Available online at www.sciencedirect.com
SCIENCE DIRECT®
ELSEVIER
Microelectronic Engineering 67–68 (2003) 623–628
MICROELECTRONIC ENGINEERING
www.elsevier.com/locate/mee

Fluorescence microscopy for quality control in nanoimprint lithography

Ch. Finder[a,*], M. Beck[b], J. Seekamp[c], K. Pfeiffer[d], P. Carlberg[b], I. Maximov[b], F. Reuther[d], E.-L. Sarwe[b], S. Zankovich[c], J. Ahopelto[e], L. Montelius[b], C. Mayer[a], C.M. Sotomayor Torres[c]

[a]*Institute of Physical and Theoretical Chemistry, University of Duisburg, Lotharstrasse 1, D-47057 Duisburg, Germany*
[b]*Division of Solid State Physics, Lund University, Box 118, S-22100 Lund, Sweden*
[c]*Institute of Materials Science and Department of Electrical and Information Engineering, University of Wuppertal, D-42097 Wuppertal, Germany*
[d]*Microresist Technology GmbH, D-12555 Berlin, Germany*
[e]*VTT Centre for Microelectronics, P.O. Box 1208, FIN 02044 VTT, Finland*

Abstract

Fluorescence microscopy is introduced as a low cost quality control process for nanoimprint lithography. To depict imprinted structures down to 1 μm lateral size and to detect residues down to 100 nm lateral size, the standard printable polymer mr-I8000 is labelled with less than 0.1 wt.% fluorescent dye. Three different types of stamps are used to determine the dependence of the shape and size of stamp features in a series of imprints. The quality of a stamp is given by the sticking polymer residues per unit area. Fluorescence light images as well as visible light images are analysed. Changes in the area of the stamp covered with polymer as a function of the number of imprints is summarised in a statistical process chart. Adhesion was artificially induced in order to observe self cleaning of virgin stamps. They were detected and monitored, suggesting that this method is a suitable technique for quality control and that it could be easily adapted to the nanoimprint process.

Keywords: Nanoimprint lithography; Fluorescence microscopy; Quality control; Stamp; Polymer

1. Introduction

In recent years nanoimprint lithography (NIL) has been developed as a low cost method for the fabrication of nanoscaled patterns. Nanoimprint lithography is a parallel process in which a structured stamp is pressed into a soft or softened polymer layer [1,2]. Due to its projected reliability, throughput

*Corresponding author.
E-mail address: ch.finder@uni-duisburg.de (C. Finder).

0167-9317/03/$ – see front matter
doi:10.1016/S0167-9317(03)00123-0

and low cost nanoimprint lithography is seen an alternative to conventional nanometer scale patterning technologies like, e.g. electron beam lithography. Prints on 6″ wafers [3] and master for nanostructures down to 10 nm [4] have been demonstrated.

To become a real alternative on industrial scale it is necessary to combine the process of NIL with a reliable and fast quality control routine to guarantee both the quality of the stamp and the quality of the imprint. Generally, scanning electron microscopy (SEM) and atomic force microscopy are used to evaluate the quality of prints or the status of the stamp. In this investigation, fluorescence microscopy has been the method of choice for nanoscale quality control because it opens ways to circumvent the resolution limit to access quality information. The status of a stamp depends on the amount of fluorescent polymer residues on its surface. These residues can be detected using a CCD-technology coupled to the fluorescence microscope.

2. Experimental

2.1. Materials

To evaluate the stamp and print quality by fluorescence microscopy a fluorescent dye is essential. Generally, standard materials for NIL do not show fluorescence in the visible spectral range [5]. Therefore a standard NIL polymer mr-I 8000 was labelled with a derivative of the commercially available fluorescent dye perylene-3,4,9,10-tetracarboxylic acid dianhydride [6]. Due to a radical polymerisation the dye could be covalently bound to the polymer matrix. This guarantees a uniform distribution of the dye during the preparation of the layers by spin coating. Experiments have shown that the small amount of dye (0.1 wt.%) does not influence the imprint behaviour of the polymer.

In this investigation three different kinds of stamps are used:

1. A 1″ Si/SiO_2 nanostamp fabricated with electron beam lithography (EBL), chromium lift-off and reactive ion etching (RIE). This stamp has nine fields in a 3×3 array with lateral feature sizes varying between 30 nm and 2 μm.
2. A silicon stamp manufactured by UV-lithography and RIE patterned with features from 50 μm down to 400 nm in lateral size on an area of 20×20 mm^2.
3. A stamp with the same layout as the first one but the 3×3 array is patterned in a new polymer (mr-L 6000XP) on a 1″ wafer. Mr-L 6000XP is an UV lithography and e-beam resist with thermoset properties [7]. All stamps are coated with the F_{13}-TCS method to avoid adhesion of the polymer on the stamp surface [8].

2.2. Fluorescence microscopy

A conventional microscope (Leitz, Orthoplan) is equipped with a supplementary UV light source using a high-pressure mercury lamp (Osram, HBO 103W/2) and a filter system (Leica, I2/3). The excitation filter of this system is a band pass filter in the range of 450–490 nm. The fluorescence light is separated from the excitation light by a dichroic mirror at 510 nm. Additionally, the system is equipped with a long pass filter transmitting wavelengths above 515 nm. For an automated process