Femtosecond laser-induced material modifications to control stress states in silica: a step toward metastable polymorphic phase generation

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Femtosecond laser exposure of silica in a non-ablative regime induces localized volume changes resulting in a stress-field surrounding laser affected zones. Here, we review these effects and illustrate potential applications of laser-induced controlled stress-state.

Non-ablative femtosecond laser pulses applied on fused silica induce mainly two types of modifications: homogeneous modifications and self-organized nanogratings\(^1\),\(^2\). Noteworthy, a localized net volume expansion is associated with the occurrence of self-organized nanogratings\(^3\) which orientation affects stress distribution\(^4\). For shorter pulses (< 200 fs) and low-energy – corresponding to the regime of homogeneous modifications, densification is observed\(^5\).

The laser pulse duration can therefore be used to introduce either tensile or compressive stress, which intensity and direction can be fine-tuned by controlling the pulse energy and the laser polarization.

Laser-induced stress in the material affects the laser exposure process but also has interesting applications. For instance, it can lead to path-dependent machining, but if controlled (see illustration), can also be used to create known stress state\(^6\). It may also offer a path for high-pressure phase generation in silica.

Controllable bulk-stress state has a high technological potential in the field of integrated microsystems, and more generally, as a possible tool for better understanding the formation of high pressure phases in silica.

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\(^6\) B. McMillen and Y. Bellouard, Optics Express 23, 86–100 (2015).