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Simple approach for improving gold deposition inside nanoporous alumina template on Si substrate

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ABSTRACT

We report on a simple approach for enhancing gold plating deposition inside the nanochannels of anodic Al oxide (AAO) on a Si substrate. The key to the approach is to insert an Al thin film deposited at a low deposition rate before further thickening the film by sputtering deposition. The deposition of only a 10 nm-thick Al film at a low deposition rate was found to be sufficient to improve the gold deposition with a given gold-plating solution. This was evidenced by the increase in the plating current during gold plating as well as the increase in the surface coverage of deposited gold to as high as 80%. The resultant AAO with plated gold segments is expected to be useful for vapor–liquid–solid techniques of fabricating nanowires guided by pores.

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1. Introduction

Arrays of Si nanowires are promising for electronic and optoelectronic [1] applications owing to the use of the quantum size effect to engineer the band gap. Hence, solar cell fabrication based on Si nanowire arrays is currently being intensively investigated. A project focusing Si nanowire solar cells called FUTURE was set up to improve their conversion efficiency to more than 30% [2]. In the first stage of this project, the growth of vertical Si nanowire arrays is being intensively studied.

Among the various methods of fabricating Si nanowires, vapor–liquid–solid (VLS) growth is one of the most promising techniques that require the use of a metallic catalyst. The growth mechanism was described in detail by Wagner and Ellis [3] and Givargizov [4]. However, it remains a challenge to realize uniform nanowires with controlled size and orientation, which is one of the key requirements for the practical applications of Si nanowires.

VLS growth guided by anodic alumina oxide (AAO) has been preferentially utilized because one-dimensional nanostructures with controlled diameter and morphology are expected as a result of their confinement inside the self-organized vertical structure of the self-ordered template [5]. However, the remaining oxidized barrier layer of Si oxide and the alumina layer at the bottom of the pores often hamper the electrochemical deposition of the metallic catalyst. As a consequence, some of the pores do not contain the metallic catalyst, and the density and distribution of Si nanowires have so far been modest. Shimizu et al. suggested that preannealing the AAO template on Si substrate in inert gas and subsequent immersing in HF acid can remove the Si oxide thin film [6]. Tasaltin et al. proposed the removal of the alumina barrier layer by reversing the polarity of the voltage in KCl solution after the anodization of Al foil with a Ti thin film [7]. However, these techniques are quite complicated and precise control is required to avoid the generation of cracks at the bottom of the AAO. Furthermore, the use of a Ti thin film limits the preferential deposition of the metallic catalyst for VLS growth.

In this contribution, we propose an alternative method for improving gold deposition, which includes controlling the adhesion of Al on a Si substrate. Kobayashi et al. found that the adhesion strength of deposited Al thin films was strongly dependent on the deposition rate and that it linearly increased with increasing deposition rate [8]. In contrast, Stone et al. suggested that a thinner film deposited by sputtering deposition exhibits higher adhesion strength [9]. For sputtering deposition, Wehner reported that the average velocities of atoms sputtered from metal surfaces were unexpectedly high approximately 5.5×10^5 cm/s corresponding to 28 eV [10]. Moreover, the kinetic energies of the sputtered atoms were more than 100 times higher than thermal evaporation energies [10]. These advantages may strengthen the adhesion of atoms bombarded on a substrate by sputtering deposition. On the basis of this, we considered that variation of incoming Al atoms deposited

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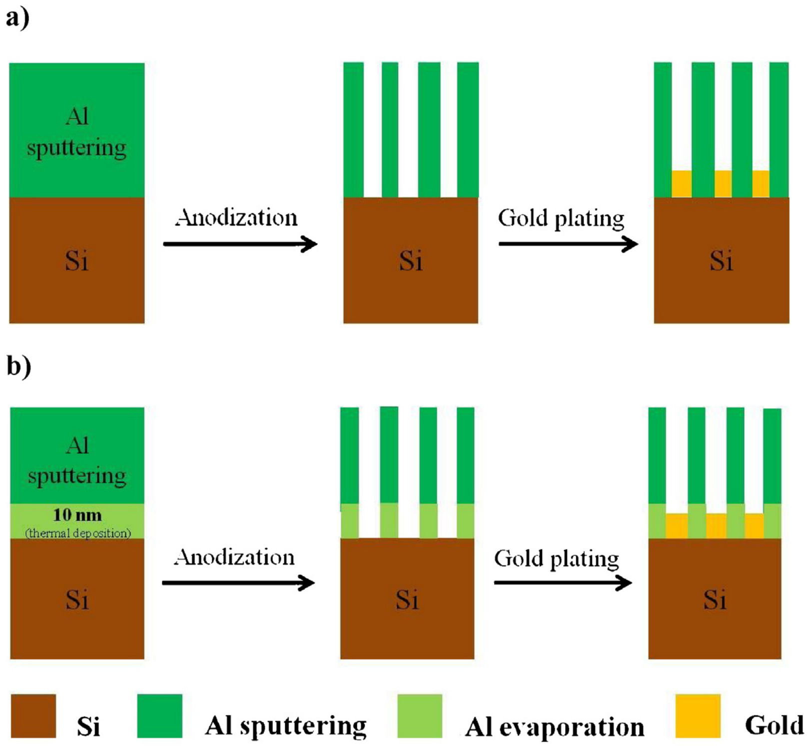

Fig. 1. Experimental processes for anodization and gold plating with (a) AAO and (b) IAAO.

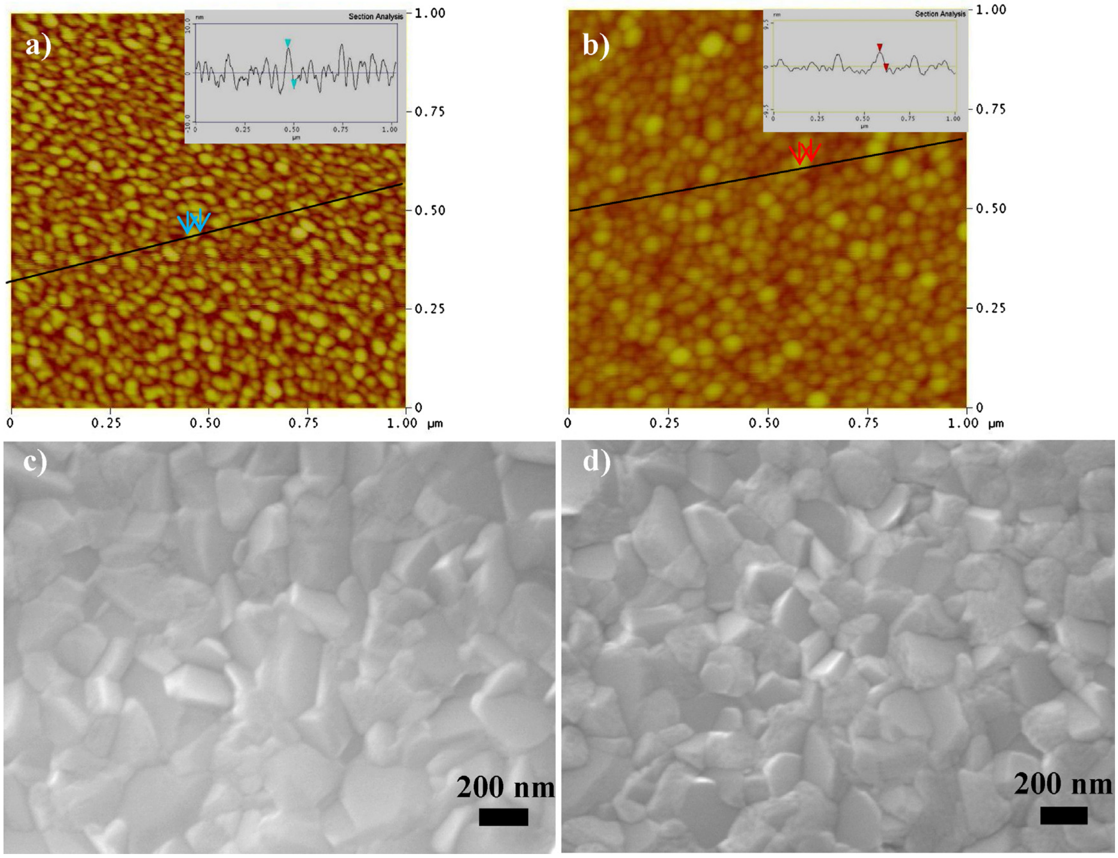

Fig. 2. AFM images of surface morphology of 10 nm-thick Al thin film on Si substrate deposited by (a) sputtering and (b) by thermal evaporation; (c) and (d) surface morphology of 2.5 μm Al thin films subsequently deposited on the films in (a) and (b) by sputtering, respectively.

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