Microelectronic Engineering 110 (2013) 403–407

Contents lists available at SciVerse ScienceDirect

Microelectronic Engineering

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

Fabrication of inverse micro/nano pyramid structures using soft UV-NIL and wet chemical methods for residual layer removal and Si-etching

J.W. Kim *, U. Plachetka, C. Moormann, H. Kurz

AMO GmbH, Otto-Blumenthal-Strasse 25, 52074 Aachen, Germany

ARTICLE INFO

Article history:
Available online 14 March 2013

Keywords:
Nanoimprint
Residual layer etching with wet chemical
Micro/nano inverse pyramids

ABSTRACT

In this study we present a novel and simple fabrication method for micro- and nano-scale inverse pyramidal structures by a combination of soft UV-NIL and wet chemical etchings. The unique feature of our method is the absence of a RIE process, which is usually applied for removal of residual layer. This is achieved by modifying the imprint resist with an O_2-plasma in asher and subsequent wet etching of residual layer by diluted HF. Combined with conventional anisotropic wet etching step with KOH/IPA, our method allows cost effective fabrication of inverse pyramidal structures on Si-substrate in batch process. Such structures in nano- and micro scale are particularly suitable for light management in photovoltaic, solid state lighting and silicon based photonic.

© 2013 Elsevier B.V. All rights reserved.

1. Introduction

Inverse pyramidal patterns in micro or nano scales into silicon (Si) substrates are versatile pattern geometries as they can be applied in the area of light management for light harvesting components such as high efficiency solar cell [1], for light guidance in solid state lightning [2], SERS (Surface Enhanced Raman Spectroscopy) to analyze material properties [3] or surface texturing of thin-film crystalline silicon solar cells, where inverse nano scale pyramids are introduced to enhance the light absorption allowing a further reduction of silicon material usage [4].

Until today, transfer of inverse high density pyramidal patterns in micro scale into Si substrate is commonly done by a combination of optical photolithography using selective opened photo resist layer and underlying hard mask (SiO_2 e.g.) followed by anisotropic wet chemical etching. But for pattern transfer of inverted pyramids in nano scale, feasible pattern resolution of conventional contact photolithography comes to its limit and alternative lithography methods such as electron beam lithography or laser interference lithography, which are cost or time intensive, have to be used.

Another cost effective lithography method is nanoimprint lithography (NIL). Compared to conventional photolithography, nanoimprint lithography (NIL) offers tailored pattern definition and replication of micro- and nano scale structures at low cost [5]. Soft Ultra-Violet Nanoimprint lithography (Soft UV-NIL) in particular enables further cost reduction by using a cast-molded flexible mold for patterning over large surface in a single process step [6].

One of main draw backs of NIL, however, is the presence of residual layer underneath the defined resist patterns, which needs to be removed before any pattern transfer process. A combined NIL and photolithography using hybrid mold by quartz mold with light blocking metal layer allows patterning without residual layer [7], but this method requires complicated quartz mold fabrication and is still bounded to resolution limit of photolithography. Hence NIL enables cost effective pattern definition for wide pattern resolution from micro to nano meter scale, but the removal of the residual layer still remains as pivotal issue and imposes an additional RIE (reactive ion etching) process step [8], which is cost intensive and hinders batch process for higher throughput.

Here we present a unique method for fabrication of periodic nano- and micro scale inverse pyramidal structures on Si substrates. Patterns were defined by soft UV-NIL. After pattern definition, imprint resists were treated with O_2-Plasma in barrel resist asher in order to increase chemical resistance during the subsequent wet etching process. Unlike common RIE, resist asher enables simultaneous treatment of multiple substrates in a single process step. Removal of residual layer and a selective etching of a SiO_2 hard mask layer, as well as following pattern transfer into Si substrates were carried out using only wet chemical etching process.

2. Experimental

2.1. Fabrication of master templates and flexible molds

Soft UV-NIL uses flexible mold as replication tool, whose fabrication requires prepatterned master templates. In this study, two master templates were used for the fabrication of flexible molds

* Corresponding author. Tel.: +49 (0) 241 8867217; fax: +49 (0) 241 8867571.
E-mail address: kim@amo.de (J.W. Kim).

0167-9317/$ - see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.mee.2013.02.098

for micro- and nano scale pattern definition. For the fabrication of master templates, hole pattern with a 2.5 μm and 500 nm pitch were defined by using an optical stepper (Canon FPA3000) and laser interference lithography (LIL) respectively. Those patterns were etched into Si using standard SF_6 RIE processes to a depth of 150 nm and 120 nm followed by deposition of anti-Sticking layer for better mold separation during the cast molding process.

Flexible molds, having inverse patterns to master templates, were made from the templates with cast molding process. Polydimethylsiloxane (PDMS) from Dow Corning (Sylgard 184) was used for the fabrication of the molds. The mixture consisting of two components (10:1, base material: curing agent) was poured onto the respective masters, degassed in a vacuum chamber and were thermally cured on a hot plate with a temperature of 90 °C for 2 h. The flexible molds were then separated from the master templates and used as replication tool for pattern definition on the target substrates.

2.2. Process flow for the fabrication of nano- & micro scale inverted pyramids

The complete process flow following the described mold fabrication is illustrated in Fig. 1.

In detail, 10 nm silicon oxide layer was deposited on Si(100) substrates acting later as hard mask for wet chemical etching. AMONIL® Imprint resist (AMO GmbH) was spin coated on substrates and the imprint process using flexible mold was carried out (Fig. 1a) for pattern definitions of micro and nano scale inverse pyramidal structures. The thicknesses of imprint resist layers were defined to 200 nm (AMONIL® MMS4, 3000RPM for 30 s) and 130 nm (AMONIL® MMS10, 2000RPM for 30 s) respectively. Imprint processes for both patterns were carried out using a soft UV-NIL tool (EVG620). An imprint pressure of 200 mbar with a UV-exposure time of 10 min was applied for the imprint process.

In order to allow a removal of residual resist and a selective wet etching of SiO_2 hard mask layer, the resist was modified with O_2-Plasma in a resist asher (Tepla Semi 300, O_2: 800 ml/min, 1000 W) (Fig. 1b). The effect of resist modification on wet chemical based residual layer etching by HF was analyzed and optimized treatment time was determined. Those results will be discussed in Results and Discussion.

For removal of the residual layer and selective etching of the deposited SiO_2 layer, substrates were dipped in 2.5% hydrogen fluoride (HF) for 30 s (Fig. 1c).

Pattern transfer for inverted pyramid structures into silicon substrates was carried out with potassium hydroxide (KOH) using selectively etched SiO_2 layer as a hard mask (Fig. 1d). For the mixture of 30% KOH, 70 g of KOH pellets were mixed with 190 ml deionized (DI) water at 70 °C. Additional 50 ml of isopropyl alcohol were added for better surface contact of etchants. Micro scale holes were etched for 60 s and nano scale holes for 45 s with subsequent cleaning of samples in 5% HF in order to remove resist residue and SiO_2 hard mask layer (Fig. 1e).

3. Results/discussion

3.1. Pattern definition by soft UV-NIL

The results of the nanoimprint process in comparison to the masters for mirco and nano patterns are shown in Fig. 2. Patterns of the both imprinted structures correspond well, within a few nanometers, to the original master templates. Holes with a period of 2.5 μm and 1.15 μm diameter were defined with a pattern height of 145 nm. Thickness of residual layer was measured to less than 10 nm (Fig. 2a and b). Patterning results of holes with 500 nm

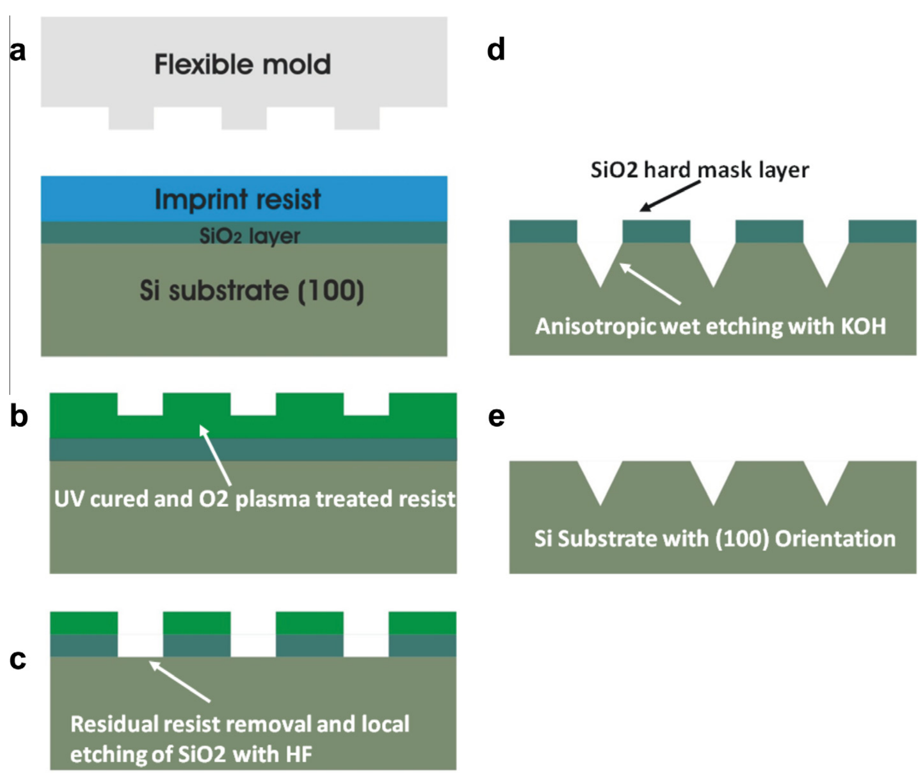

Fig. 1. Process flow for fabrication of inverse pyramids, SiO_2 layer was deposited as a hard mask layer and pattern definition step by soft UV-NIL was carried out (a), patterned imprint resist was treated with O_2-Plasma (b), residual layer and SiO_2 layer was etched with diluted HF (c), anisotropic wet etching was carried out with KOH/IPA etchant (d), substrates were cleaned with HF in order to remove SiO_2 layer and resist residue (e).

Download English Version:

https://daneshyari.com/en/article/544303

Download Persian Version:

https://daneshyari.com/article/544303

Daneshyari.com