EFFECT OF EXCIMER LASER PARAMETERS ON THE ABLATION DEPTH DURING MICROMACHINING OF POLYCARBONATE

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Abstract: *Polycarbonate (PC) material widely used in micro pumps & micro valves. In machining of PC using Excimer laser ablation rate is one of the important factors in achieving desired features. In the present work, micromachining of Polycarbonate (PC) was carried out using KrF excimer laser of 248 nm wavelength. A micro- hole of Ø150µm was machined on PC substrate during the experimentation. The PC substrates were exposed to a different number of pulses (1-100) at repetition rates of 2-10 Hz respectively by keeping the pulse energy unchanged at 100mJ. The effect of pulse repetition rate and a number of pulses on ablation depth has been investigated in the current work.*

Keywords: *Micromachining, Excimer Laser, Polycarbonate, Ablation Depth, Pulse Repetition Rate, Number of Pulses*

1. INTRODUCTION

Laser micromachining is used for micro channel and micro-electromechanical systems production for many applications. This include telecommunications, glass cutting, micro sensors [1]. Laser micromachining processes include drilling, cutting, milling, and engraving of materials with micro-dimensional tolerances Despite the fact that laser micromachining is a technically complex manufacturing process, research work has enabled the fabrication of increasingly precise, smooth, & clean components at high speeds [2]. Laser microfabrication is a material processing technique that uses the laser to induce managed thermal alteration of the shapes and dimensions of the material at the micrometer scale provides a broad overview of the applications of lasers in different areas and with diverse objectives [3]. All laser micromachining techniques use the process of laser ablation, where the interaction of the laser energy with the sample leads to material removal [4].

The Excimer laser is a type of gas lasers that operate mainly in the ultraviolet range of wavelength. The Excimer laser in generated from mixture of two gases generally rare gas and halogen gas. The laser is generated when a high-intensity discharge ionizes the mixture, which relaxes to form excited molecules of the two gases. The oppositely charged ions combine to form a dimmer in an Excimer state. Thus a population inversion is readily achieved resulting in a high gain system. The excited dimmers and through stimulated emission, resulting in a built up of radiation in the cavity to give rise to laser radiation [5]. It has been recognized that Excimer lasers offer distinctive possibilities in plastic /polymer processing. They emit in the ultra-violet range of spectrum intense, monochromatic light pulses which can be repeated in a train of pulses [6]. Excimer lasers have become the most widely used source of moderate power pulsed ultraviolet sources in laser applications. The infrared laser has been widely used for material processing, however, deep ultraviolet (DUV) Excimer laser is considered to have potential. The Excimer lasers at wavelength and 248nm: KrF (output power; up to 120W) have been used in semiconductor manufacturing for long years and it is proved that they possess high stability and reliability. In addition to that, high power (>400W) wavelength 248nm Excimer lasers are applied to the annealing process of Flat Panel Display [7].

2. EXPERIMENTATION

2.1 Experimental Setup

Fig. 1 shows schematic representation of an excimer laser micromachining system. This setup has a KrF laser having wavelength 248 nm, pulse duration 20 ns, pulse repetition frequency 50 Hz and maximum pulse energy up to 400mJ. Beam delivery system consists of attenuator, Homogenizer, Field lens, Mask and Doublet.

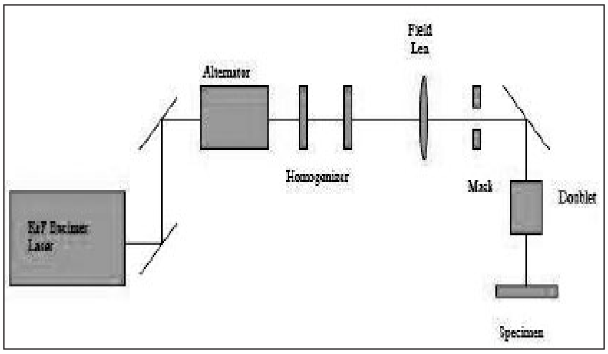


Fig 1. Experimental Setup for Excimer Laser Micromachining of PC

2.2 Excimer Laser Technical Specifications

Table 1: Technical Specifications

Technical Specifications	
Wavelength	248 nm
Pulse duration	20ns
Max Pulse Energy	400mJ
Min. feature size	1.5 µm
Repetition Rate	50 Hz
Traverse X, Y & Z	2.5 µm
Beam size	24mm x10mm

2.3 Process

The experiments were carried out on a sample (75 x 25 x 3 mm) of Polycarbonate (PC) polymer. Before and after laser ablation, the sample is cleaned ultrasonically with distilled water. The laser beam from a KrF Excimer laser (Model: Coherent COMPexPro 110) with wavelength 248 nm is focused on the sample by optical arrangement and work piece movement is

Fig 2. Excimer Laser Micromachining System

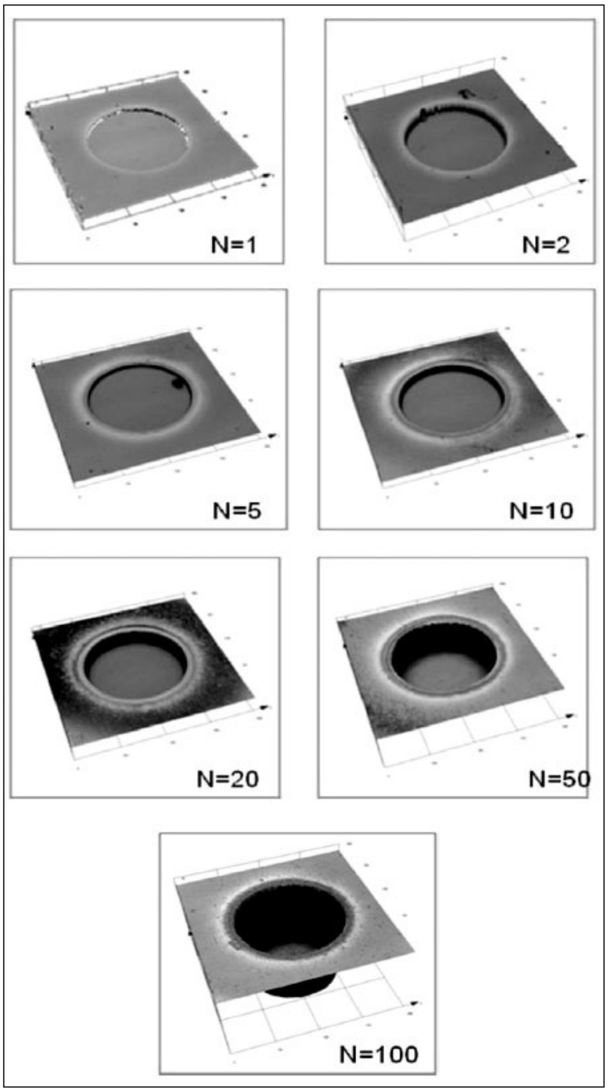


Fig 3. Confocal Images of the PC Samples Ablated at Repetition Rate of 10 Hz at Variable Number of Pulses (1-100 Pulses)

Table 2: Depth of Ablation (μm)

Number of Pulses (N)	Repetition Rate (Hz)		
	2 Hz	5 Hz	10 Hz
1	0.352	0.276	0.410
2	0.719	0.780	0.834
5	1.712	1.826	2.044
10	3.516	4.193	3.935
20	7.807	7.658	7.458
50	18.288	18.672	18.171
100	35.776	35.136	35.498

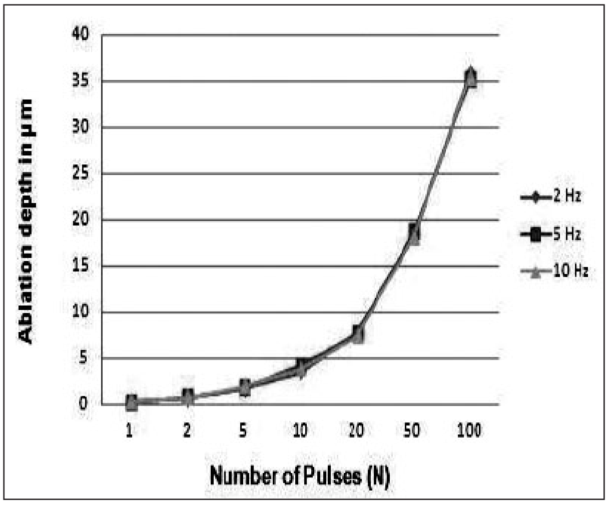


Fig 4. Variation of Ablation Depth with Increase in Number of Pulses at Pulse Energy of 100mJ

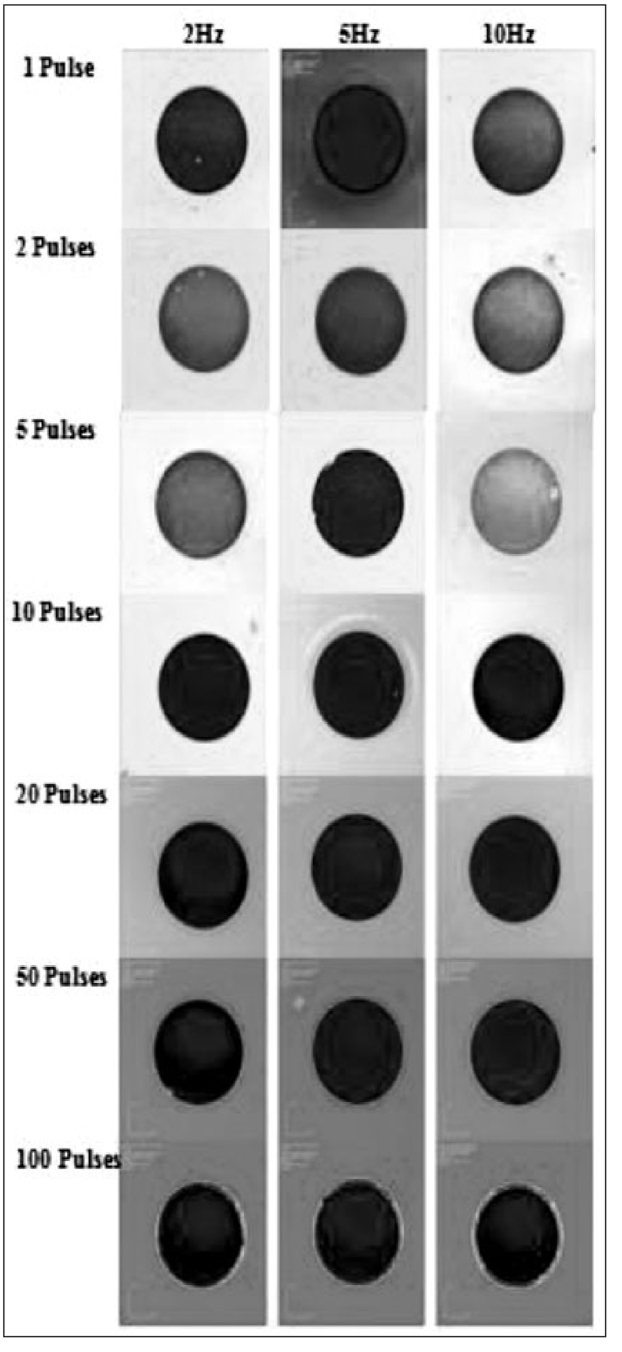


Fig 5. Surface Mapping Micrographs Show Ablation Characteristics for Machining PC at 100mJ at Variable Repetition Rates (2- 10 Hz) and Number of Pulses (1-100)

achieved by XYZ translational stage. Micromachining is carried out at different operating conditions, i.e. a number of pulses (1, 2, 5, 10, 20, 50 and 100) and pulse repetition rates (2, 5 and 10 Hz) by keeping pulse energy constant at 200mJ. The objective was to find out the variation of ablation depth with a number of pulses and pulse repetition rate. Fig. 3 shows confocal images of the PC samples ablated at repetition rate of 10Hz at variable number of pulses (1-100 Pulses). Fig. 5 shows surface micrographs taken by a confocal microscope at 20X (Make: OLYMPUS, Model: OLS4000). The measured values of ablation depth are tabulated in Table 2.

3. RESULTS AND DISCUSSIONS

A preliminary test of ablation for PC samples is conducted at constant pulse energy of 100mJ and repetition rate of 2 Hz with variable number of pulses. Ablation depths for different repetition rates are measured using confocal microscope and are tabulated in table 2. In Fig.3 and Fig. 5, significant ablation depth is observed. Between 1 and 2 number of pulses, an average increased of 0.367μm per pulse is observed. During 2- 5 number of pulses of 1.712μm with an average increase (etch rate) of 0.331μm per pulse.

Among 5 and 10 number of pulses, an average increase of 0.360μm per pulse is observed. For the period of 10–20 number of pulses, the ablation depth increased at an average of 0.429μm per pulse. During 20–50 number of pulses, the ablation depth increased at an average of 0.3491μm per pulse and during 50-100 number of pulses 0.3497μm per pulse. Minor increase in diameter of the hole geometry is observed as the number of pulses are increased.

Fig. 4 shows the variation in ablation depth with the increase in number of pulses (1–100 pulses at 2–10 Hz) at pulse energy of 100mJ.

4. CONCLUSIONS

In the present work, micromachining of Polycarbonate (PC) using KrF Excimer laser has been investigated and arrived at the following conclusions

- The depth of ablation increases with the number of pulses and establishes the relation between no of pulses in ablation depth.
- Pulse repetition rate has no significant effects on the ablation depth.

4. REFERENCES

1. Heng Qi, TaoChen, LiyingYao, TiechuanZuo (2008). Micromachining of micro channel on the polycarbonate substrate with co2 laser direct writing ablation.

2. Issa, A., Computational control of falser system for micro-machining, 2007.

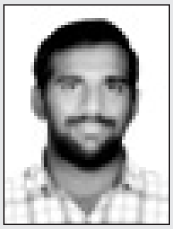
3. Majumdar. J, Manna. I,(2003). Laser processing of materials.sadhana 28(3). 495-562.

4. Nadeem Rizvi and Paul, (2000)" Developments in laser micromachining techniques", ICOPE, 2000 Conference, Singapore..

5. Syed nadeem akhtar, (2015). Micro machining on thin films and surface of metals polymers using Excimer laser

6. Toshio Mimura, Kouji Kakizaki, Hiroaki Oizumi, Masakazu Kobayashi (2017). High power DUV lasers for material processing 323-8558

7. Junichi Fujimotoa, Masakazu Kobayashia, Koji Kakizakia, Hiroaki Oizumia (2017). 248nm high power laser for the micro and macro material processing ◘



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