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Fabrication of micro and nanostructures on glass using non-isothermal thermal imprinting

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A B S T R A C T

The formation of micro/nano scale pattern features on glass using direct thermal imprinting has gained continuous attention due to its potential to replicate glass with various functional surfaces at an atomic scale resolution. Unfortunately, the long thermal cycle issue in regular thermal imprinting remains the main obstacle that hampered the process to be viable for mass production. In this paper, the fabrication of micro/nano scale pattern features directly on glass substrate using non-isothermal thermal imprinting is proposed. Compared to conventional thermal imprinting, this method eliminates the serial process of heating, soaking, pressing, demolding, and cooling that commonly took place in one close chamber. Therefore, the duration of each imprinting cycle is significantly decreased, which in turn could reduce the cost per unit price to fabricate these glass devices with micro and nanostructures. The morphology of these imprinted glass nanograting and microlens array (MLA) was characterized via the scanning electron microscope (SEM), atomic force microscope (AFM) and surface profiler. Overall, the imprinted nanograting and MLA pattern using the non-isothermal thermal imprinting method result showed good replication fidelity, comparable to the regular thermal imprinting and outperforms the conventional one in terms of overall cycle time reduction, minimized variation of mold temperature and lower energy consumption. The proposed method is expected to become an interesting approach for fabrication of various patterns directly on glass substrate with high pattern quality and shorter thermal cycle.

1. Introduction

Nowadays, glass based optical components with various micro-nanostructures features are becoming prominent in optical applications where high thermal stability, excellence transmittance in the ultraviolet (UV) region, high durability and superior optical performance are necessary. Due to the growing demand for miniaturization devices in a wide range of industries, researchers have devoted a significant amount of effort to develop new glass-based devices as well as improving the process efficiency. The numerous potential applications include optical imaging [1,2], microfluidics [3,4], sensors [5,6], illumination [7] and fiber coupling [8,9]. A wide variety of well-established micro-nano fabrication methods have been practiced in the industry and continuously investigated by the academia. These include micro-injection molding [10], thermal reflow [11,12], photolithography [13], nano imprinting [14–16], laser structuring [17,18], direct imprinting [19–21] and hot embossing [22,23].

Photolithography has been successful for a long time as a micro-patterning method on various substrate processes with great homogeneity, precise geometrical shape, optics surface finish, and excellence repeatability. Nevertheless, the photolithography procedure necessitates a costly and sophisticated setup to complete the patterning process. Furthermore, this process requires an expensive photomask, limited resolution, and multiple steps which are only suitable for fabrication of master mold template. Meanwhile, laser structuring is another interesting direct patterning approach for fabrication of micro/nano features [24]. Unfortunately, the process requires a secondary process such as heat treatment, etching and cleaning due to the ablated material in the form of debris and poor pattern uniformity after the laser scanning process. Polymer based micro-devices could be produced by injection molding process with numerous advantages such as one single production step, low production cost and complex shape. Despite that, this

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