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Fabrication of Au Nano-ring Arrays Using Anodic Aluminum Oxide Film as RF-sputtering Mask

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1. Introduction

In recent years, the interest of nanometer-sized rings, nano-rings, having uniform and regular structure in large area has been grown due to their utilization in various fields of nanotechnology such as magnetic recording media, novel ring-type MRAM, and persistent currents in metallic or superconductive nano-materials [1-4].

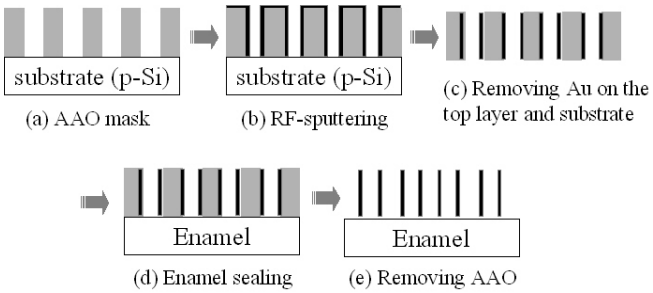
Today, the most common technique used to fabricate nano-ring structure is electron beam lithography and nano-sphere lithography [5,6]. Although such methods might make it possible to prepare the structure in small area, these methods have some disadvantage, such as unreality in the case that a large area or a large throughput are needed and high cost equipment. The alternative approach to overcome the disadvantage and accomplish the structure more easily is to use of self-organized nanochannel-array materials as a template for the preparation of nano-structures. The anodic aluminum oxide film has a highly ordered porous structure with very uniform and nearly parallel pores that can be organized in an almost precise close-packed hexagonal structure [7,8].

In this study, we attempted to make Au nano-ring arrays, which were fabricated using anodic aluminum oxide (AAO) film as an RF-sputtering mask. A through-hole AAO membrane was used for the preparation of the Au nano-ring arrays. The morphology of Au nano-ring arrays was studied by using field-emission scanning electron microscopy (FE-SEM). Typical dimensions of Au nano-ring prepared by this work were 65 nm inner diameter, 20 nm wall thickness 100 nm center-to-center spacing with 700 nm height. The diameter, height, and spacing of the ring arrays corresponded to those of templates. Energy dispersive spectrometer (EDS) analysis indicated that the Au nano-rings were almost consisted of pure Au in the arrays.

2. Experiment

AAO template was prepared via a two-step anodization process [9]. AAO template having highly ordered arrangement of through-hole was put on the Si substrate, and then Au was sputtered with RF sputtering method. After sputtering, AAO mask was taken off from the substrate and one side of the mask was sealed with enamel. Finally, AAO mask was removed with 5 wt% H_3PO_4.

The deposition was performed with RF sputtering at a gas pressure of 0.53 Pa using Ar gas with an RF power of 100 W. The deposition time was 10 min. This process is shown in schematic 1. Surface morphology was observed using field-emission scanning electron microscopy (FE-SEM, Hitachi, S-4800). To examine the composition of the films, energy dispersive X-ray spectrometer (EDS, Oxford, INCA energy) attached to the FE-SEM instrument was obtained with a Mn Kα X-ray source ($h\nu$=136 eV).



Schematic 1. Schematic diagrams of the fabrication of Au nano-ring arrays. (a) The AAO template on Si wafer, (b) Au depostion into the pores with RF sputtering, (c) removing Au layer on the top of the mask and separating the sample from the substrate, (d) sealing with enamel on the one side, (e) removing AAO mask with 5 wt% H_3PO_4.

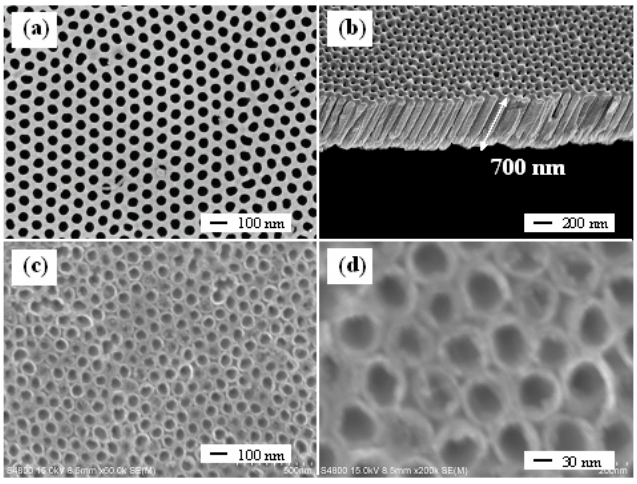


Fig. 1. FE-SEM images of (a) AAO template using as sputtering-mask, (b) oblique view of AAO template, (c) Au nano-ring arrays after removing the AAO template, low magnification, and (d) high magnification.

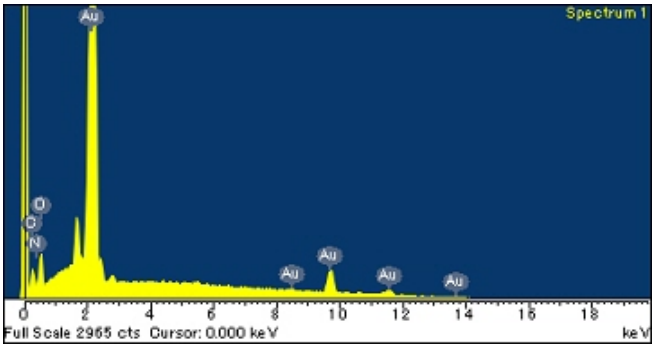


Fig. 2.EDS result of Au nano-ring arrays fabricated using AAO template as sputtering mask shows that the nano-ring is almost composed of Au.

3. Results and discussion

A typical FE-SEM image of the as-prepared AAO template is shown in Fig. 1(a). The image indicates that the template contains a highly ordered hexagonal arrays of cylindrical pores with an average pore diameter of 65 nm and a pore density of 1×10^{10} cm^{-2}. Chemical and thermal stability and high mechanical strength is included in various advantages of AAO template.

In this study, it was observed that the structure of AAO template was kept on the original state during the sputtering process (not shown).

Fig. 1(b) shows FE-SEM image for an oblique view close to the surface of the template. It can be seen that the pore arrays has uniform distance (100 nm) and the thickness of the template was 700 nm, therefore an aspect ratios (diameter versus length) of the pores of about 10 were obtained. The thickness was controllable depending on the anodization time. In this case the anodization time was 10 min in 8 °C, 0.3 M oxalic acid.

Fig. 1(c) shows Au nano-ring arrays after removing the AAO mask following the sputtering step. It can be seen that Au nano-ring arrays obviously replicates the highly ordered hexagonal structure of the AAO template, and maintains the circular feature and size uniformity. This result means that Au nano-ring arrays are truly defined by the structure of the AAO template.

The dimensions of Au nanoring arrays fabricated using AAO templates were 65 nm inner diameter, 20 nm wall thickness and 100 nm center to center spacing. The diameter, height, and spacing of the ring arrays corresponded to those of templates precisely. Showing the higher magnification, it was clearly shown that Au nano-rings were individually separated in the arrays (Fig. 2(d)).

The EDS result of the Au nano-ring arrays is presented in Fig. 2, which shows that Au nano-ring arrays are almost composed of demanded material, gold. The quantitative analysis of the spectrum indicates that the amount (wt %) of Au is as high as 86.59 and atomic % of Au is 31.20 %, respectively (Table 1).

Table I Conponents of Au nano-ring arrays

Element	Weight %	Atomic %
C	4.77	28.15
N	3.65	18.50
O	4.99	22.15
Au	86.59	31.20
Totals	100.00	100.00

4. Conclusions

Au nano-ring arrays were fabricated by using AAO template as RF sputtering mask. The dimensions of the nano-rings were 65 nm inner diameter, 20 nm wall thickness and 100 nm center-to-center spacing. The diameter, height, and spacing of the rings are dependent on those of template. EDS analysis indicated that the Au nano-rings were almost consisted of demanded material, gold, in the arrays.

The present technique has been expected to applicant easily for the development of nanoscale devices. More detailed results will be discussed.

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