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Plasma Splashing from Al and Cu Materials Induced by an Nd:YAG Pulsed Laser

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Abstract—Plasma splashing from Al and Cu target materials and the growth of thin films on Cu and Al, respectively, has been studied using a Q-switched Nd:YAG laser with a 1064-nm, 80-mJ, 8-ns pulse width as the source of ablation. The target kept rotating and the substrate, Cu for Al and vice versa, was placed at an angle of 15° with respect to the beam axis. During the laser–matter interaction, the targets absorbed thermal energy within the thermal region depth of 4.7 (1.1) nm, yielding an ablated skin depth of 6.7 (4.2) nm. The surface morphology of the exposed targets was studied by analyzing SEM micrographs obtained using a ZEISS SUPRA 35 VP. The obtained results are explained on the basis of different sputtering/ablation mechanisms. Comparatively severe damage forming a bigger crater is seen on the Al target surface in contrast to the crater on the Cu surface. This observation is correlated with the blustering effect and/or debris formation. Energy dispersive spectroscopy (EDX) of the substrates yielded the deposition of micrometric grain-size particles.

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1. INTRODUCTION

Pulsed laser irradiation of solid targets has been rapidly expanding since the 1980s, featuring a wide application in different fields, such as nuclear physics, microelectronics, engineering, and biomedicine. It can be used, for example, to produce high temperature plasmas, to generate ions or electron beams to deposit films on different substrates, and to investigate complex phenomenon occurring in nonequilibrium plasma [1–3]. Plasma splashing has a wide application in industry for surface treatments to reduce friction, wear to many machine components and tools, and for coatings on large area plates for the embossing of decorative material; in medicine for the hardening of surgical instruments and artificial joints, etc.; in electronics for the fabrication of many electrical devices such as sensors; and in defense and material processing [4, 5]. Thus, it appeared long after all major events accompanying laser-induced plasma ablation had ceased [6, 7]. In this paper, we demonstrate the nonequilibrium phenomenon and splashing effect due to the interaction of an IR laser with copper and aluminum targets. Deposition of micrometric grain-sized particles have been found on the substrates positioned at 5.5 cm and a 5° angle from the splashed targets.

2. THEORETICAL BACKGROUND

Plasma emission from the target surface starts soon after the laser photon reacts with the target surface and it is called laser-produced plasma [8]. Practically, when the laser radiation is absorbed by the solid surface, electromagnetic energy is converted into electrical excitation resulting in thermal energy, chemical energy, and mechanical energy, which essentially cause evaporation, ablation, excitation, plasma formation, and exfoliation. Evaporants form a plasma plume consisting of a mixture of energetic species including atoms, molecules, electrons, ions, clusters, micron-sized particles, and molten globules [9]. Plasma near the surface of the target has a maximum density of atoms, ions, electrons, and vapors; this layer is called the *Knudsen Layer*, and the plasma on this layer is called vapor plasma. Within this layer, ions interact with each other and they also generate more ionization states by collisions [8]. From this layer, the plasma expands thermodynamically away from the target as the species from the ions have a maximum flux in the radial direction and a minimum in the axial direction. Also, it was concluded experimentally that the maximum value of the velocity of the plasma ejectants lies along the normal to the target surface and continues decreasing as the angle with the normal increases; it becomes minimum in the perpendicular direction along the normal. This is known as forward peaking [10]. As the plasma plume accelerates, its density decreases. The plasma frequency is proportional to the square root of the electron density [11]. Thus, the plasma frequency will decrease with a decreasing electron concentration. The layer or surface where the plasma frequency equals the frequency of the incoming laser radiation is called the critical layer and