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Impact of plasmonic modes and metal thermophysical properties on the formation of self-organised nano-patterns in thin films

Panagiotis Lingos[1], **George Perrakis**[1], **Odysseas Tsilipakos**[2,1], **George D. Tsibidis**[1,3], **Emmanuel Stratakis**[1,4]

1. Institute of Electronic Structure and Laser (IESL), Foundation for Research and Technology (FORTH), Vassilika Vouton, 70013, Heraklion, Crete, Greece
2. Theoretical and Physical Chemistry Institute National Hellenic Research Foundation, GR-11635 Athens Greece
3. Department of Materials Science and Technology, University of Crete, 71003, Heraklion, Greece
4. Department of Physics, University of Crete, 71003, Heraklion, Greece

Nanoscale laser-induced periodic surface structures in thin metal films (of the size of the optical penetration depth) is a yet unexplored area that is expected to open new routes for laser patterning and a wealth of exciting applications in optics, photonics, and sensing. In contrast to the common belief that excitation of Surface Plasmon Polaritons (SPPs) on the air/metal interface plays the dominant role in the features of the induced topographies, in this work, we demonstrate that the excitation of coupled SPPs in both air/metal and metal/substrate interfaces (Fig.1a), along with other parameters such as the thickness of the material, the photon energy, and the substrate refractive index, dictate the spatial modulation of the absorbed energy. Results are shown for Au while the methodology can be followed for any metal. A detailed theoretical analysis of the excited plasmonic waves and a multiscale modelling of laser-induced physical phenomena manifests that depending on the laser conditions and thickness of the irradiated solid, topographies with periodic features of diverse sizes (ranging from $\lambda_L/3$ to λ_L, where λ_L stands for the laser wavelength) and different orientation can be realized (Fig.1b) [1].

Furthermore, to illustrate the role of thermophysical properties of the irradiated solids on the features of the produced periodic topographies, the formation of periodic patterns on two materials of different electron-phonon coupling and electron heat conductivity (Au, Stainless Steel) is analysed in detail (Fig.1c,d). Results demonstrate the pronounced role of these parameters [2]. The capability to control and tune the characteristics of the produced structures on thin films is expected to enable novel surface patterning approaches.

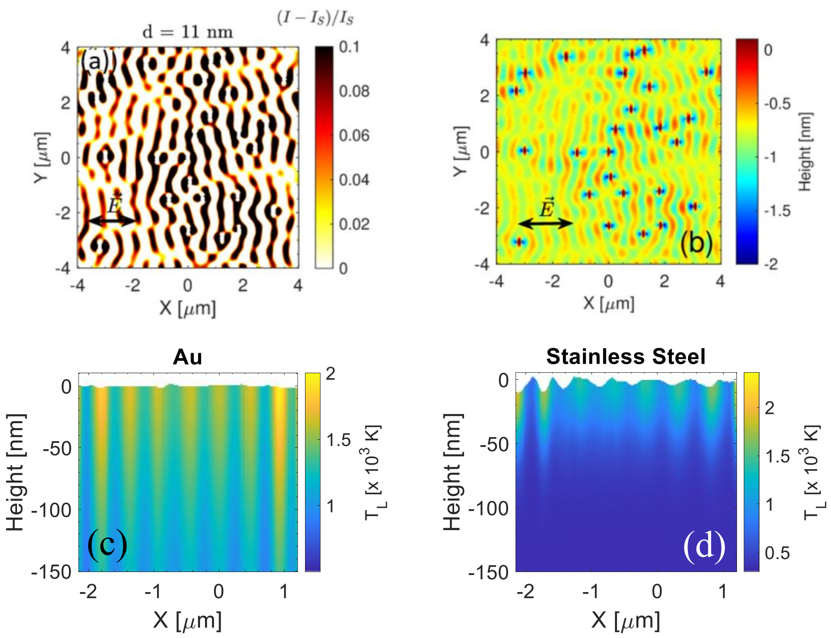

Fig. 1 (a) Scattering by randomly distributed nano-defects of radius r = 50 nm and average spacing l ≈ 1.6 μm for film thickness d=11 nm (air/Au/SiO2 structure). Intensity distribution in the xy plane just below the top air/Au interface for λ = 1026 nm. (b) LIPSS patterns on Au for thickness d = 11 nm. (c) Lattice temperature spatial profile at time t=20 ps for (c) Au, (d) Stainless steel. Produced corrugation is shown in (c), (d) after 5 pulses.

References

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