INTRODUCTION

In femtosecond (fs) laser ablation, the entire pulse will strike the material surface before the plasma (that is created from the laser-material interaction) is dense enough to cause energy loss due to plasma shielding. Also, the pulse duration is shorter than the time required for the deposited energy to thermally conduct through the material[1]. In the nanosecond (ns) regime, deposited energy can thermally conduct because of the longer timescale. The material surface is subjected to a higher mechanical stress than in the fs regime due to thermal expansion and the force of the escaping material from the crater. This leads to rough edges and cracking of the material inside and around the crater[2].

The goal of this investigation was to observe the different dominating mechanisms for the two regimes on the surfaces of commonly used materials in manufacturing.

I. Central Zone

II. Shock Wave Zone

III. Heat Affected Zone and Crater Wall

IV. Affected Surface

In Figure 1, the ablation regions are classified as follows:

Central Zone: Characterized by a smooth surface with few ripples. This is where the most intense part of the beam hit.

Shock Wave Zone: This region is where most of the molten material was pushed towards. A combination of ejecting gasses/plasma and surface tension made the molten material rise up from the surface of the sample.

Heat Affected Zone: All material here was ablated, but some molten material was ejected from the inner regions forming droplets in this region and the next.

Affected Surface: This is the area outside of the crater wall that has either been subjected to possible electron excitations from the neighboring irradiated areas, turning it into a brighter colored surface, the deposition of the droplets, or both.

ANALYSIS OF SURFACE MORPHOLOGY

There was an abundance of nanodroplets along the fs GaAs craters (Fig. 3j – 3l). In the ns regime, very straight fracture lines appeared across the crater (Fig. 4j, 4k).

ZnSe craters had a very abrupt transition from the Affected Surface to the crater wall (3n, 4c). There were also, fracture lines throughout the craters, like in the GaAs samples, but in both regimes. Lastly, the craters were among the smallest of each regime.

Ejecting material through the surface caused the Al nanopits. The ambiguous regions of the Cu craters were a result of the sample’s well known higher conductivity. The lack of significant material loss is consistent with similar investigations[2]. In both regimes, Ti had the largest and shallowest craters resulting from its lower energy conductivity, hardness, and lattice strength. In the ns regime, the GaAs fracture lines were due to thermomechanical stresses fracturing the crystalline structure of the sample. The nanodroplets of the fs regime were created from non-thermal phase change and recondensation[1,3]. The well contained ZnSe crystals also showed the same crystalline fractures, but in both the fs and ns regimes, due to the energy from the heavy ablation regime [4].

In the ns regime, formation of a homogeneous and beam shaped crater of Ti (Fig. 3b, 5g) indicate a contribution from the beam/plasma interaction, most likely due to recoil pressure[5].

REFERENCES


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