Assessment of Direct Laser Writing using Nd YAG Lasers for Microfluidic Applications

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ABSTRACT

The rapid growth in the use of Micro/Nano products in variety of industries such as Micro electromechanical systems (MEMS), microelectronics, Biomedical/Bio-MEMS, automotive (motion sensors), telecommunications etc, has demanded new micro manufacturing methods. The challenge with the manufacturing of Microfluidic devices/biochips is that they often make use of broad range of materials within a single chip, making it difficult to manufacture these devices with conventional photolithographic based techniques. Laser processing of materials has proved to be an important tool for the development of these devices because of the accuracy, flexibility and the most important one material independence it offers. This research focus on optimization of laser process parameters for the machining of Microfluidic channels with AISI 1045 steel. Design of experiments (DOE) technique was used in order to study the effect of laser process parameters on rectangular and semicircular cross-section channels.

Keywords: Direct Laser Writing, DOE, Micro-Electromechanical Systems (MEMS), Microfluidics, Nd:YAG Laser

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INTRODUCTION

Lasers in manufacturing industry are widely used in drilling, cutting, marking, milling and micromachining applications because of the various advantages it offers such as absence of mechanical forces and tool wear, ability to machine difficult to cut materials, precise operation and flexibility etc. Although laser processing of materials offers lot of advantages; it is a complex process involving large number of factors and the quality of machining depends on the proper selection of parameters.

Laser micromachining works on the principle that when a high energy density laser beam is focused on work surface the thermal energy is absorbed which heats and transforms the work volume into a molten, vaporized or chemically changed state that can easily be removed by flow of high pressure assist gas jet. Laser micromachining is a layer by layer material removal process and is affected by factors like laser pulse frequency, laser scan speed, layer thickness, track displacement and scan strategy.

A lot of research is being done in order to study the effect of process parameters during laser processing of materials by using various advance statistical tools. Ghoreishi et al. (Ghoreishi, Low, & Li, 2002) applied CCD and Response surface methodology to analyze the effect of laser process parameters on hole taper and circularity in laser drilling of stainless steel. Almeida et al. (Almeida et al., 2006) used the factorial design approach to determine the effects of laser process parameters on the surface roughness and dross formation on the Nd:YAG laser cutting of pure titanium and titanium alloy (Ti–6Al–4V). Mathew et al. (Mathew, Goswami, Ramakrishnan, & Naik, 1999) used central composite design for the process optimization of pulsed Nd:YAG laser cutting of fibre reinforced plastic composite sheet. Chen et al. (Chen, Tam, Chen, & Zheng, 1996) applied Taguchi methodology for optimization during micro-engraving of photo-masks. Campanelli et al. (Campanelli, Ludovico, Bonserio, Cavalluzzi, & Cinquepalmi, 2007) used Full Factorial Design to evaluate the influence of the laser process parameters on the success of the ablation process in terms of depth of removed material (DP) and surface roughness (SR). Pham et al. (Pham, Dimov, & Petkov, 2007) conducted single factor experiments for the laser milling of ceramics using a Nd: YAG laser with a wavelength of 1024nm. Yousef et al. (Yousef, Knopf, Bordatchev, & Nikumb, 2003) used artificial neural networks to model and analyze the material removal process.

Microfluidic systems have been a topic of extensive research in the recent times. Microfluidic devices are basically the miniaturized biological assays such as DNA sequencing and separation, polymerase chain reaction (PCR), enzymatic assays, immunoassays, cell counting and separation, cell culture etc, these devices are generally disposable and used only once to avoid sample contamination. Because the micro-fluidic chip can perform multiple tasks in a typical biochemical analysis laboratory, such as mixing, reaction, separation, and detection, etc.,
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