Fabrication of Si Nanotube Arrays by Nanoimprint Lithography with Spacer Patterning

International Center for Materials Nanoarchitectonics (MANA), National Institute for Materials Science (NIMS)[1]

°Yonglie Sun[1], Wipakorn Jevasuwan[1], Naoki Fukata[1]

E-mail: SUN.Yonglie@nims.go.jp

Introduction

Top-down approaches provide vertical 1D structure with smooth surface, high crystal quality, and highly ordered arrangement, which make them suitable for electronic applications. Lithography, and self-assembled nanosphere bead templates have more recently been developed to fabricate Si nanotubes (SiNTs), but they require a complex manufacturing process, long processing time, or use of noble metals. On the other side, spacer patterning is known as one of the techniques used to overcome the resolution limit in the semiconductor industry [1].

Here, we propose the use of nanoimprint lithography (NIL) and spacer patterning technique atomic layer deposition (ALD) to fabricate SiNTs with high aspect ratio and nano-scale wall thickness.

Experimental section

The fabrication process to fabricate vertical Si NT arrays is shown in Figure 1a. Si(100) substrates were patterned by a photoresist nanohole array by UV-NIL. Then, an Al_2O_3 layer is uniformly deposited over the photoresist by ALD. Trimethylaluminum (TMA) and deionized water were used as precursors and the thickness of Al_2O_3 was controlled by the number of ALD cycles. Next, the ring-like array pattern was achieved using inductively coupled plasma reactive ion etching (ICP-RIE) with CF_4 and Ar gases. To fabricate nanotube structures with high aspect ratio, SF_6 plasma followed by C_4F_8 plasma (Bosch process) was applied. The height of SiNTs was controlled by the number of Bosch cycles. Finally, the remaining Al_2O_3 was removed in HF.

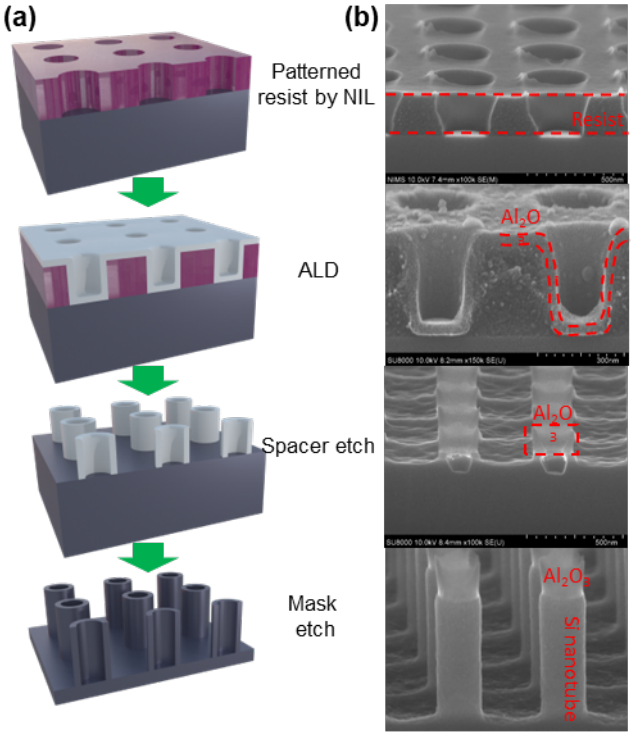

Figure 1. (a) Schematic illustration of the fabrication procedure for Si nanotube arrays using nanoimprint lithography (NIL) with spacer patterning. (b) Corresponding 30°-tilted SEM images.

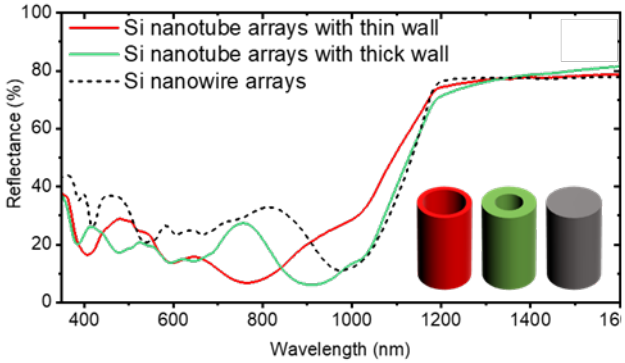

Figure 2. Reflectance spectra of Si nanotube arrays with different wall thicknesses.

Results and discussion

Figure 2 shows the reflectance spectra of Si NT arrays. Si NT arrays show a reduced reflection compared to Si nanowire arrays, demonstrating the enhanced light absorption effect of NTs. Si NT arrays with a larger diameter or a longer length seem to have an overall reduction in reflectance for 350−1100 nm.

[1] E. J. Nowak et al., IEEE Circuits Devices Mag., vol. 20, no. 1, pp. 20–31, Jan. 2004