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Atmospheric pressure plasma treatment of fused silica, related surface and near-surface effects and applications

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We report on an atmospheric pressure plasma treatment of fused silica and its related surface and near-surface effects. Such treatment was performed in order to improve laser micro-structuring of fused silica by a plasma-induced modification of the glass boundary layer. In this context, an atmospheric pressure plasma jet applying a hydrogenous process gas at ambient temperature was used. By the plasma treatment, the transmission of the investigated glass samples was decreased by maximum 4.28% at a wavelength of approx. 200 nm. Further, a decrease in the superficial index of refraction of approx. 3.66% at a wavelength of 636.7 nm was detected ellipsometrically. By surface energy measurements, a decrease of the surface polarity of 30.23% was identified moreover. These determined modifications confirm a chemical reduction of silicon dioxide to UV-absorbing silicon suboxide that was already reported in previous work. Further, a change in reflexion by maximum 0.26% was detected which is explained by the superposition of constructive and destructive interferences due to a surface wrinkling by the plasma. With the aid of atomic force microscopy, an increase of the surface root mean squared roughness by a factor of approx. 19 was determined. In terms of chemical and mechanical stability, it was found that both the surface energy and the strength of the fused silica surface were reduced by the plasma treatment. Even though such treatment led to a clustering of surface-adherent carbonaceous and aluminium-containing contaminants, a surface-cleaning effect was confirmed by secondary ion mass spectroscopy and energy-dispersive X-ray spectroscopy. The initially-mentioned increase in UV-absorption allows enhanced laser ablation results of fused silica as shown in previous work. It was demonstrated that finally, the increase in absorption can almost be reversed by thermal re-oxidation of the plasma-treated glass surfaces.

Keywords
plasma-induced surface modification
optical and topographic surface parameters
fused silica
hybrid laser-plasma ablation