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Fabrication of plastic microlens array using gas-assisted micro-hot-embossing with a silicon mold

C.-Y. Chang [a], S.-Y. Yang [a,*], L.-S. Huang [b], J.-H. Chang [a]

[a] Department of Mechanical Engineering, National Taiwan University, Taipei 106, Taiwan
[b] Institute of Applied Mechanics, National Taiwan University, Taipei 106, Taiwan

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Abstract

This paper reports an innovative method for fabrication of plastic microlens arrays. By using gas pressure to press the plastic film onto silicon mold of holes array, microlens array can be directly fabricated. A machine with closed chamber for gas-assisted micro-hot-embossing was constructed and tested. The 300×300 plastic microlens array with a diameter of 150 μm and a pitch of 200 μm were successfully produced. Under the condition of 150 °C, 10–40 kgf/cm^2 gas pressure and 30–90 s duration, the microlens with uniform and strong focusing function were formed on the polycarbonate film. The shape and height of microlens can be changed by adjusting the processing temperature, pressure and duration. This technique shows great potential for fabricating microlens array on large plastic films with high productivity and low cost.

Keywords: Gas-assisted micro-hot-embossing; Hot embossing; Deep reactive ion etching; Replication; Silicon mold; Microlens array

1. Introduction

In recent years interest has grown in fabrication of microlens arrays due to their wide applications in optical computing, optical signal processing, optical interconnection, optical data storage, display, etc. Many methods for fabricating microlens array have been proposed and demonstrated, such as thermal reflow [1–3], excimer laser ablation [4], gray scale photolithography [5], microjet fabrication [6], hot embossing of plastic material on a lens array mold made by focused ion beam milling [7] and hot intrusion process [8]. Among them, Most are expensive and not easily accessible to scientists and industrialists. Although the thermal reflow technique is regarded as a low cost mass-production process, the reflow of photoresist is difficult to control to yield precise shape.

The conventional hot embossing [7] and hot intrusion process [8] are comparatively inexpensive, but there are inherent problems due to the pressing mechanism using hot plates of press. The pressure between the mold and plastic substrate is higher in the center and lower in the edge. The pressure distribution is not uniform. The embossing area is thus limited. Besides, the mold material is limited to metal. Glass or silicon molds are often too brittle to be pressed by hot plates.

* Corresponding author. Fax: +886 2 8369 5574.
E-mail address: syyang@ntu.edu.tw (S.-Y. Yang).

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In order to overcome the problem, we developed an innovative method using gas to exert isotropic pressure for micro-hot-embossing. Perfectly uniform embossing pressure throughout the whole area can be achieved. In addition, silicon molds can be used.

In this study, gas-assisted micro-hot-embossing is used to fabricate plastic microlens array. A silicon mold with holes array microstructures is first fabricated by conventional photolithography and deep reactive ion etching process. Plastic film is then placed on top of the mold, and the stack is placed in the closed chamber. Upon heating above the glass transition temperature (T_g) of the plastic film, nitrogen gas is introduced into the chamber. Under gas pressure, the polymer material is partially filled into the circular holes, and a convex surface is formed due to viscoelastic deformation and surface tension.

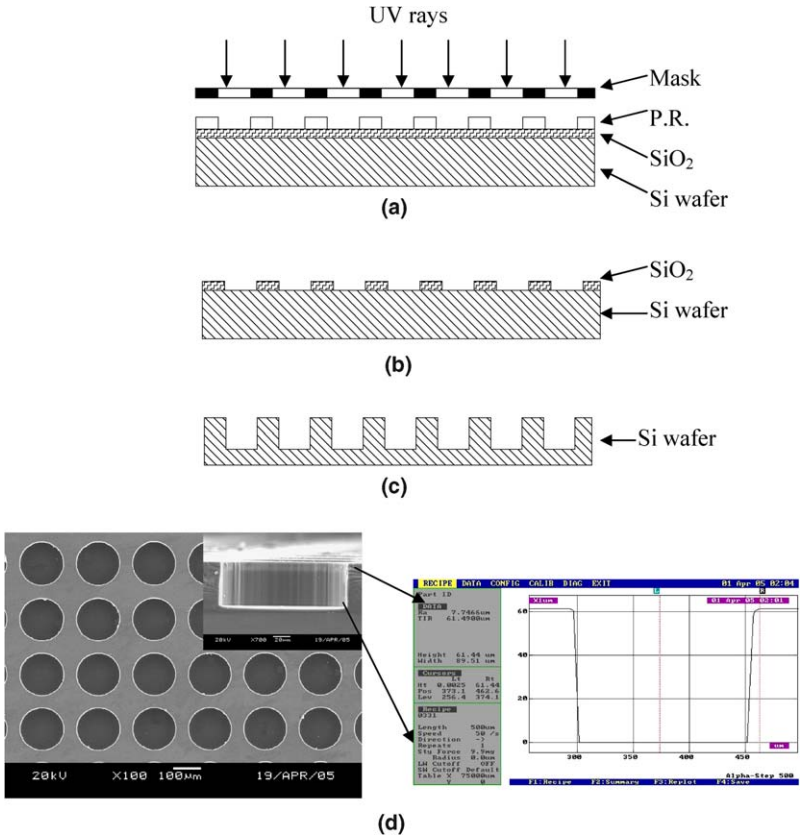

Fig. 1. Procedures for fabricating silicon holes array mold. (a) Photolithography, (b) mask etching, (c) silicon etching and (d) SEM image and surface profile of silicon mold.

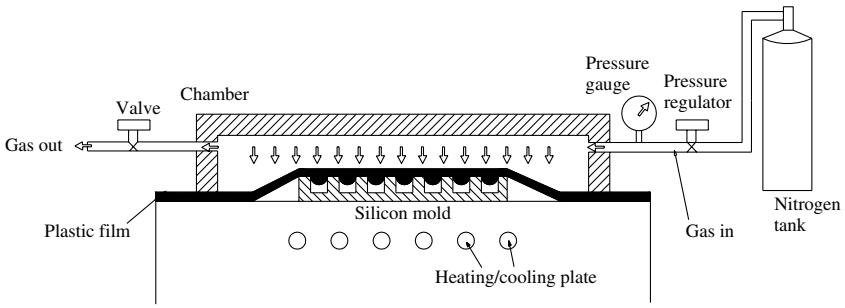

Fig. 2. Schematic showing the gas-assisted micro-hot-embossing machine.