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Direct fabrication of glass microfluidic channel using CO_2 laser

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A B S T R A C T

The design and development of small and compact devices with numerous new functions and vast benefits to the society is steadily receiving global attention. These sophisticated small devices require the production of accurate and intricate micro and nano-scale patterns with different three-dimensional (3D) shapes, sizes, and aspect ratios. Microfluidic device or so-called lab-on-a-chip (LOC) is one example of a highly sensitive and compact integrated device capable of detecting multiple analytes, usually used as a diagnostic device. In this study, we demonstrate the feasibility study for direct fabrication of microfluidic channel on transparent optical glass substrate via CO_2 direct laser structuring. A custom-built direct laser structuring setup mainly consist of a commercial continuous type of CO_2 laser source and glass preheating apparatus is utilized. First, the relationship between the process parameters, mainly the laser scanning speed, number of lasers passes and initial glass preheating temperature to the formation of microchannel of different width, height and shape were established. Then, the form accuracy and the morphology of the microchannels were characterized using laser scanning confocal microscope (LSCM) and surface profiler. Overall, the result reveals that the combination of higher laser power, lower scanning speed and higher number of laser passes promotes the increase of both the width and height of the microchannel. Preheating was found to be necessary for the glass used in this study in avoiding either micro-cracks or bulk glass cracking. Based on the relationship between laser scanning speed and the number of laser passes, a prototype of a microfluidic channel with average width and height of about 235 ± 10 μm and 6 ± 0.3 μm, respectively was successfully fabricated. This study opens an opportunity for further improvement and research for fabrication of crack-free and smooth microfluidic channels using low-cost CO_2 laser structuring setup.

1. Introduction

The demand for microfluidic devices has raised much intention due to their competitive advantages, such as highly accurate results, low-cost fabrication, equipment-free, and disposability [1]. A microfluidic device contains a micropattern design on the surface of a substrate, and it allows fluid to flow into a desired region for the purpose of stimulation and sensing the liquid sample. Water monitoring [2–4], medical diagnostic [5,6], chemical screening [7–9], and pharmaceutical analysis [10,11] are examples of applications that can be utilized by using a microfluidic device. An organs-on-chips (OOAC) device integrated with microfluidic system that can mimic a part of a human lung had also been demonstrated [12]. All of these examples show the importance and future potential of microfluidic devices in various fields.

Several methods have been demonstrated in the literature to fabricate various microstructure patterns on a substrate. These methods include photolithography [13–15], hot embossing [16–18], injection molding [19–21], lithography-free process [22], electrochemical discharge machining [23–25], water jet machining [26] and 3D printing technique [27,28]. Photolithography is a well-known method to fabricate micro and nano-scale pattern on a substrate which generally requires the use of an expensive photomask to define the initial shape and dimension on the photoresist before pattern transfer to selected material. This method guarantees a high level of precision and quality of the fabricated patterns on either on metal, polymer or glass substrate. Unfortunately, the fabrication of microfluidic channel using this method is very low in throughput since the process requires multiple serial processes such as spin coating of a photoresist, soft and hard bake, exposure of UV light, photoresist removal, and etching [29,30]. Hot embossing is regarded as a suitable mass production technique for repetitive replication of pattern with the use of a micro structured mold that act as a template to transcribe the pattern onto the glass surface at a temperature of above the glass T_g. Despite of that, the fabrication of a durable mold that can sustain high embossing temperature and pressing load is very

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