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Interaction of intense nanosecond pulses of extreme ultraviolet (EUV) with gases and solids

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Results of investigation on interaction of intense nanosecond extreme ultraviolet (EUV) pulses with gases and solids are presented. EUV is generated using laser plasma sources based on plasma produced by irradiation of a gas puff target with nanosecond laser pulses. Commercially available Nd:YAG lasers (EXPLA) generating 4 ns/0.8 J or 10 ns/10 J at 10 Hz were used to irradiate the double-stream Kr/Xe gas puff targets. EUV radiation, with a strong maximum around 11 nm, was focused using an axisymmetric ellipsoidal grazing incidence mirror (Rigaku). The EUV beam diameter (FWHM width) in the focus was about 1 mm with the maximum fluency approaching 0.1 J/cm2 in case of low laser energy and 0.5 J/cm2 in case of high laser energy.
Interaction of EUV pulses with gases was performed by focusing EUV radiation onto a gas stream injected into the focus region. Various gases, including atomic (Xe, Kr, He, N2) and molecular (SF6, CH4) gases, have been used in the experiments.The spectral measurements in the visible and EUV regions have shown that cold plasmas (Te < 1 eV) with relatively high density (1017 −1018 cm-3) were produced as a result of photo-ionization of gases with EUV photons. The EUV photo-ionized cold and dense plasma has high potential for the use in material engineering for modification of surfaces.
Investigations on interaction of EUV nanosecond pulses with solids have been performed by focusing an EUV beam onto a flat sample placed in the focus. The effects of the interaction depend on the type of material being exposed by the EUV pulses. In the case of irradiation of the polymer, strong ablation of the material and modification of its surface by the formation of micro- and nanostructures were observed. Exposure of the crystals led to the appearance of cracks along the crystalline surfaces, while irradiation of semiconductors modified their surface. Irradiation of metal surfaces with a low melting point caused the formation of craters, whereas no visible changes were observed on the surface of metals with a high melting point.
The EUV interaction process with solids has been also studied using the theoretical hydrodynamic model and computer simulation. Interaction of 3 ns EUV pulses with a 50 micrometer-thick tungsten plate at energies of the pulses: 1 mJ and 10 mJ was studied. Spatial and temporal profiles of temperature and density of the EUV irradiated plated. The maximum temperature in the surface layer was up to 4500 K in case of higher energy of the EUV pulse and about 3500 K in case of lower energy.
Exposure with nanosecond EUV pulses can be applied in micromachining polymers, surface modification of polymers and semiconductors, and the technology of rapid heating of solid materials (annealing) in order to change their internal structure without introducing changes to the surface.

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