Microelectronic Engineering 123 (2014) 65–72

Contents lists available at ScienceDirect

Microelectronic Engineering

journal homepage: www.elsevier.com/locate/mee

A novel template-release method for low-defect nanoimprint lithography

Takuya Kitagawa [a,b], Naoto Nakamura [a], Hiroaki Kawata [a,b], Yoshihiko Hirai [a,b,*]

[a] Osaka Prefecture University, Graduate School of Engineering, Department of Physics and Electronics Engineering, Sakai 599-8531, Japan
[b] Japan Science and Technology Agency, Core Research for Evolutionary Science and Technology, Kawaguchi 332-0012, Japan

ARTICLE INFO

Article history:
Received 22 October 2013
Received in revised form 31 March 2014
Accepted 9 May 2014
Available online 17 May 2014

Keywords:
Template
Release
Nanoimprint
Defect
Damage
Push back

ABSTRACT

Various template-releasing methods, including a newly proposed novel method for nanoimprint lithography, are examined and evaluated in terms of defect rates for line and pillar patterns. The newly proposed method, called the push-back method, shows excellent releasing performance. In the push-back method, a template is repeatedly pushed up and back to a resist pattern. We evaluated defect rates after template releasing for various methods using a newly developed tool controlled in multiple axes.

1. Introduction

The template-release process is one of the key processes in nanoimprint lithography because adhesion between the template and the resist causes mechanical defects and significantly affects the yield of the process [1]. To eliminate the defects, chemical and mechanical approaches have been proposed. One of the most effective methods is the use of an anti-sticking coating on the template surface [2–7] that decreases the surface energy of the template. Additionally, improving the material properties of template or resist were approached based on a chemical point of view [8–11]. Furthermore, several approaches have been reported related to the optimization of the process conditions or template structures [12–19] and investigations related to the formation of defects [20–22]. However, few approaches have been developed that focus on the release of the template [23,24]. In this paper, we propose a new novel template release method for low-defect nanoimprint lithography based on a mechanical point of view and evaluate the defect rate in various patterns.

2. Experiment

2.1. Template releasing tool

We used a newly developed, three-axis, controlled-template releasing tool [24] to examine various release methods. Fig. 1(a) shows a schematic diagram of the tool. A template was gulled on the base stage and a resist was coated or dropped on the mold. A quartz plate, which acted as a substrate, was placed on an ultraviolet (UV)-curable resist and UV light was exposed to the resist through the quartz plate. The quartz plate was 2 mm thick and 150 × 150 mm square and was held in place by three movable rods, which were installed 60 mm away from the center of the template on the base on the circumference. Fig. 1(b) shows an image of the tool.

After UV exposure, the resist was cured and stuck on the quartz plate. The rods were individually driven in by ball screws (BSSCK0802, MISUMI Group Inc.) using stepping motors with a 1/100 reduction gear (CRK523PBP-H100, ORIENTAL MOTOR Co. Ltd.). The displacement of the rod was controlled at 2 nm per pull and counted by the number of steps. By controlling the displacement of each rod, the three-dimensional motion of the template against the quartz plate was realized and various release methods were investigated, as examined below.

* Corresponding author at: Osaka Prefecture University, Graduate School of Engineering, Department of Physics and Electronics Engineering, Sakai 599-8531, Japan. Tel.: +81 072 254 9267; fax: +81 722549908.
E-mail address: hirai@pe.osakafu-u.ac.jp (Y. Hirai).

http://dx.doi.org/10.1016/j.mee.2014.05.016
0167-9317/

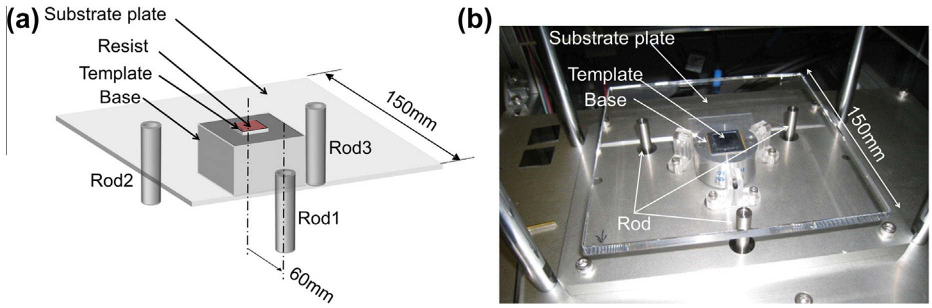

Fig. 1. The three-axis, controlled-template release tool. (a) The system structure and (b) image of the system.

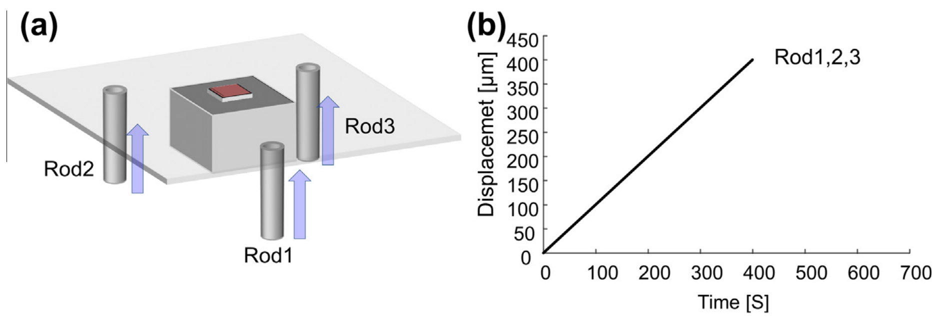

Fig. 2. The lift-off method. (a) Schematic of the release method and (b) diagram of the rod motions.

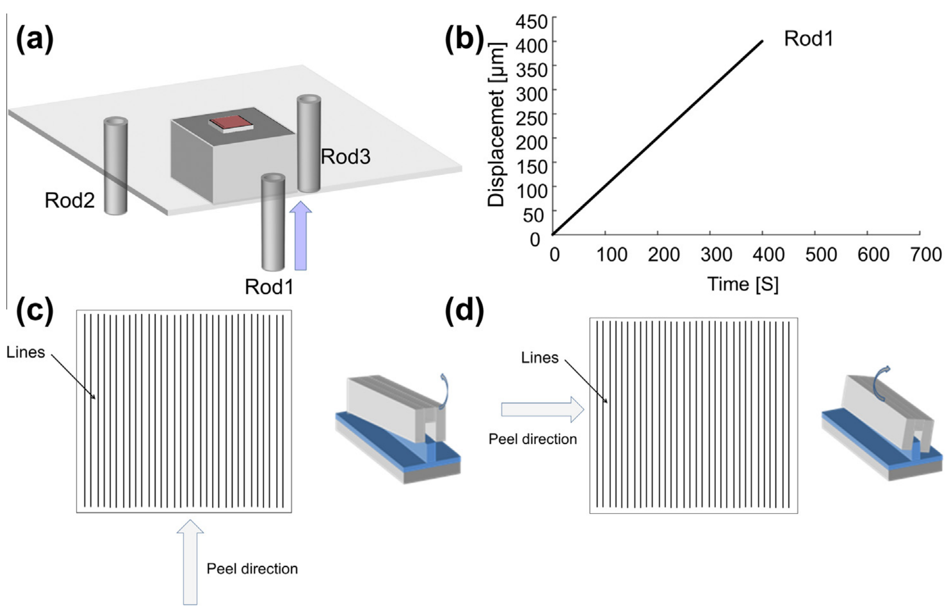

Fig. 3. The peeling methods. (a) Schematic of the release method, (b) diagram of the rod motion, (c) the parallel setting, and (d) the cross-setting.

2.2. Template release methods

In this paper, five release methods are examined. Three of these methods have already been proposed and the remaining two methods are newly proposed. A typical method is the so-called lift-off method, as illustrated in Fig. 2(a). The three rods push up on the plate at the same time and the plate is lifted in a vertical direction against the template. Fig. 2(b) shows the time sequence of the rod displacement. In this report, the lifting velocity of the rod is 1.0 $\mu m\, s^{-1}$. The second is a peeling method, where the plate is lifted by a single rod from the one side and peeled off, as shown in Fig. 3(a). The time sequence of the rod displacement is shown in Fig. 3(b). In this case, only the first rod is actuated. In the peeling method, we examined two kinds of configurations. One configuration is a setting parallel to the orientation of the lines in the template, where the plate is peeled off parallel to the orientation of lines, as shown in Fig. 3(c). The other configuration is a cross setting to the lines, where the plate is peeled off in a direction