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Novel organic polymer for UV-enhanced substrate conformal imprint lithography

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ABSTRACT

In this work, a novel kind of UV curing polymer is introduced as promising resist for UV-enhanced substrate conformal imprint lithography (UV-SCIL). This fully organic polymer is an epoxy based material and can crosslink via UV exposure to form a solid layer. The curing time of 17 s for this epoxy based resist is ten times shorter compared to commonly used resists for UV-SCIL. Imprints with this material are shown in this work as well as results of an HBr dry etch process of silicon, where the material served as etching mask. Using this polymer as resist for UV-SCIL enables shorter process times whereby the fidelity of the structures remains high.

1. Introduction

Substrate conformal imprint lithography (SCIL) is a novel full wafer scale soft-nanoimprint technology [1]. This sub-micrometer patterning method uses flexible PDMS stamps for the structure transfer. The concept behind this technology is soft lithography. Originally, the SCIL technology was developed for the transfer of structures into sol gel materials which hardened via diffusion of solvents into the PDMS stamp material. The work of Ji et al. [2] showed the extension of SCIL to UV-enhanced SCIL (UV-SCIL). With this new option, UV curable materials can be used as resists for the SCIL-method.

Common resists for the SCIL or UV-SCIL contain inorganic chemistry [2,3]. In order to use one of them as etching mask for different substrates like Si, SiO_2 but also GaN or metals this fact limits their suitability for it. Furthermore, all common resists for SCIL or UV-SCIL need long curing times (3–15 min) [2,3]. In this work, purely organic materials are investigated in order to have one imprint resist suitable as etching mask for different substrates. Also the further processing of the substrates can then be realized with the same techniques as for organic photo resists. As shown, another advantage of UV polymers for UV-SCIL is the reduction of curing time compared to commonly used resists. So, using UV curing polymers shortens the overall SCIL process time essentially.

For a first evaluation of UV-curing polymers for UV-SCIL, the UV-SCIL process was emulated on a NPS 300 nanoimprint stepper. With that, the curing behavior in contact to PDMS stamps and the adhesion behavior to PMDS stamps of several different UV-curing polymers could be characterized. Hereafter, a process flow from material deposition to etching for the most suitable UV-SCIL polymer was developed which is an experimental UV curing adhesive from DELO Industrial Adhesives, Katiobond OM VE 110707. This material is an epoxy based polymer and cures by photo initiated cationic polymerization [4].

2. Experimental setup

For first investigations on promising UV-curing polymers for UV-SCIL, a NPS 300 nanoimprint stepper with PDMS stamps and an imprint pressure of 20 mbar was used, a typical UV-SCIL imprint pressure. This emulation of the UV-SCIL process was necessary to be able to test many different polymers without spin coating them and in order to save not negligible costs for PDMS stamps. For that, stamp pieces of 1 cm^2 size were prepared out of the wafer size PDMS stamps. With these small PDMS stamp pieces, imprints into several different manually dispensed UV-curing polymers were performed. The interaction between UV-curing polymers, silicon substrates, and PDMS were analyzed to assess well suitable polymers for UV-SCIL.

Material deposition of the most promising polymer (i.e. DELO Katiobond OM VE 110707) on silicon substrates was realized by

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Table 1
List of tested UV-curing polymers for UV-SCIL with their polymer base and their imprint result with PDMS stamps.

Name of tested UV-curing polymer	Polymer base	Imprint result
NOA 61; Norland Products	Acrylates	Weak substrate adhesion
NOA 84, Norland Products	Acrylates	Curing not possible
NOA 89, Norland Products	Acrylates	No substrate adhesion
mr-UVCur21SF, micro resist technologies	Acrylates	Curing not possible
mr-UVCur06, micro resist technologies	Acrylates	Homogeneous imprint
Photobond OM VE 512494, DELO Industrial Adhesives	Acrylates	Curing not possible
Photobond GB310, DELO Industrial Adhesives	Acrylates	Strong adhesion to PDMS stamps
Katiobond OM VE 110707, DELO Industrial Adhesives	Epoxides	Homogeneous imprint

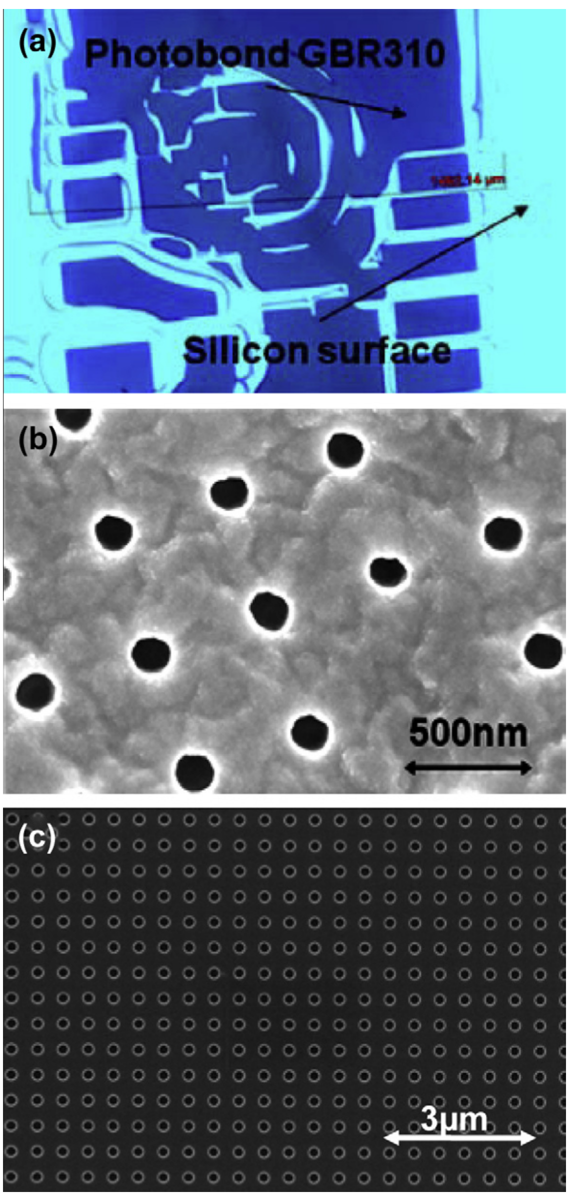

Fig. 1. (a) Optical microscopy image of a partially released Photobond GB310 imprint. (b) Secondary electron microscopy (SEM) image of a structured partially cured Photobond OM VE 512494 imprint. (c) SEM image of a structured and cured Katiobond OM VE 110707 imprint.

spin coating on 100 mm wafers for the wafer scale patterning by UV-SCIL. A manual coating system was used for the material deposition. The film thicknesses of deposited layers were measured with an interferometer.

The UV-SCIL imprint processes for this polymer were performed on a MA8/BA8 mask aligner with SCIL upgrade from SUSS MicroTec. For a final structure transfer of imprinted structures into the silicon substrates, an ICP RIE etching process system from STS was used. The employed etching process utilizes argon plasma for the removal of the residual layer and HBr plasma for the silicon etching [5].

3. Experimental results

3.1. UV-SCIL Emulation on NPS 300

The results of the first evaluation on UV-curing polymers for UV-SCIL on the NPS 300 are summarized in Table 1. It shows that most of the investigated materials are not suitable for soft-nanoimprint lithography with PDMS molds (i.e., for UV-SCIL). For example, some materials have a very strong adhesion to the PDMS stamp after the UV-curing (e.g. Fig. 1a)). Other materials could not be cured during the contact with the PDMS stamp (e.g. Fig. 1b)) because of oxygen inhibition [4]. Oxygen from the atmosphere absorbed by the PDMS material inhibits the curing of most acrylate based polymers.

Only two of the evaluated polymers exhibited suitable properties for UV-SCIL during these experiments, mr-UVCur06 and DELO Katiobond OM VE 110707 (e.g. Fig. 1c). mr-UVCur06 was already used as resist for UV-SCIL e.g. in the work of Wang et al. [6] so that the suitability for UV-SCIL was expected. As DELO Katiobond OM VE 110707 is a novel material, in the following, all required process steps for its use as UV-SCIL resist were developed.

3.2. Spin coating

In this work the following coating process for Katiobond OM VE 110707 was developed. Before spin coating, the surface of the silicon substrates was conditioned with O_2 plasma and the polymer was diluted with chlorobenzene. Fig. 2 shows a spin speed curve for Katiobond OM VE 110707 diluted with 80 wt% chlorobenzene for a manual coating system. For post coating processing the coated wafer is soft baked on a heat plate. With this spin coating

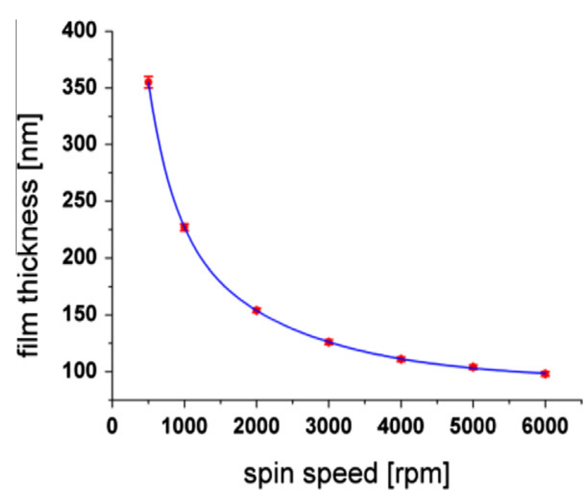

Fig. 2. Spin speed curve for Katiobond OM VE 110707 diluted with 80 wt% chlorobenzene.