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3D MULTIPHYSICS FEM MODELING OF NANOSECOND PULSED LASER INTERACTION WITH METALLIC FILMS

Evaggelos Kaselouris[1,2], Ioannis K. Nikolos[2], Yannis Orphanos[1,3], Efthimios Bakarezos[1,4], Nikolaos Vainos[3], Nektarios A. Papadogiannis[1,4], Michael Tatarakis[1,5] and Vasilis Dimitriou[1,6]

[1]TEI of Crete, Centre for Plasma Physics & Lasers, 73133 Chania, 74100 Rethymno, Greece
v.kaselouris@chania.teicrete.gr, yorphanos@staff.teicrete.gr, bakarezos@staff.teicrete.gr
npapadogiannis@staff.teicrete.gr, m.tatarakis@chania.teicrete.gr, dimvasi@chania.teicrete.gr
and http://www.cppl.teicrete.gr
[2]TUC, School of Production Engineering & Management, University Campus 73100 Chania, Greece, jnikolo@dpem.tuc.gr and http://www.dpem.tuc.gr
[3]UoP, Department of Materials Science, 26500 Rio, Greece, vainos@upatras.gr and http://www.matersci.upatras.gr/
[4]TEI of Crete, Department of Music Technology & Acoustics, 74100 Rethymnon, Greece and www.teicrete.gr/mta
[5]TEI of Crete, Department of Electronics, 73133 Chania, Greece and https://www.chania.teicrete.gr/academic/electronics-department
[6]TEI of Crete, Department of Natural Resources & Environment, 73133 Chania, Greece and https://www.chania.teicrete.gr/academic/natural-resources-department

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The 3D dynamic response of thin metallic film-substrate solid structures excited by a nanosecond laser pulse is studied. A coupled thermal-structural, transient model based on the Finite Element Method (FEM) is developed to give an integrated spatiotemporal numerical solution in the three dimensional (3D) space. The model is built in a sophisticated way so as to compute the phase changes of matter, with respect to the material properties and the laser irradiation parameters used. Mathematical and material modeling, are robustly updated by the help of criterions based on the thermal changes of the sample. The parametric model offers insights to key physical quantities such as displacements, temperatures, velocities, stresses etc. at every spatiotemporal solution. To validate the numerical results, a whole-field experimental dynamic interferometric technique is used. This diagnostic technique allows the direct monitoring of the spatiotemporal deformation of a macroscopic area on the surface with ultrahigh lateral resolution, at every regime: elastic, melting, ablation/plasma.

In the thermoelastic regime the thin film surface deforms after the laser excitation without altering its elastic properties. Absorption of the laser pulse results in an increased localized temperature, which in turn causes thermal expansion and generates surface acoustic waves (SAWs) [1]. For greater laser intensities the target surface temperature overcomes its melting point and the thermal and optical properties of the irradiated material change. When the target surface temperature overcomes its boiling point, ablation occurs. For incident laser intensities greater than the ablation threshold a large amount of electrons, ions and excited neutrals is present in the vaporized material and absorb the laser light forming plasma [2]. To simulate the laser matter interaction with the thin film substrate, a 3D quarter symmetric FEM model is developed. The performed simulations assume gold (Au) metal films deposited on glass BK7 substrates and are carried out using the transient thermal-structural analysis of ANSYS® 14.5 [3,4,5].

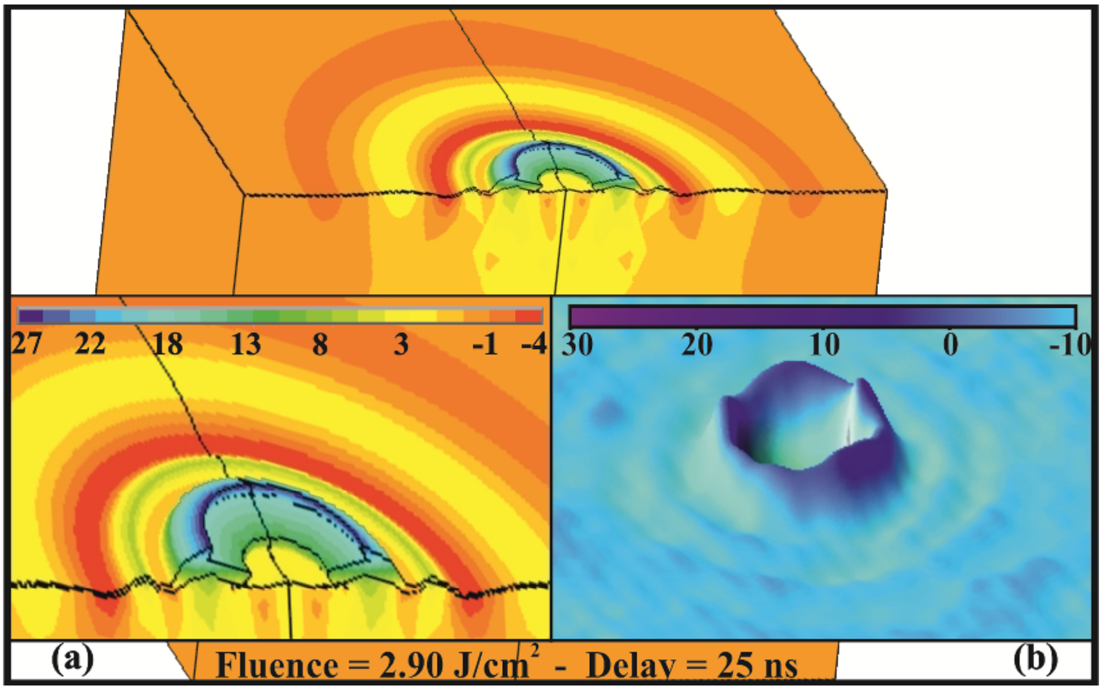

Figure 1. Validation of the model. FEM *vs* Experimental results.

Representative FEM (a) *vs* Experimental (b) results are presented in Fig. 1. A crater-type deformation with elevated edges is generated around the laser irradiated region, while SAWs propagate in matter in the form of concentric rings. The agreement concerning the amplitude of the SAWs and their distance from the epicenter as well as the ablation depth validates the numerical model. The same holds for the elastic and melting regime, indicating that the 3D FEM model is capable to fully describe the dynamic response of a solid target in the thermoelastic, melting and plasma/ablation regimes, depending upon the laser energy. As it can be noticed from Fig1.a (detailed view of the background image) the 3D model offers insights to the whole solid structure where the transverse propagation of SAWs is observed, while the experiment is capable to monitor the dynamic surface behavior.

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