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Femtosecond laser structuring in dielectrics[1]

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Three-dimensional (3D) structuring of glasses, crystals, and polymers by tightly focused femtosecond laser pulses is a promising technique for microfluidic, micro-optical, photonic crystal and micro-mechanical applications [1-4]. The 3D laser microstructuring of resists is demonstrated by direct laser writing [1] and holographic recording using phase control of interfering pulses [2]. Tightly focused laser pulses can reach dielectric breakdown irradiance without self-focusing when sub-1 ps pulses are used for laser-structuring inside dielectrics. The limiting case of microstructuring, a void recording, can be achieved [3]. The mechanism of void formation has been explained as a result of dielectric breakdown and micro-explosion. The absorption is localized within a skin depth of tens-of-nanometers in the plasma at the focus. This defines an ultimate localization of the energy delivery by a laser pulse. The absorbance reaches 0.6 in a fully ionized solid state density breakdown plasma. The high temperature and pressure buildup is large enough to generate a shock wave (strong micro-explosion). For example, a single 100 nJ laser pulse forms a void under tight focusing conditions even in the high strength sapphire (Young modulus of 400 GPa). It is considered that material fails upon compression rather than tension for which the mechanical failure threshold is by an order of magnitude smaller. This scenario of breakdown by compression is corroborated by numerical modeling of the strong explosion at our experimental conditions. Modification of materials by tightly focused femtosecond pulses opens new material processing routes for inert dielectrics [4] and can possibly be used for creation of new high-temperature and pressure phases inside the volume of irradiated samples. These regions with altered nano-structure have different chemical properties as was found in silica glass, quartz, and sapphire by wet etching of the "shocked" regions in aqueous solution of hydrofluoric acid. Current challenges of structural characterization of micrometer-sized volumes of nano-structures materials are discussed. The achievable resolution limits and potential of the fabricated 3D patterns in photonics, micro-fluidics, and sensor applications will be presented. [1] K. K. Seet et al., Adv. Mat. 17, 541, 2005. [2] T. Kondo, et al., New J. Phys. 8, 250, 2006. [3] S. Juodkazis, et al., Phys. Rev. Lett. 96 166101 2006. [4] S. Juodkazis, et al., Adv. Mater. 18 1361 2006.

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