Comparison of different models describing the temperature dependent dielectric function: Validation of models with time-resolved pump-probe reflectometry and ellipsometry

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Irradiating thin metal films with single pulsed ultrafast laser radiation two distinguishable ablation regimes are obtained experimentally depending on the applied fluence, so called gentle and strong ablation regimes [1]. The principle mechanism causing gentle and strong ablation are studied either by hydrodynamic [2] or atomistic [3, 4] approaches. Nevertheless, time-resolved metrology [5], like ultrafast pump-probe reflectivity and ellipsometry, measuring the temporal evolution of the spatial distribution of the reflectance and complex refractive index, and thus the temperature and stress dependent dielectric function, have to be performed to validate simulations in terms of simulated and experimentally obtained changes of the dielectric function. Therefore, the temperature and stress dependence, especially for non-equilibrated electron and phonon systems, caused by heating the material with single pulsed laser radiation with a pulse duration of several 10 femtoseconds, and subsequently induced rarefaction and shock waves, must be included in a wide range model for the dielectric function.

In our approach, using the Drude-critical point model with fitted parameters to reproduce the experimentally determined complex refractive index for gold at rest and additionally modifying the model to include the temperature and stress dependence. Finally, the simulated relative reflectance change and the complex refractive index of an irradiated thin gold film ($d = 200$ nm) with ultrafast laser radiation (pump radiation: $\tau_H = 40$ fs, $\lambda = 800$ nm, probe radiation: $\tau_H = 60$ fs, $\lambda = 440$ nm) are compared with the experimentally obtained results (Fig. 1). The temperature and stress distribution are calculated by a hydrodynamic approach [4].

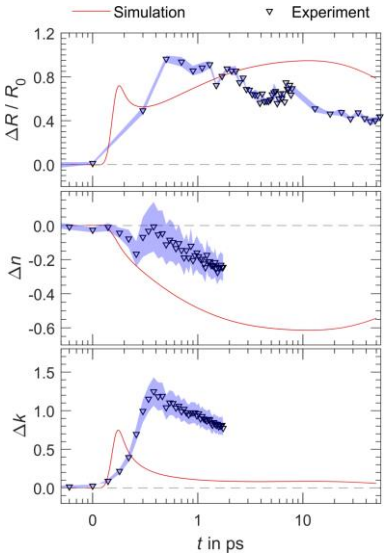

Fig. 1. Comparison of experimentally determined and simulated relative change of reflectance and complex refractive index

Keywords: pump-probe ellipsometry; pump-probe reflectometry; ultrafast material processing; thin films of gold

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