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Laser-induced breakdown spectroscopy and shadowgraphic analysis of selective thin-layers removal by laser ablation

M. S. Rabasović[1], D. Šević[1], N. Lukač[2], M. Jezeršek[2], J. Možina[2], P. Gregorčič*[2]

[1]*Institute of Physics, University of Belgrade, Pregrevica 118, 11080 Zemun, Serbia*

[2]*Faculty of Mechanical Engineering, University of Ljubljana, Aškerčeva 6, 1000 Ljubljana, Slovenia*

E-mail: peter.gregorcic@fs.uni-lj.si

Selective laser ablation of thin layers means subliming or vaporising a thin (i.e., under 100 μm) layer without damaging the substrate or the intermediate underlying layer. This is especially important in several applications, such as rapid prototyping of printed circuit boards. In this case it is essential that the copper is removed from an engraved track without damaging the composite substrate under the copper, while the damaged substrate may carbonize and therefore cause the unwanted altering of its electrical properties [1]. Since the laser-engraved track depth significantly varies with different parameters, such as copper layer thickness, surface conditions, and processing-laser parameters, an adaptation of the laser-processing parameters is needed to achieve optimal results. However, the current laser engraving systems lack of an on-line monitoring method that would enable selective layer removal of changing surface properties during the laser processing.

Several methods of detecting the acoustic waves and plasma spectrum during the thin layer removal have been investigated [1, 2, 3]. Here, the acoustic waves have been measured by a microphone and a laser-beam-deflection probe [4, 5]. The main idea behind these methods is to detect the time-of-flight of the shock wave, which is generated during the laser ablation. Since the shock wave's velocity varies with the optodynamic energy-conversion efficiency [6], this results in different time-of-flights at a constant distance between the probe or microphone and the laser-material interaction site. Here, the main idea is that the optodynamic energy-conversion efficiency changes when the ablated material changes, e.g., since a thin layer is already removed and the ablation of the substrate takes place. The second type of the method for monitoring the removal of thin layers is laser-induced breakdown spectroscopy (LIBS) that enables the spectrum analysis of the plasma emission generated during the laser-material interaction. In such a way, the identification of the elemental composition of the material being ablated is possible [7].

In the presented study we simultaneously use two monitoring methods, the shadowgraphy [6] and LIBS [8] for the analysis of laser ablation of copper from a printed circuits board. Here, a laser pulse of 5 ns having the energy of 16 mJ at 1064 nm was used to ablate an 18-μm-thin copper layer from the substrate. On the basis of shadowgraphs of the shock wave induced by a laser ablation, we measured the optodynamic energy-conversion efficiency. Our results show that this efficiency, defined as the ratio between the mechanical energy of the shock wave and the excitation-pulse energy, is significantly higher for the laser-pulse-copper interaction than for the interaction between the excitation pulse and the substrate. The presented shadowgraphic results enable a better insight into the shock wave dynamics that is important to understand and optimize measurements with other optodynamic methods, such as a laser-beam-deflection probe and microphone measurements. LIBS was simultaneously employed in our experimental setup. Thus, the optical emission from plasma plume was collected by using a spectrograph and recorded with a streak camera. Here, the time-resolved streak images enable monitoring of temporal evolution of the ionic and atomic emission lines. We will show that advancing of laser ablation through the copper layer and reaching of the substrate can be estimated by tracking the intensity ratio of doublet Copper lines (515.3 nm and 521.8 nm) and doublet Aluminium lines (394 nm and 396 nm). Therefore, our results confirm that LIBS method enables an on-line monitoring needed for selective thin-layers laser removal.

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