Modeling of Factors Influencing Bulge Formation in Polymers During Laser Micromachining

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ABSTRACT

Laser micromachining has been widely applied in the manufacturing of Micro Electro Mechanical Systems (MEMS). It uses photo thermal melting to remove material.

The use of heat as a means of material removal has various negative effects on different materials. Distortion of the material is one of the negative effects, especially in polymers. Polymers are often used in medical devices, microelectronic and sensor industries where high precision and high quality is required. During laser micromachining of polymers, bulges are formed mainly due to resolidification of molten material on the rim of the channel and thermal stress caused by the sharp temperature gradient between laser ablation zone and substrate body.

Carbon dioxide (CO2) lasers have characteristics such as long wavelength and diffraction limited divergence, which are suitable for the micromachining of polymers.

In this thesis, a mathematical model has been developed using finite element method to study the behavior of Poly Methyl Methacrylate (PMMA) during CO2 laser cutting. The model is formulated using a three dimensional computational domain. Ablation of the polymer is assumed to occur in one step, that is from solid to vapor, for the material. The solution of the mathematical model determines the temperature distribution within the material and tracks the moving boundary that occurs due to material ablation. This model considers as a function of depth the surface absorption of laser energy.

The mathematical model was implemented on FEMLAB finite element software.

The effect of varying the scanning velocity and laser power, which are considered important laser micromachining parameters, was studied.

The model was verified by comparing the numerical results obtained to theoretical structures. The results were found to correlate well in magnitude and shape of the curves. The model

developed was, therefore, found to be a good representation of the behavior of PMMA during laser cutting.

The effect of the laser parameters on the morphology of PMMA was also studied.

Increase in power at a low velocity was also found to increase the amount of resolidified material on the kerf. This increases the probability of bulge formation on the surface of the workpiece. It was also found that a large heat affected zone increased the chances of bulge formation. The results showed the need for optimization of laser power and scanning velocity for reduction of the height of the bulge. The relationship between the ratio of laser power and scanning velocity, P/v, and bulge height was used to obtain the best combination of laser parameters to use in order to achieve minimum bulge height. It was found that laser power of 20 W and velocity of 0.5 m/s gave a balance between low bulge height and few number of passes.

The model developed in the study can therefore be used as an efficient design tool to arrive at optimal configuration for the laser cutting of PMMA and polymers in general. It will result in efficient laser power and scanning velocity settings in order to undertake laser cutting in a cost effective manner.