Laser-Induced Backside Wet Etching: Mechanisms and Fabrication of Microoptical Elements

T. Lippert*, G. Kopitkovas, A. Wokaun
General Energy Department, Paul Scherrer Institut , CH-5232, Villigen-PSI, Switzerland

One of the most important commercial applications of quartz micro-lens arrays is laser beam shaping and homogenizing. Homogenizing of the collimated laser beam intensity is achieved by splitting the beam into many beamlets which are superimposed in the focal plane of the collecting lens. Micro-lenses in quartz are commercially fabricated by a multistep process, which involves photolithography, resist melt-reflow and Reactive Ion Etching processes. An alternative one step technique for etching of quartz was developed by Wang et al [1] where an organic solution which is in contact with the quartz is used for the absorption of laser photons. This technique has been named *Laser Induced Backside Wet Etching* (LIBWE). Our research on LIBWE is focused on studying the mechanism and to apply this technique for the fabrication of microoptical elements. A possible mechanism of LIBWE starts with the generation of a rapid temperature jump in the thin liquid-absorption layer. The temperature jump in the liquid layer causes in heating, melting or boiling of the quartz surface. The fast temperature rise in the thin quartz-liquid interface generates a shock wave and results in boiling of the solution. The rapidly expanding shock wave and collapsing of the laser induced bubbles yield a pressure jump. The temperature and pressure jumps are the key elements in the etching mechanism and we probe them with various methods. The laser induced temperature jump was studied experimentally by time resolved fluorescence spectroscopy of the organic compound, i.e. pyrene. The pressure jump was evaluated from the expansion of the shock wave and from the laser induced bubbles which were analyzed from time resolved shadowgraphy images. The experimental data are compared to a model of the LIBWE process which includes a temperature and pressure evolution. The calculated temperature decay of 3 μs agrees quite well with the experimentally obtained data, confirming very fast cooling process.

The etching of quartz by LIBWE and 308 nm irradiation reveals a complex behavior, which is depending on the concentration of the absorbing dye in the solution, laser wavelength and the laser pulse length. The best etching conditions in terms of the lowest etch roughness of <20 nm and etch rates of 10-30 nm/pulse are applied for the fabrication of microoptical elements. The necessary 3 dimensional structuring is achieved by the combination of LIBWE with projection of a Diffractive Gray Tone Phase Mask. This allows us to fabricate various microoptical elements e.g. plano convex micro-lens arrays in quartz [2]. These micro-lens arrays have been successfully tested as beam homogenizers for a quadrupled Nd:YAG and various excimer lasers.

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[2] G. Kopitkovas, T. Lippert, C. David, S. Canulescu, A. Wokaun and J. Gobrecht, J. Photochem. Photobiol. A-Chem. **166**, 135-140 (2004).

*Presenting Author: thomas.lippert@psi.ch; Telephone: +41 56 310 4076; Fax: +41 56 310 2688