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Ultrashort laser modification of transparent materials: Synergy of excitation/relaxation kinetics, thermodynamics and mechanics

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Ultrafast laser modification of transparent materials is an important technique enabling production of 3D photonic structures whose practical applications are rapidly widening. The physics behind laser-induced modifications is extremely rich and involves a variety of consecutive processes initiated by radiation absorption during the laser pulse and extending to millisecond timescales when the final structure becomes "frozen" in the material matrix. The quality of the final structures depends of the synergetic action of excitation of confined electron plasma, its relaxation with drawing matter into different thermodynamic states from soft heating to extreme conditions, generation of GPa pressures resulting in shock-induced material deformations, re-forming of covalent bonds upon photo-excitation of the material network. In this report, we will review the physical processes responsible for various forms of laser-induced modification in wide-bandgap materials, including volume nanograting formation. We will present the modeling results obtained on the basis of the Maxwell's equations supplemented with equations describing the dynamics of the laser-induced electron plasma on the example of silica glass for typical experimental conditions. The temperature and associated stress levels are mapped in the laser energy absorption zone which may be foreseen at the end of electron – glass matrix relaxation, enabling to make conclusions on the routes of glass modification. Finally, the energy balance is considered, matching the free electron density and temperature with several threshold values (melting, plastic deformation, material failure with void formation, sublimation).

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Biography

Nadezhda M. Bulgakova studied physics at the Novosibirsk State University, Russia (Chair of Plasma Physics). After graduation, she joined the Institute of Thermophysics (Siberian Branch of the Russian Academy of Sciences) where she received her Ph.D. degree in 1985 and Dr.Sc. degree in 2002. In 2010 she received a Marie Curie International Incoming Fellowship and in 2011 joined the Optoelectronics Research Centre at the University of Southampton. Her research interests include processes in solid targets absorbing laser radiation; dynamics of plasma plumes during pulsed laser ablation of solids; cluster formation in free gaseous jets and laser-ablation plumes; plasma-chemical reactions.

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