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Fabrication & Characterization of Microfeatures on PMMA Using CO_2 Laser Machining

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Abstract

The micro-features are employed in a wide range of applications like Lab on a chip (LOC), micro Total Analytic Systems (μTAS), Textured hydrodynamic bearings, Micro Heat Sinks, etc. The fabrication of microfeatures is a critical task. This paper focuses on the fabrication and characterization of micro features using CO_2 Laser machining. The three micro feature shapes are considered in the study viz. circular, square, and hexagonal. The size of the microfeatures has been varied from 300 μm to 1000 μm with an interval of 100 μm. The micro-features have been fabricated on polymethylmethacrylate (PMMA) material. The experiments have been performed to study the effect of process parameters (power, scanning speed) on the surface roughness and the dimensions. The characterization has been performed using RAPID I Vision 5 Microscope and Mitutoyo surface roughness tester.
Further, the straight channels also have been fabricated with a width varying from 300 μm to 1000 μm with an interval of 100 μm. The characterization of the straight channels has been carried out. The fabricated channels are observed to be in agreement with the required dimensions. Thus, CO_2 laser machining is capable of fabrication the straight channels and micro features which have a significant application for the fabrication of mold in soft lithography.

1 INTRODUCTION

The microfluidics has been evolved as a key technology in the areas like bio-engineering and analytical chemistry, etc. A microchannel is an essential and decisive component in Lab on a chip (LOC) LOC system. The microchannels are employed for mixing of reagents, delivery of reactant, fluidic control, physical particle separation, and cooling of computer chips. The microchannels when used for mixing generally termed as micromixers. The micromixers are of two types - active and passive. Active micromixers utilize external energy source for the mixing enhancement while in passive micromixers, different geometric shapes and fluid characteristics are effectively used (No external energy source). The flow in the microchannels is laminar, and hence the mixing depends upon diffusion only. Thus, the use of obstacles in the microchannels has significantly improved the mixing characteristics of microchannels. The obstacles are nothing but the micro-features provided along the length of the microchannel. The obstacles may be of various shapes viz. triangular, rectangular, square, circular, J shape, etc. [1],[2],[3]. The microfeatures are also useful in micro-texturing of a hydrodynamic journal bearing [4].

The microchannels are fabricated using different materials. One of the suitable and straightforward method of microchannels fabrication is soft lithography. For the soft lithography process, molds are required to be fabricated. The most used materials in soft lithography are PMMA (Polymethylmethacrylate) and PDMS (Polydimethylsiloxane). The molds can be fabricated using different methods like wire-cut electric discharge machining, photochemical machining CO2 laser machining, etc. [5],[6],[7],[8]. Each approach has some advantages and limitations. Amongst these, CO2 laser machining is one of the easy and suitable methods for fabrication of microchannels molds on PMMA material. Laser cutting technology employs a laser to cut the materials. The laser beam is focused on the material, which then either burns, melts, or vaporizes away by a jet of gas, leaving an edge with a high-quality surface finish. In industries, the laser cutters are employed to cut different types of sheet material, structural and piping materials. The different studies on laser machining of polymer materials have been reported by various researchers for studying the machining performance [9],[10],[11].

The fabrication of micro-features is very critical. There is a good scope for fabrication of micro-features and channels using any non-conventional process. The fabrication of micro-features and straight channels on PMMA material using CO_2 laser machining and its characterization is presented in this paper. The straight channels and microfeatures with eight different sizes from 300 μm to 1000 μm have been fabricated using CO_2 laser machining.

2 MATERIAL AND METHODS

The material selected for fabrication of microchannel is Polymethylmethacrylate (PMMA) also called as Acrylic. This material is durable and stiff with excellent weather resistance, and the chemical formula is C5H8O2. It has higher tensile and flexural strength. Its impact strength is about ten times more than glass [11]. PMMA has the highest surface hardness of all common thermoplastics and is also highly scratch resistant. PMMA is transparent, and it has good scope in microfluidic applications. Also, it is compatible with the soft lithography process. Therefore, for the fabrication of microfeatures and microchannels, PMMA material is suitable.

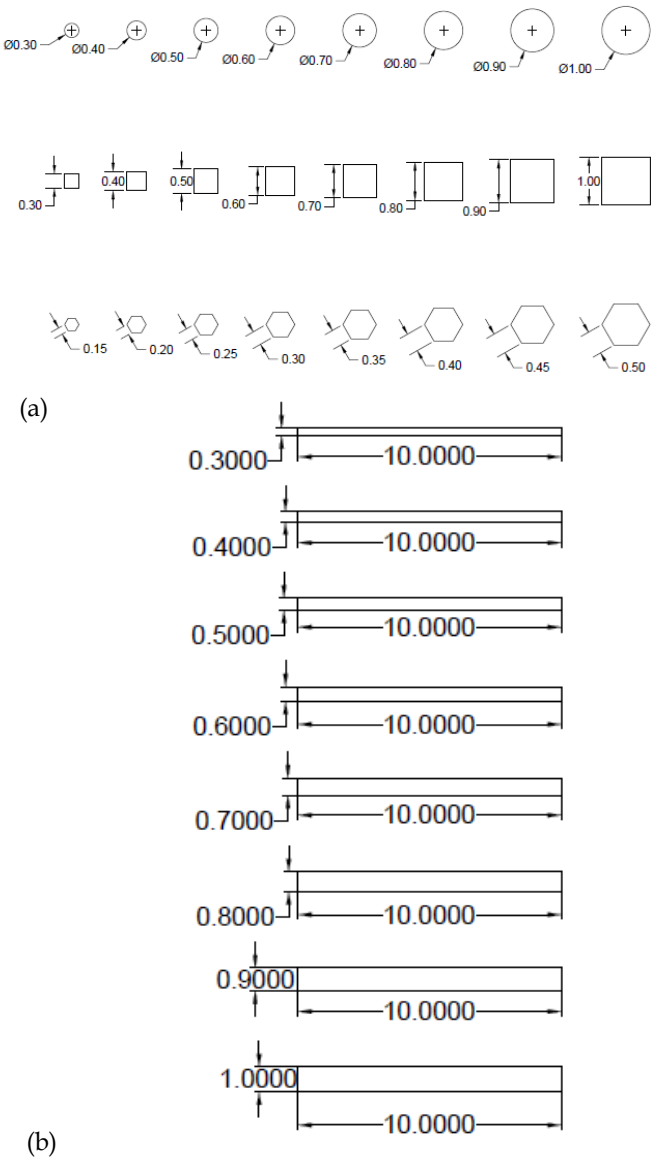


Figure 1: CAD Geometry for (a) Microfeatures (b) Straight channels

The design of the microfeatures and straight channels is made ready with the help of AutoCAD software. The different drawings for the straight microfeatures and microchannel geometries with different widths are depicted in Figure 1 (a). The size of the microfeatures is varied from 300 µm to 1000 µm with an interval of 100 µm. The width of the straight channels is also changed the same as for microfeatures. The geometries for straight channels is depicted in Figure 1 (b). These drawings are imported in the LASER cutting machine database. The laser cutting machine photograph is shown in Figure 2. The microfeatures and channels have been fabricated by varying the two process parameters, i.e. laser power and laser speed.

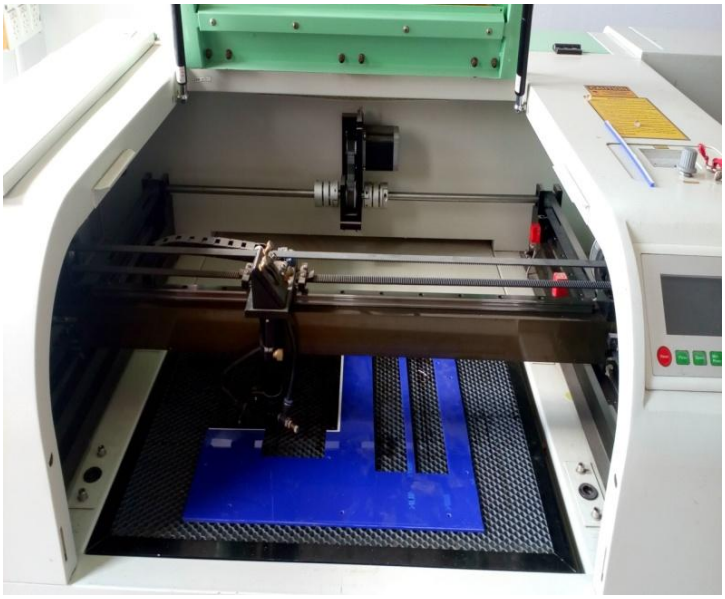
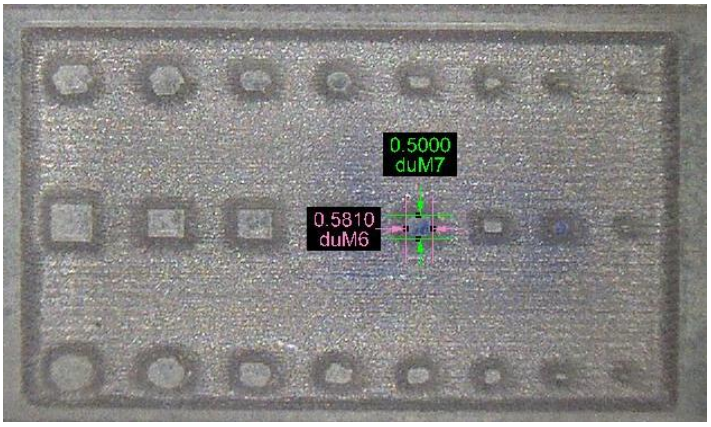


Figure 2: Laser Cutting Machine

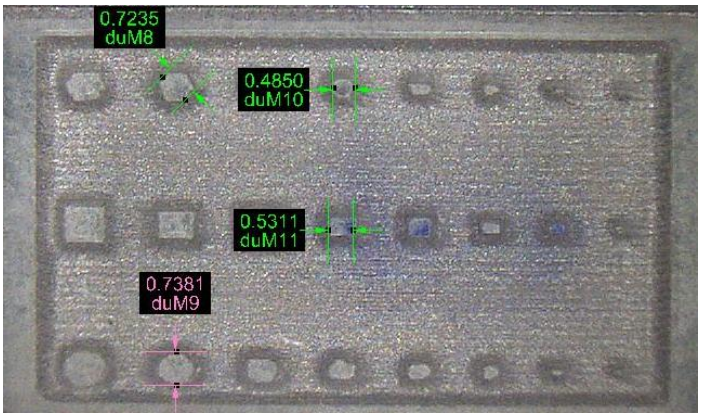
3 RESULT AND DISCUSSION

The laser machining has been performed on PMMA material for two different conditions for achieving different depths and surface conditions. The fabricated microfeatures on PMMA material are shown in Figure 3. The characterization for dimensions has been performed using RAPID I Vision 5 Microscope. The desired aspects for microfeatures are achieved using CO_2 Laser machining. It is observed that the microfeatures having a size greater than 500 µm are more accurate in dimensions as compared to the smaller ones.

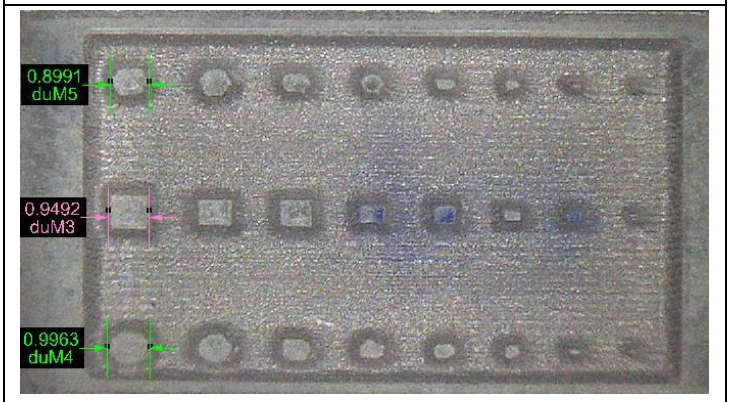
The straight channels have also been fabricated using CO_2 Laser machining. The fabricated straight channels are shown in Figure 4. The characterization for dimensions has been performed using RAPID I Vision 5 Microscope. The required width has been achieved for straight channels.



(a)

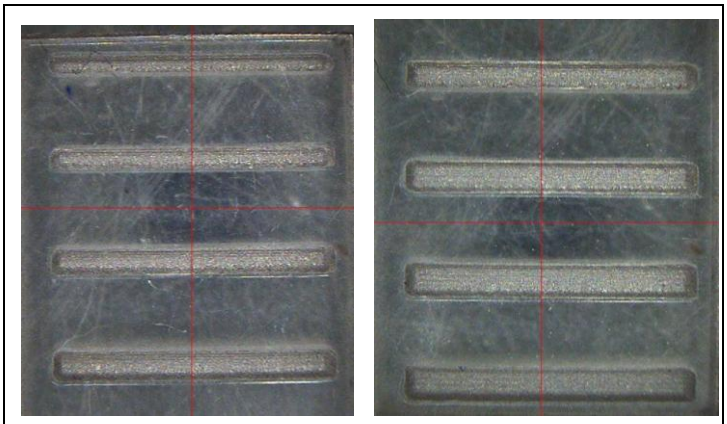


(b)

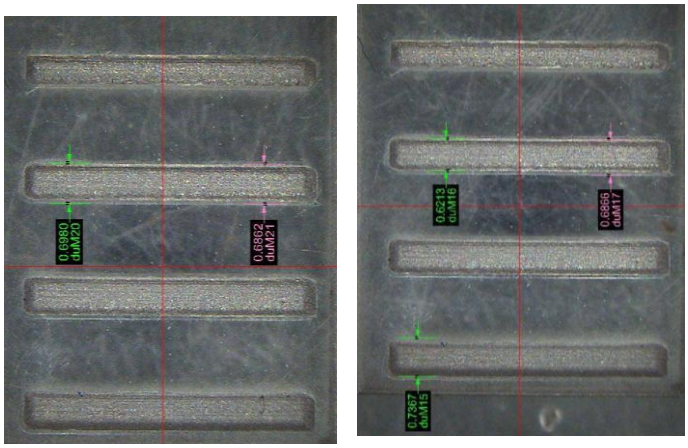


(c)

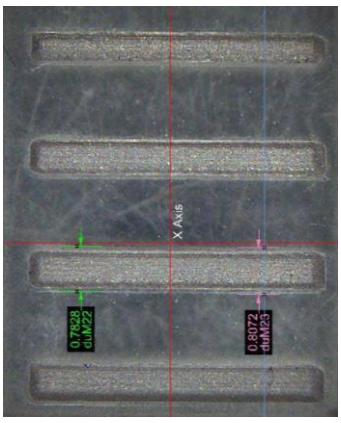
Figure 3: Fabricated Microfeatures



(a)



(b)



(c)

Figure 4: Fabricated Straight Channels

4. CONCLUSION:

The microfeatures and straight channels have been fabricated using CO_2 laser machining on the PMMA material. The three shapes of microfeatures as circular, square and hexagonal with different sizes from 300 µm to 1000 µm with a variation of 100 µm. The microfeatures are having a size greater than 400 µm are observed to be fabricated as per the required dimensions. The straight channels with a width from 300 µm to 1000 µm with a variation of 100 µm have been fabricated and are found to as per the required sizes. Thus, CO_2 laser machining is a good candidate for fabrication of microfeatures and straight channels on PMMA (acrylic) material.

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