

3-D Fabrication of Microfluidic Channels in Fused Silica Using Focused Femtosecond Laser Beams and Selective Chemical Etching

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Abstract

Control of the polarization of femtosecond lasers can lead to the production of long-range periodic arrays of nanoplanes embedded inside fused silica. The nanoplanes result from the collapse of spherical shaped nanoplasma droplets into spheroids and finally into nanoplanes as the laser intensity increases above a threshold. This leads to the production of a “memory” of the nanoplanes or grating-like regions which then impose their structure in a self-replication manner on subsequent laser irradiated zones as the sample is scanned under the fixed focus of a lens. The nanostructures when exposed to chemical etching produce arrays of nanoslots whose orientation is perpendicular to the laser polarization direction. By choosing the laser polarization correctly it is possible to control the etch rate selectively within two orders of magnitude leading to very high etch rates compared to etching of uniformly modified material i.e. without nanoplanes.

We observe the existence of laser pulse energy thresholds for a wide range of laser pulse durations at which etching becomes highly selective¹. Focused (40-500fs) femtosecond pulsed radiation from a regeneratively amplified Ti:sapphire near-infrared laser ($\lambda=800$ nm, 100 kHz repetition rate, 300 mW average power) is used to modify zones inside optical grade fused silica blocks (Suprasil). The focusing is achieved by using NA = 0.45 lens with 13 mm working distance allowing microstructuring of thick blocks of material. To write the modification structures the sample is translated along (axial writing) or perpendicular (transverse writing) to the direction of propagation of the laser beam with speeds of 30-110 $\mu\text{m/s}$ whereby the sample is exposed to several thousand laser shots per micron of travel. Selective chemical etching in weak hydrofluoric acid (HF) is used to preferentially etch the modified zones to produce microfluidic channels².

One promising application of this technology is the direct writing of sub-wavelength pitch Bragg grating structures into fused-silica based fibers. In addition the capability of fabricating periodic array of nanoslots which can have slot widths as narrow as 10nm may be very useful in biosensing applications. Strong field enhancement at the sharp edges of the small metalized nanoslots can lead to surface enhanced Raman scattering for the label free detection of pathogens. It may also be possible to use this technology to create a nanopen to directly write imbedded lines with 10 nm precision. We will also demonstrate the feasibility of writing tapered small diameter (a few microns) microfluidic channels inside glass microscope slide for flow cytometry applications.

References:

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