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3D glass fabrication utilizing electric field and heat treatment induced image mirroring

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Abstract

Despite the numerous advantages of a glass, difficulty of the fabrication, especially 3D fabrication, is still an obstacle. Here, we show a novel method to fabricate Pyrex glass in a simple and precise way. Combining conventional MEMS processes and a heat and electric field treatment, the Pyrex glass etching is realized by aluminum substitution for boron. Maximum depth and etching rate are influenced by temperature, applied voltage and aluminum thickness. By applying a range of voltages to different spot patterns or varying the thickness of the aluminum pattern, we were able to control the depth on a single substrate.

Keywords: Glass fabrication; 3D fabrication; Heat and electric field treatment; Image mirroring; Aluminum substitution; Depth control

1. Introduction

Advancement in MEMS technology enables the improvement of many technological fields including biotechnology, optical technology and various sensor technologies. However, since the basis of MEMS fabrication is planar patterning, there is a limitation of how complex a structure can be. Recently, 3D microstructures have become increasingly important, and efficient fabrication processes are currently sought to increase the dimensionality. The most common approach is multiple lithography processes with inter-level alignment to combine several microfabrication techniques: wet bulk micromachining, wafer bonding, dry etching and thin film technology [1–3]. However, this technique requires many process steps and is time consuming. But there is no simple way to fabricate microscale 3D structures.

Because of chemical and thermal stability, high electrical resistibility, hydrophilicity and transparency, glass is one of the most popular substrate to work with biological substances. Despite its numerous advantages, difficulty of fabrication is still an obstacle, especially in 3D. Researchers are trying to reduce the fabrication time and make more precise end product. The most conventional method of glass fabrication is to dip a glass into HF based solution for a certain time until a desired etching depth is achieved [4]. A wet etching method has an inherent size limitation problem because of its isotropic etching profile. Other glass etching methods such as powder blasting [5,6], deep-reactive-ion etching (DRIE) [7], laser drilling [8], using photosensitive glass [9,10] and electro-chemical discharge machining (ECDM) [11] have been introduced by various research groups. Although these techniques present some advantages, their drawbacks include size limitations, expensive equipment requirements and long fabrication time. Thus, glass fabrication is still a subject for further study.

In this paper, a novel method to fabricate 3D structures on a Pyrex glass will be introduced. By changing the temperature and electric field applied to the Pyrex glass and aluminum on the Pyrex glass, the depth of the desired shape can be effectively controlled. 3D structures of desired shape were formed by the image mirroring process which resulted from the heat and electrical treatment.

2. Principle mechanism

The principle mechanism of our method is shown in Fig. 1. The whole process is based on aluminum substitution by heat

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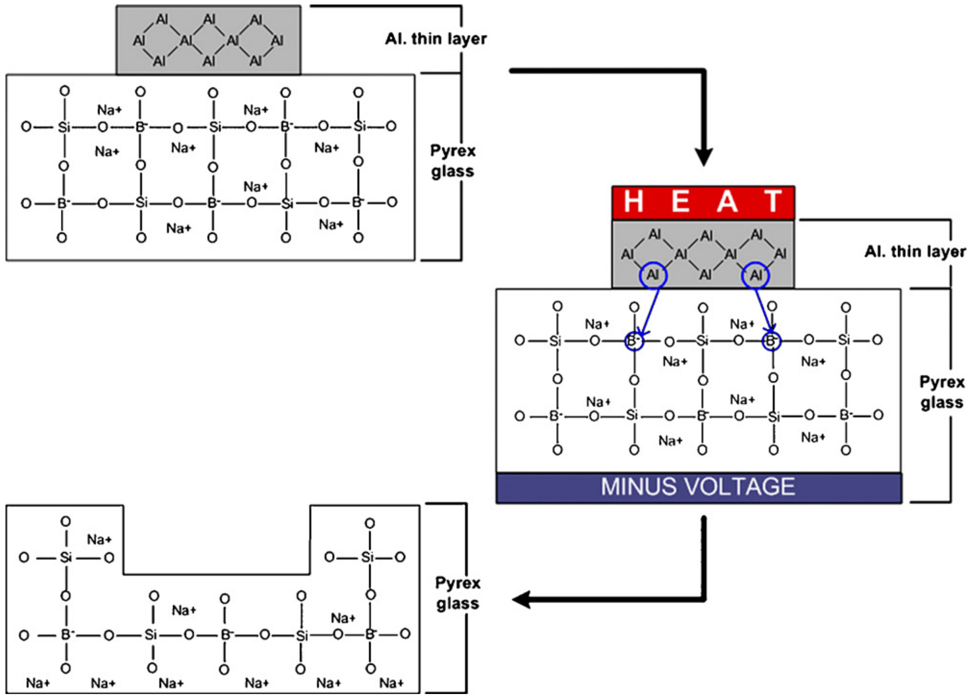

Fig. 1. Basic mechanism of depth development on Pyrex glass. First, an aluminum thin layer is sputtered on a Pyrex glass. Then heat and negative voltage is applied. Subsequently sputtered aluminum is substituted in place of boron. Finally, HF etches away the structurally weakened area of aluminum substitution region.

and electrical treatment resulting in an exact inverse image of the aluminum pattern. After patterning the aluminum on Pyrex glass, the heat and electric field are applied to initiate the reaction between the aluminum thin layer and Pyrex glass surface. This supplies the enough energy to overcome the free energy among the atoms forming the crystal structure and to break the structural bond. When the structural bond in the crystal is broken by the external force, the more free atoms

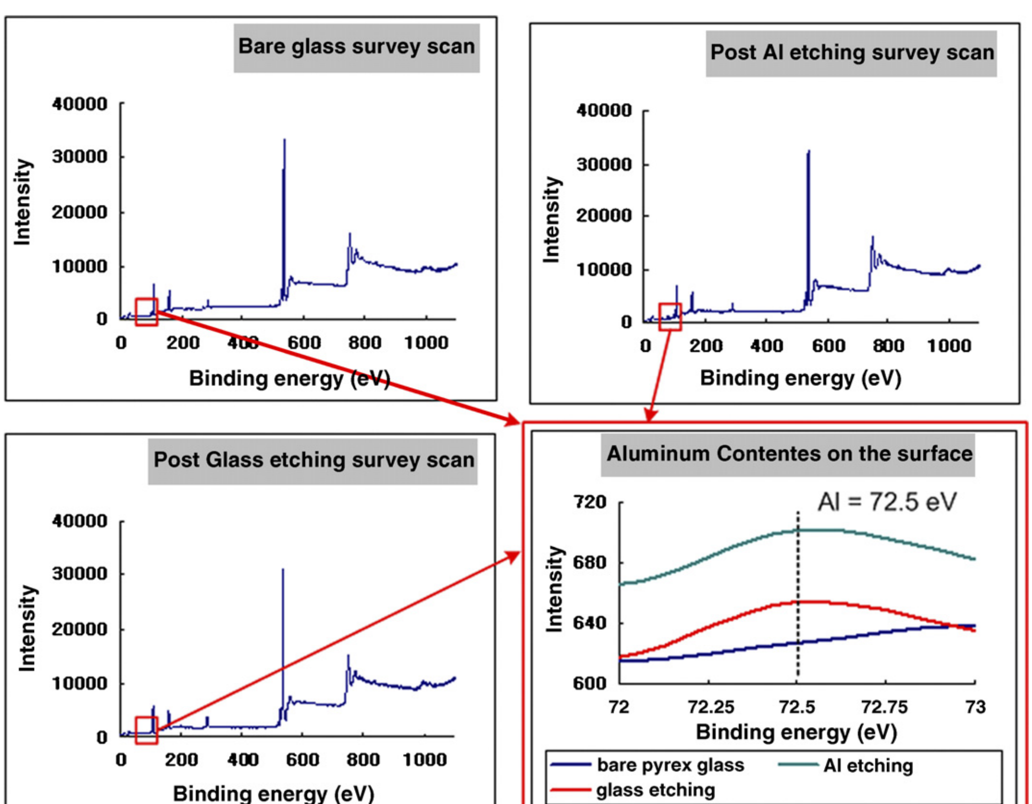

Fig. 2. XPS measurement of the aluminum content at each phase of the fabrication.