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ScienceDirect
Sensors and Actuators A 136 (2007) 412–416
SENSORS AND ACTUATORS A PHYSICAL
www.elsevier.com/locate/sna

Fabrication of high aspect ratio metallic microstructures on ITO glass substrate using reverse-side exposure of SU-8

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Received 25 November 2005; received in revised form 29 October 2006; accepted 2 November 2006
Available online 4 December 2006

Abstract

This paper describes a simple and inexpensive method to fabricate high aspect ratio metallic microstructures without the requirement of specialized equipments. In the method, a patterned nickel film is deposited on the conductive layer of an ITO glass, which works as an electrode supplying current to the nickel pattern. The nickel pattern electrodeposited serves as both the exposure mask and the seed layer for electroforming of metallic microstructures later on. Conventional contact UV lithography was applied to pattern a thin AZ4620 positive photoresist film coated on the ITO layer of the glass substrate. After development of the photoresist, a nickel film was electrodeposited in the recesses where exposed AZ4620 had been lifted up by using the emerged ITO layer as the conductive electrode. The formed Ni pattern functioned as an exposure mask to pattern a thick SU-8 photoresist coated on it. SU-8 microstructures with high aspect ratio were fabricated with reverse-side exposure. By using the fabricated SU-8 microstructure as a template, and the nickel pattern on the ITO glass substrate as the seed layer, nickel microstructures with high aspect ratio of about 15 and a sidewall slope of 89° were successfully fabricated after removing the SU-8 template in the hot Remover PG followed by a wet etchant.

Keywords: High aspect ratio; SU-8; ITO glass; Ni exposure mask; Metallic microstructures

1. Introduction

High aspect ratio microstructures are widely used in mechanical, electrical, chemical and biomedical devices and systems, including microactuator [1,2], micro accelerator [3], microfluidic device [4,5], micro mixer/reactor [6], and polymerase chain reaction (PCR) system [7]. For example, a metal structure with vertical sidewalls and a high aspect ratio can enhance the output force of a microactuator [2] and can be used as a mold for replica multichannel polymer chips with a high aspect array of separation channels [4]. The traditional techniques to fabricate high aspect ratio microstructures, such as LIGA [8,9] and deep reactive ion etching (DRIE) [10,11], are no doubt among the best choices for commercial scale production. However, in the research and development stage, advanced equipments as well as complicated fabrication procedures have become an evident burden to production cost, particularly when frequent modification is demanded for the microstructure design.

Since the epoxy-based SU-8 negative photoresist was reported, UV lithography of SU-8 offers an alternative to X-ray lithography for the fabrication of high aspect ratio microstructures at a much lower cost. However, a prominent problem of SU-8 is its high viscosity, which may lead to a poor photoresist coverage for spin coating particularly at a low speed. As a result, photomasks will not be in perfect contact with the photoresist due to the existence of the edge bead, which occurs for films thicker than 50 μm [5,12]. Due to the air gap between the photomask and the substrate, a bad lithography image will be created. Besides, in conventional UV-LIGA process, it is difficult to control the UV exposure conditions precisely as required [12,13]. If there is not enough energy to drive the crosslinking reaction at the base, the photoresist will remain unexposed and the entire structure will be lifted from the substrate, while overexposure from the reflected UV light from silicon substrate will destroy the base resolution of the SU-8 microstructure and cause fill-up of the micro channels [14].

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0924-4247/$ – see front matter
doi:10.1016/j.sna.2006.11.001

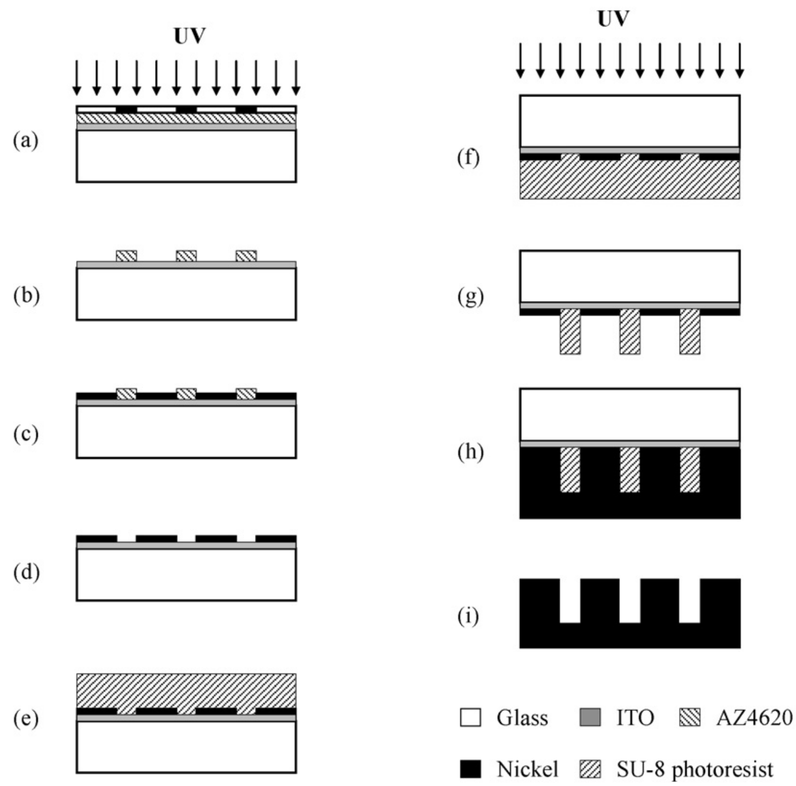

Fig. 1. Schematic fabrication process for high aspect ratio metallic microstructures. (a) Patterning of a thin AZ4620 positive photoresist coated on the ITO layer of a glass substrate. (b) Development of the AZ4620 photoresist. (c) Electrodeposition of a thin nickel film on the ITO layer as an exposure mask. (d) Lifting up of the unexposed AZ4620. (e) Coating of a thick SU-8 photoresist on the Ni exposure mask. (f) UV exposure through the ITO glass substrate with patterned Ni. (g) Development of the SU-8 to create a high aspect ratio micro structure. (h) Nickel electroforming within the patterned SU-8 template on the nickel base. (i) Detaching the electroplated nickel mold from the substrate and removal of the SU-8 template.

Peterman et al. [15] suggested a technique to produce high aspect ratio structures with thick photoresists, in which the SU-8 resist was exposed from the bottom by defining the amorphous silicon mask as a part of the glass substrate. The reverse-side exposure approach can eliminate the problem of light scattering due to the air gap between the mask and photoresist and also avoid light reflection at the interface between the photoresist and substrate. With this idea, more complicated SU-8 structures, such as in-channel 3D micromesh structures [16], and a tapered hollow metallic microneedle array [17], have been realized. However, the amorphous silicon layer on the glass substrate cannot be used as a seed layer for electroforming of metal microstructures. Besides, this method is limited to fabrication of SU-8 microstructures.

In this paper, a simple and inexpensive process is developed to fabricate high aspect ratio metallic microstructures on the ITO glass substrate. The ITO layer works as conductive electrode supplying current to the nickel pattern and the nickel pattern electrodeposited on the conductive ITO layer serves as both the exposure mask and the seed layer for electroforming of metallic microstructures. The fabrication processes for high aspect ratio SU-8 microstructures and nickel microstructures with the fabricated SU-8 microstructures as a template will be presented and discussed.

2. Methods

A schematic of the fabrication process for high aspect ratio metallic microstructures is shown in Fig. 1. ITO glass wafer was used as the substrate. A layer of AZ4620 positive photoresist with a thickness of 3 μm was spin-coated on the substrate and patterned with routine UV lithography (Fig. 1(a)). After development, the exposed AZ4620 was lifted up (Fig. 1(b)) and a nickel membrane was deposited in these left open spots by Ni electroplating with the ITO layer as the cathode (Fig. 1(c)). The electrodeposition was carried out in a nickel sulfamate bath at 45 °C with a current density of 2 A dm^{-2} for 10 min. The electrolyte composition was Ni $(SO_3NH_2)_2$ 450 g, H_3BO_3 30 g, $NiCl_2{\cdot}6H_2O$ 10 g and surfactant 0.1 g in 1 l of de-ionized water. The pH value of the electrolyte solution was buffered at 3–4. After electroplating, unexposed AZ4620 was rinsed away using acetone. A thin Ni pattern (∼2 μm) was formed on the ITO layer (Fig. 1(d)). Then, a thick SU-8 2100 (Micro Chem. Corp.) negative photoresist was spin-coated on the nickel mask to the desired thickness (100–300 μm) (Fig. 1(e)) and baked according to the manufacturer's specification. As shown in Fig. 1(f), UV light was illuminated through the ITO glass substrate for SU-8 exposure. After development in propylene glycol methyl ether acetone (PGMEA), SU-8 microstructures with different thickness could be obtained (Fig. 1(g)), which could be used