Damage processes in ruthenium thin films induced by femtosecond laser pulses for a wide range of incident photon energy

I. Milov, I.A. Makhotkin, N. Medvedev, V. Lipp, B. Ziaja, V. Khokhlov, V. Zhakhovsky, Yu. Petrov, V. Shepelev, D. Ilnitsky, K. Migdal, N. Inogamov, E. Louis, F. Bijkerk

MESA+ Institute for Nanotechnology, University of Twente,
Drienerlolaan 5, 7522 NB Enschede, The Netherlands

Radiation stability of optical elements exposed to a high dose of laser radiation is an important issue in developing optical elements for x-ray free electron laser light sources. In order to prevent optics from being damaged, the fundamental mechanisms governing the material response to ultrashort high peak power XFEL pulses must be identified and studied. In this paper we present a study on the interaction of fs laser pulses with Ru films in a wide range of incident photon energies from ~1 up to 10000 eV.
Since reflective thin metal films operate at grazing incidence conditions, absorption of the light occurs in the top part of the Ru mirrors (~1 – 10 nm). Hybrid multi-scale modeling of target evolution after irradiation is performed. The model takes into account photoabsorption and non-equilibrium electron cascading occurring on a fs timescale, thermal diffusion and electron-phonon energy exchange on a ps timescale and lattice dynamics up to ns timescale. Different photon energies result into qualitatively different absorbed energy profiles by the time of thermalization of the electronic system. The effects of such a difference on the hydrodynamical evolution and eventual damage of Ru are discussed. Details of processes such as melting, cavitation, ablation and recrystallization are revealed for selected photon energies. The results show good qualitative agreement with the experimental observations on Ru ablation.