Reversal Patterning of Si Substrate Using Localized Anodization and Subsequent Chemical Etching

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Semiconductor materials with ordered nanostructures have generated considerable interest in both basic research field and commercial applications because of their new electronic, optical, magnetic, or biological characteristics. The common techniques used in fabricating these functional devices of nanometer dimensions are conventional lithographic technologies using optical, electron, or X-ray beams. Although these techniques have many advantages, they have some drawbacks, such as low throughput and high cost. Here we present a novel approach to the patterning of an ordered nanostructure on a silicon (Si) substrate using anodic porous alumina as a mask for a localized anodization.

The formation of anodic porous alumina using an evaporated or sputtered film of aluminum on various solid substrates has attracted attention because of the usage of applying a template or mask for the fabrication of nanometer-scale structures and devices. We previously reported the anodization behavior of aluminum film sputtered on Si substrate to transfer the hexagonal array of cells of anodic porous alumina directly into the underlying Si substrate[1)]. We continued our preliminary work and established two kinds of patterning process of Si substrate.

A schematic of the patterning process is shown in Fig. 1. Anodization of aluminum film sputtered on Si substrate was carried out as described previously[1)]. The periodicity of the holes in the mask for localized anodization was basically determined by the anodization voltage. In this study, the anodization voltage was set to 40 V corresponding to the self-ordering condition in oxalic acid. In the case of anodization at 40 V, the interval between the holes, that is, the size of the cell was approximately 100 nm [Fig. 1(a)]. When the aluminum film was almost consumed, the barrier layer of the porous alumina reached the Si surface. With further anodization, convex feature, which was suggested to be silicon oxide, formed at the center of each cell [Fig. 1(b)]. After removing anodic porous alumina, the Si substrate was treated using two kinds of chemical etching techniques: HF treatment and KOH treatment.

After removing silicon oxide by chemical etching in HF, the nanohole array in the Si was observed, as shown in Fig. 2. It was confirmed that the average hole interval and depth were 100 and 9nm, respectively by the analysis of AFM. This result indicates that the silicon oxide produced by the localized anodization of Si substrate underneath the barrier layer of anodic porous alumina, was removed selectively.

In the case of chemical etching in KOH, the silicon column array, which was an inverse structure to that shown in Fig. 2, was obtained (Fig. 3). From the cross section analysis of AFM, it was confirmed that the dimensions of a silicon column were 60 nm in top diameter, 100 nm in under diameter and 20 nm in height. This result indicates that the arrangement of the silicon column array corresponds to that of the upper anodic porous alumina. Therefore, the silicon oxide is assumed to act as a mask.

Thus, the two types of structure were fabricated using different chemical treatments for anodized Si substrate. The present process would be suitable for the nanopattrning of different types of substrates including other semiconductor and metals.

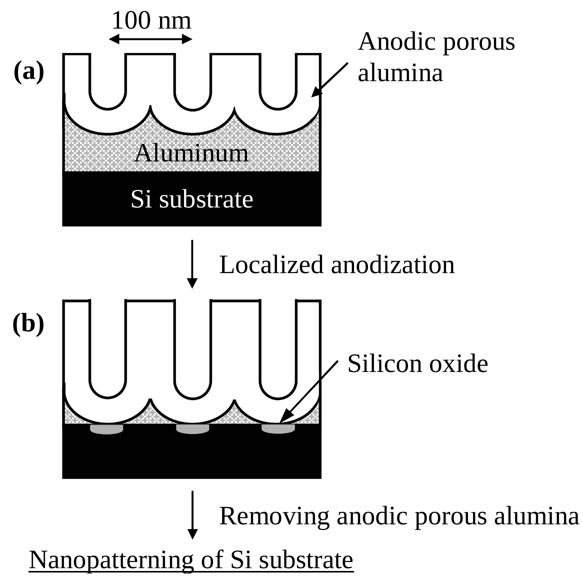

Figure 1 The schematic of patterning

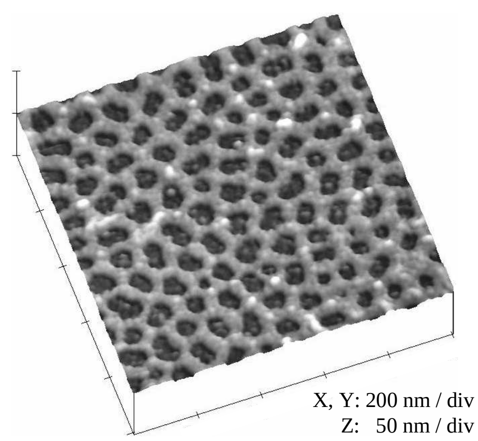

Figure 2 AFM image of silicon nanohole array

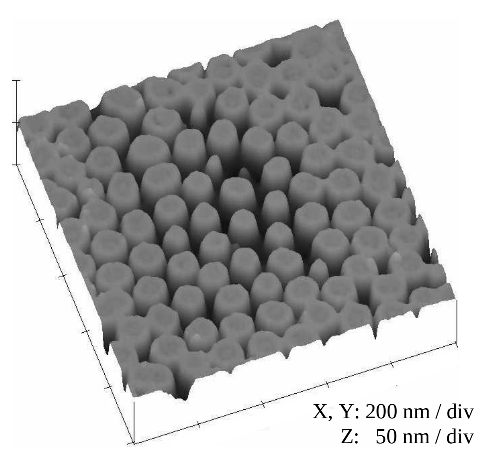

Figure 3 AFM image of silicon column array

1) H. Asoh, M. Matsuo, M. Yoshihama, and S. Ono *Appl. phys. Lett.*, **83**, (21), 4408-4410 (2003)