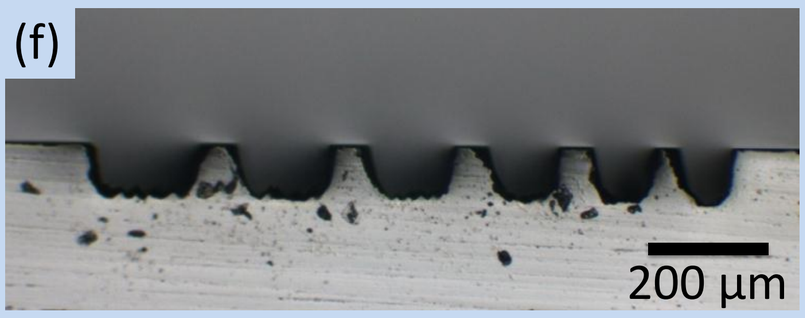


(e)



(f)

(g)

(a) HF etched tunnels, room temperature, 8h*
(b) KOH etched tunnels, 3.2μJ, 40°C, 5h
(c) KOH etched tunnel lengths vs energy and speed, 80°C, 4h
(d) SEM image of a tunnel inlet
(e) Blind tunnels by 3D stacking, 11mm long, breaking a previous record of 9mm-long through tunnels**
(f) A sideview of surface channels with line separations varied
(g) Fused silica IfM logo, 9.8 × 4.8 × 1.8 mm^3

5. Future work

A correlation between Si-richness and etch rate is yet to be discovered. Optimisations of FLICE are essential to the improvement of device precision and fabrication throughput and will be examined, such as laser pulse shaping, irradiation pattern design, enhancement of mass transfer in thin tunnels and heat treatments. These efforts will pave the way towards a feasible manufacturing process in microfluidics industry.

*C. Hnatovsky et al., Opt. Lett., vol. 30, pp. 1867-1869, 2005. **S. Kiyama, et al.,The Journal of Physical Chemistry C, vol. 113, pp. 11560-11566, 2009.

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