GROWTH OF LASER-INDUCED PERIODIC SURFACE STRUCTURES UNDER COMPETING ABLATION AND PHOTO-EXPANSION MECHANISMS

We study the formation of laser-induced periodic surface structures (LIPSSs) using a femtosecond pulsed laser source on the basis of the Sipe-Drude theory solved with a finite-difference time-domain (FDTD) scheme. LIPSSs consist of wavy nanometric structures and can be categorized depending on their orientation with respect to the incident laser polarization and their periodicity Λ with respect to the incident laser wavelength λ. The Sipe-Drude theory predicts with success a few types of experimentally observed structures by considering electromagnetic propagation through the rough surface of a bulk with given ionization density. For instance, structures orientated perpendicular to the light polarization and with periodicity of $\Lambda \sim \lambda$ are predicted for strongly absorbing materials, such as metals or ionized dielectrics. For less absorbing materials, structures parallel to the polarization with periodicity of $\Lambda \sim \lambda/\mathrm{Re}(\tilde{\epsilon}^{1/2})$ ($\tilde{\epsilon}$ is the permittivity obtained with the Drude model) are predicted. With our FDTD solver, we find, in as yet unexplored regions of parameter space, that a linearly polarized laser pulse can interact with a rough surface such that bidimensional structures could grow with both parallel and perpendicular periodicity of $\Lambda \sim \lambda$.[1]

However, this theory cannot predict the strong organization and regularity in the space domain, as observed in the experiments. Implementing self-organization mechanisms in the model as inter-pulse feedback is a possible solution to simulate the growth of strongly organized LIPSSs from one laser pulse to the next. This method, introduced recently by Skolski *et. al.*,[2] uses a non physical ablation process to qualitatively account for material removal between two laser pulses. This new model can reproduce a larger variety of structures with much better spatial regularity than the Sipe-Drude Theory, but still fails to predict amplitude growth of some of the structures. We suggest that those remaining structures can grow by considering an inverse mechanism, a non physical photo-expansion process. By combining ablation and photo-expansion mechanisms, we have successfully simulated the growth of a large class of LIPSSs. The calculations are qualitatively supported by experimental results.[3]

The next step of this study will be to implement an intra-pulse feedback mechanism by considering the time and space dependence of the bulk ionization in the early stage of a femtosecond pulse irradiation. This will reveal key information on the contribution of local permittivity variations within the first few optical cycles of the incident beam. Future perspectives and extensions will be discussed at the conference.

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[1] J.-L. Déziel, J. Dumont, D. Gagnon, L. J. Dubé, S. H. Messaddeq, and Y. Messaddeq, (to be published).

[2] J. Z. P. Skolski, G. R. B. E. Römer, J. Vincenc Obona, and A. J. Huis in't Veld, J. Appl. Phys. **115**, 103102 (2014).

[3] S. H. Messaddeq, J.-L. Déziel, A. Dumont, and Y. Messaddeq, (to be published).