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Transfer of thin, patterned gold layers from poly(methyl methacrylate) stamp onto photoresist surface

O. Lyutakov [a,*], J. Tuma [a], M. Janousek [b], I. Huttel [a], V. Švorcík [a]

[a] Department of Solid State Engineering, Institute of Chemical Technology, 166 28 Prague, Czech Republic
[b] Department of Microelectronics, Faculty of Electrical Engineering, Czech Technical University, Prague, Czech Republic

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ABSTRACT

A simple technique for the transfer of thin gold layer from poly(methyl methacrylate) (PMMA) stamp onto SU-8 photoresist is described and verified. The procedure comprises sputtering of thin gold layer on flat or laser patterned PMMA, bringing the PMMA stamp into contact with photoresist substrate, transferring of the gold layer onto photoresist and finally dissolution of the PMMA stamp. Surface morphology of as sputtered and transferred gold layers was determined by profilometry, confocal microscopy, and atomic force microscopy (AFM) techniques at three different scales. Electrical properties were examined by conductive AFM technique. The transfer from patterned PMMA stamp leads to simultaneous patterning of the gold layer and creation of a system of ordered conductive gold strips separated by non-conductive areas on photoresist surface.

1. Introduction

Periodical nano- and micro-structures prepared on different substrates find applications in plasmon photonics and optoelectronics. For that reason various methods of nano-scale metal patterning have been investigated and developed [1].

Standard lithographic techniques (electron-beam lithography, deep ultraviolet photolithography, etc.) use an expensive instrumentation and are suitable for patterning of only small areas of some very flat special materials. Alternatives are contact printing, molding, embossing, and writing [2]. Soft techniques can overcome the resolution limit of photolithography and their application is not restricted to flat and rigid surfaces [3,4]. Additionally, these methods allow preparation of 3D structures [5,6] and become essential manufacturing tools in optoelectronics, photonics and many other existing and emerging areas of technology [7,8].

In the soft techniques a thin polymer film (stamp) is first patterned by different techniques and covered by thin metal layer. Then the metal structure is transferred from the stamp onto suitable substrate. Simultaneous transfer and patterning of thin metal layer are also possible. The transfer of metal structure and its attachment relies on a physico-chemical interaction between the metal plated stamp and the substrate when they are brought into contact [9]. Achievable resolution of the transferred pattern may be below 100 nm. Also non-covalent surface forces may mediate the transfer process [10,11]. Transfer of a top layer deposited onto patterned polymer stamp was described in [12]. In this case only a part of ink, deposited on pattern "hills", is transferred onto substrate and the transfer process is controlled by surface adhesion forces. Another technique of the preparation of periodical material array is based on molecular transfer along the edges of the stamp features (so-called edge transfer lithography) [13].

The disadvantage of the abovementioned techniques is that they are limited to systems with specific covalent or surface interactions that can mediate the transfer of the metal from the stamp surface to the substrate. This limitation can be overcome by applying soluble polymer as a stamp which can later be removed [14,15]. The transfer can be accomplished regardless of difference between surface energies of the substrate and the stamp.

In this work the transfer of gold film from the poly(methyl methacrylate) stamp to the surface of photoresist novolac resin is described.

2. Experimental

2.1. Materials

Poly(methyl methacrylate) (PMMA) of optical purity was supplied by Goodfellow UK and epoxy novolac resin photoresist (Su-8) by Micro Resist Technology GmbH. Meso-tetraphenylporphyrin of 99.7% purity was obtained from Frontier Scientific. 99.99% pure gold target was provided by Safina, CZ.

* Corresponding author. Tel.: +420 22044 3205.
E-mail address: lyutakoo@vscht.cz (O. Lyutakov).

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2.2. Methods

PMMA film, 1 μm thick, and photoresist Su-8 film, 5 μm thick, were prepared on microscopy glass (Glassbel Ltd, CR) by spin-coating method under 3000 rpm. Patterning of PMMA surface was performed on a confocal microscope by the technique described in [16,17]. Gold layer (100 nm thick) was sputtered onto flat or patterned PMMA surface on Balzers SCD 050 device from gold target. The deposition conditions were: DC Ar plasma, gas purity 99.995%, room temperature (25 °C), sputtering time 120 s, current of 40 mA, total Ar pressure of about 4 Pa, and an electrode distance of 50 mm. The PMMA, flat or laser patterned, was sputtered with gold and then it was brought into contact with Su-8 surface. External pressure (100 Pa) and elevated temperature (160 °C) were applied to bring the stamp into better contact with the substrate and to facilitate gold transfer. The whole assembly is then exposed to UV light for photoresist hardening. Then the PMMA stamp was dissolved in chloroform. As a result Au layer was transferred from PMMA onto photoresist surface. Schematically the whole process is schematically shown in Fig. 1.

2.3. Measurement

Surface morphology and surface roughness of the prepared samples were characterized by atomic force microscopy (AFM). Surface profile was examined in a tapping mode with Digital Instruments CP II set-up. Surface roughness was measured by profilometry and confocal microscopy too. Macro-scale profiles of the samples were measured

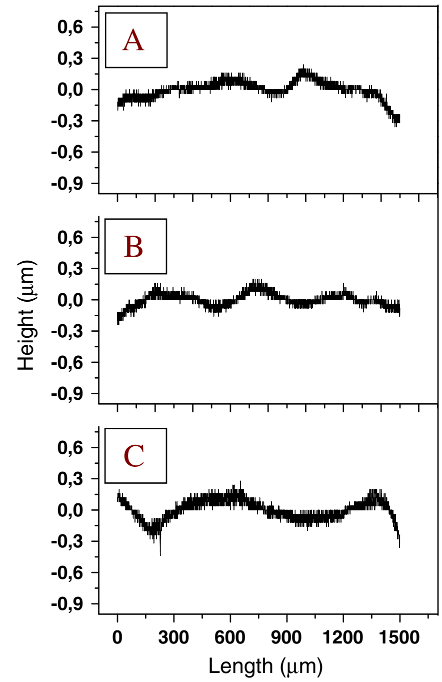

Fig. 2. Surface profiles measured at "long" distances by profilometry: (A) — pristine PMMA surface, (B) — polymer surface with sputtered Au, (C) — surface of Au after transfer onto photoresist.

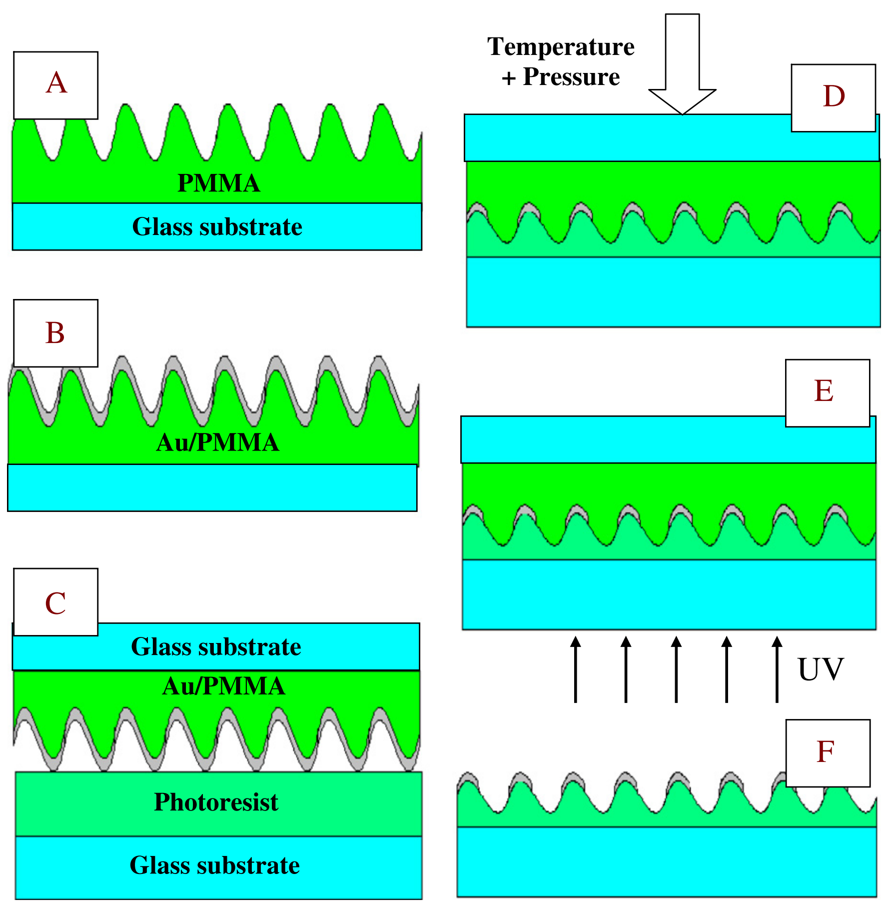

Fig. 1. Scheme of gold transfer from PMMA surface onto photoresist: (A) — patterned PMMA surface, (B) — patterned PMMA surface covered by Au, (C) — PMMA brought into contact with photoresist surface, (D) — application of pressure and temperature, (E) — photoresist hardening by UV light, (F) — resulted structure obtained after PMMA dissolution.