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Short communication

Heat treatment and photoluminescence of 3-D vertical arrays of Al_2O_3 nanopores on Al fabrics or foils

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ABSTRACT

Porous anodic alumina (PAA) with highly ordered arrays of nanopores was prepared on Al fabrics or foils by a two-step anodization process. Studies on structural and thermal properties of the prepared PAA membranes were carried out. Scanning electron microscopy and transmission electron microscopy were performed on the prepared PAA membranes at room temperature and 600 °C. Photoluminescence (PL) properties of PAA on Al foils under different annealing temperatures (100–600 °C) and PAA on Al fabrics before-after dyeing by Rhodamine B (RhB) have been investigated. For PAA on Al foils, with the increase of the annealing temperature, the PL intensity increases first, which reaches a maximum value at 500 °C, and then it decreases. For PAA on Al fabrics after dyeing by RhB, the white sample changed to pink and a new peak at 580 nm in the PL curve was found.

1. Introduction

Porous anodic alumina (PAA) can be easily available by controlled anodization of aluminum surfaces in aqueous acids [1], which has a similar structure to nanoporous alumina membranes obtained by the block copolymer lithography and atomic layer deposition method [2]. PAA can be used as unique templates for the fabrication of nanometer-scale fibrils, rods, wires, and tubules of metals, semiconductors, carbon nanotubes, and others [3]. So far, most PAA arrays have been prepared on flat Al foils as well as other flat substrates, such as glass and silicon [4]. Fabricating 3-D PAA on Al wire or its fabric has not been researched to the best of our knowledge. Some synthesis methods, such as chemical (CVD) or physical vapor deposition (PVD), require high temperature environments and following high-temperature heat treatment to get the targeted nanostructures [5]. In order to extend the application fields of PAA membranes, profound knowledge of their physical properties including their structural and thermal properties at room temperature and at higher temperatures is crucial, which is the research topic on PAA membranes of this research.

Different works have been carried out on the fabrication of nanosized photonic materials combined with the PAA template, such as ZnO [6], In_2O_3 [7], TiO_2 [8]. Also, nanomaterials with strong photoluminescence (PL) confined in PAA by a doping method have been reported, for example, Tb [9] and Cr [10]. Since the PAA template is part of the nanocomposite, attention should be paid to the light-emitting properties of PAA itself. Some studies have focused on this problem, and a blue emission has been obtained [11]. In a previous work, the PL observed in the PAA template was considered as the emission from the F (or F^+) centers caused by the voids in PAA. Further, as an insulator with large band gaps of 7–9 eV [12], alumina itself provides a good matrix to implant various phosphors, with good prospects for achieving emitting properties.

In this study, PAA films on Al foils or fabrics were fabricated and their thermal stability properties and PL properties were investigated. Mechanisms of the PL were discussed in detail.

2. Experimental details

The Al_2O_3 nanopores used in this work were prepared in a two-step electrochemical anodization process. High-purity (99.999%)

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aluminum foils and aluminum fabrics were used as the starting materials, and the fabrics were made of 0.2 mm aluminum wires in both latitude and longitude using a weaving method. Before anodization, the aluminum foils and fabrics were first degreased with acetone, and then electropolished in a solution of perchloric acid and ethanol ($HClO_4$:$CH_3CH_2OH_5$ = 1:9 in volume, current density = 0.3 A cm^{-2}). Anodization was carried out in 0.3 M oxalic acid solution at 10 °C. The anodization voltage used for the oxalic anodic alumina films was 40 V. After the first anodization process for 2 h, the alumina layer produced on the aluminum substrate was removed in a mixture of phosphoric acid (6 wt%) and chromic acid (1.8 wt%) solutions at 60 °C for 6 h, then the specimens were anodized again for 2 h under the same conditions as used in the first step.

Heat treatment was carried out at 100, 200, 300, 400, 500, and 600 °C for Al_2O_3 nanopores on Al foil, and 300 and 600 °C for Al_2O_3 nanopores on Al fabrics, and all for 2 h. Some of the as-prepared PAA fabrics were immersed in an RhB (1 wt.%) aqueous solution for 24 h to form PAA/RhB nanocomposites. After the impregnation of dye molecules was completed, the top surfaces of the samples were cleaned to remove all residual dyes using a few drops of deionized water on their surface. The sample was then dried at 60 °C. The morphology of the samples was characterized by scanning electron microscopy (SEM, JEOL JSM-6300) and transmission electron

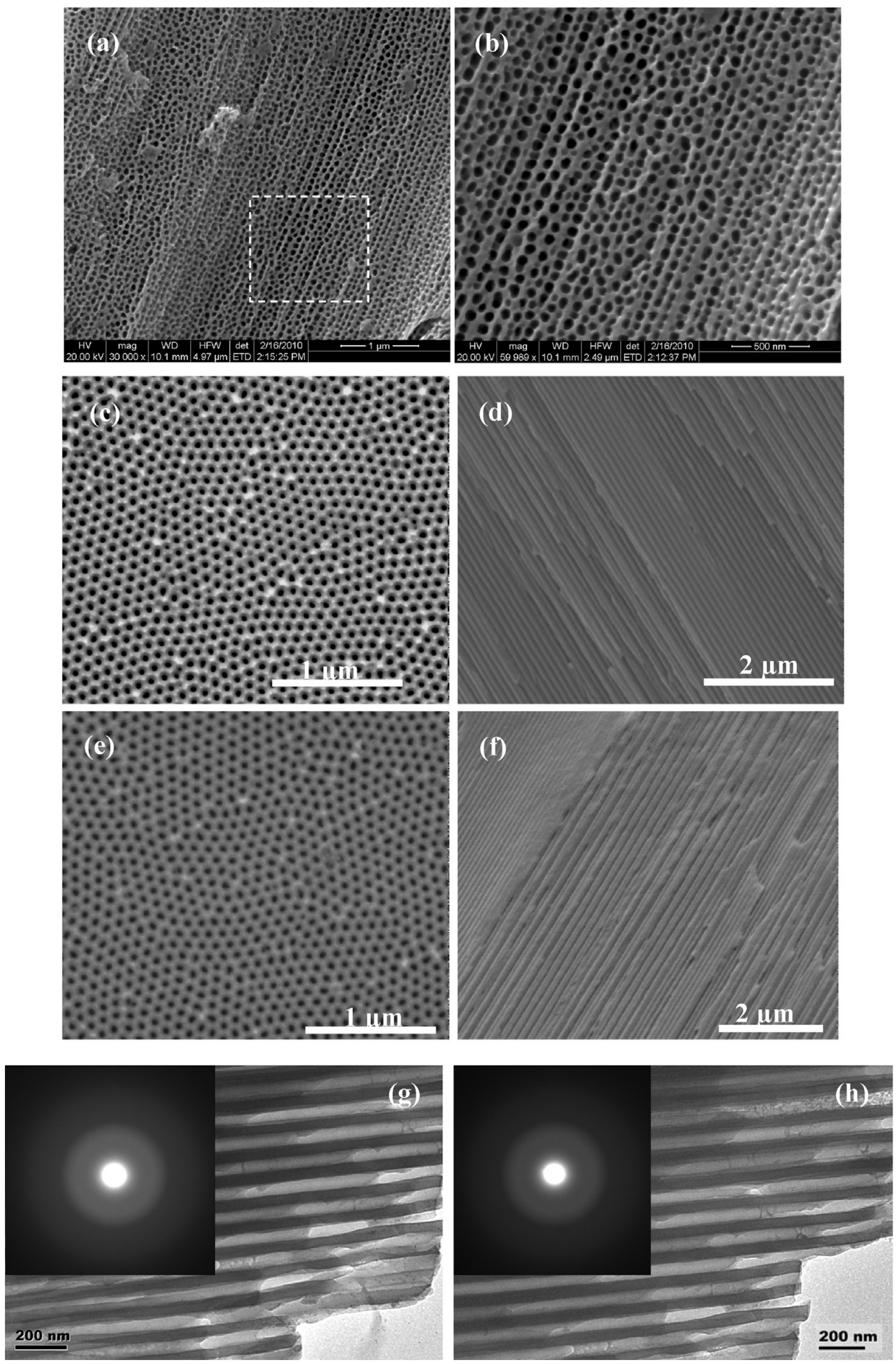

Fig. 1. SEM images of the as-prepared PAA on Al foil after one-step anodization (a, b), two-step anodized PAA along top view (c) and cross-section view (d); and two-step anodized PAA after annealing at 600 °C along top view (e) and cross-section view (f). In situ TEM observation of the as-prepared sample is shown at 20 °C (g) and 600 °C (h). The corresponding selected-area electron diffraction (SAED) patterns are shown in insets of (g) and (h).