Abstract

This thesis investigates the process of ultrashort pulsed laser ablation of dielectrics using a combination of ex-situ morphological examinations with in-situ time-of-flight mass spectrometry of the ablated species. Non-thermal and thermal processes are identified under specific conditions of irradiation. The thesis will discuss the identification of the different mechanisms involved and emphasize their temporal characteristics. Results of both static and dynamic experiments are presented. In the first set, investigations on the morphology of the irradiated spot as well as on the induced laser plume are reported together with measurements on the kinetic quantities describing the plume that are particular to specific mechanisms of ejection. Analysis of the energy spectrum of ablation products provides a wealth of information on the processes occurring during femtosecond laser ablation of materials. The presentation will focus on the case of sapphire (Al_2O_3) and discuss the fundamental processes in ultrashort pulsed laser sputtering. Two different ablation phases have been identified, a „gentle“ phase with low ablation rates and high efficiency in ion production, and a „strong“ etch phase with higher ablation rates, but with lower structure quality. A comparison of the energy and momentum distributions of ejected ions, neutrals and electrons allows one to distinguish between non-thermal and thermal processes that lead to the macroscopic material removal. Fast positive ions with equal momenta are resulting from Coulomb explosion of the upper layers at low fluence and low number of irradiating laser pulses („gentle“ etch phase). Pump-probe studies with fs laser pulses reveal the dynamics of excitation and electron mediated energy transfer to the lattice. At higher laser fluences or after longer incubation, evidence for phase explosion can be derived from both the morphology of the surface and the results of the in-situ experiments.

In the second set of experiments, the process of electron emission from ultrashort pulsed laser irradiated dielectric surfaces is followed. Prompt electrons are evidenced as a direct product of excitation. Their temporal dynamics support the idea of an electrostatic repulsion of material due to electrostatic energy accumulation balanced by heat deposition due to electron phonon coupling.

Finally, the knowledge gained from the fundamental studies is used to advocate the tremendous potential of femtosecond pulses for transparent material micromachining. Some examples are given.