

Anodizing of Aluminum for Solar Cell Application

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Received: March 14, 2016

Accepted: May 03, 2016

Published: May 04, 2016

Citation: Abushgair K, Al-Araidah O. 2016. Anodizing of Aluminum for Solar Cell Application *NanoWorld J* 2(1): 15-19.

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Abstract

The aim of this research is to use the porosity property in anodic alumina to produce well-ordered silicon Nanowires for solar cell applications. The study uses a single step anodizing process as a main process in the experiments. Samples produced from a 99.97% purity Aluminum (AL) foil, and others produced from AL-silicon wafers coated by an AL film with different AL thicknesses are used in the study. The study investigates the effects of varying the anodizing conditions (voltage, acid concentration, electrolyte type, and time) on the parameters of the anodic aluminum oxide (AAO) including pore diameter and interpore distance. Samples were characterized using scanning electron microscope (SEM). Results show a stable performance of both AL foils and AL-silicon wafers in growing silicon Nanowires for solar cell applications.

Keywords

Nanowires, Aluminum, Crystallization, Electrolyte

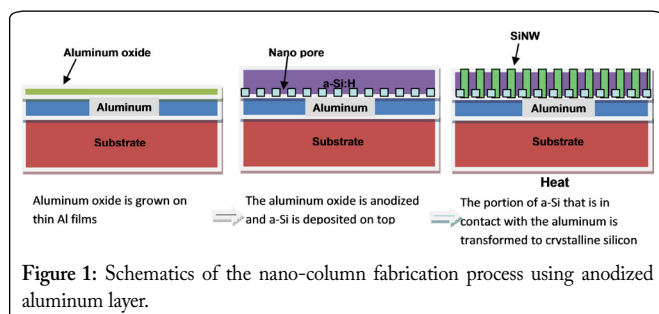
Introduction

Nanotechnology found various applications in electronics, health sciences, biotechnology and pharmaceuticals. However, implementing nanotechnology into devices and systems is one of the most challenging tasks. Semiconductor nanowires (NW) and carbon nanotubes are attractive components for future nanoelectronics [1, 2]. There have been several attempts to utilize these wires into single-wire devices [2].

Anodizing Aluminum in acidic electrolytes is among the most used methods in forming porous alumina layers [3-8]. Nanostructured wires and dots have also been formed by deposition of metallic and nonmetallic substrates into the pores of alumina membranes [4]. Moreover, etching masks of Anodic Aluminum Oxide (AAO) membranes are pattern transfer into other substrates [5]. In the literature, researchers distinguish two fabrication methods of anodic alumina including prepatterned-guided and self-organized anodization [6-8]. Anodizing imprinted Aluminum results in perfect arrangements of pores in the final structure with a [9-11]. On the negative side, in addition to being expensive and time consuming, the size of the resulting structure is determined by geometry of the master mold [10]. For selforganized anodization, results on arrangements of pores are of inferior quality compared to prepatterned methods. Self-organized anodization may be performed in solutions of sulfuric, oxalic or phosphoric acids [3-8]. Unlike prepatterned-guided anodization, the process is not limited by a certain surface area [4]. Under optimized conditions, the process may yield an array of uniformly shaped parallel channels. Quality characteristics of anodized

structures, including regularity arrangement, diameter of the resulting pore and interpore distance, depend on anodizing conditions and type of used electrolyte [1]. From literature, using sulfuric acid solutions results in high density of fine pores [12], and phosphoric acid electrolytes increase pore diameter and interpore distances [8]. Resulting pores have diameters of 10 to over 300 nm, interpore distances of 35 to 500 nm depending on the used electrolytes and applied potentials, and depth of channels varying based on anodizing time [1].

This study aims at incorporating nanowires into devices by directly fabricating them inside the device using a low cost, highly scalable, manufacturing process in the end we aim to fabricate silicon nanowires (SiNW) inside hydrogenated amorphous silicon (a-Si:H) thin films. The wires will be grown using metal induced crystallization (MIC) process. Using an external electrical field, the nanowires will grow in columnar structures inside the amorphous matrix. Figure 1 shows schematics of the growth process. Aluminum (Al) is the agent metal in this process. Thus, the resultant wires are expected to be p-type doped. Implementing these p-type wires into n-type a-Si films opens the door to make a new kind of P/N junction. The depletion region in this junction is expected to extend along the entire wire since these wires are fabricated directly into the silicon matrix. When the films are exposed to light, for example, the photo generated carriers in the matrix are swept out very fast through these wires since there is no barrier between the wires and the matrix. The wires will form a huge transport network to collect the charge carriers from the film.

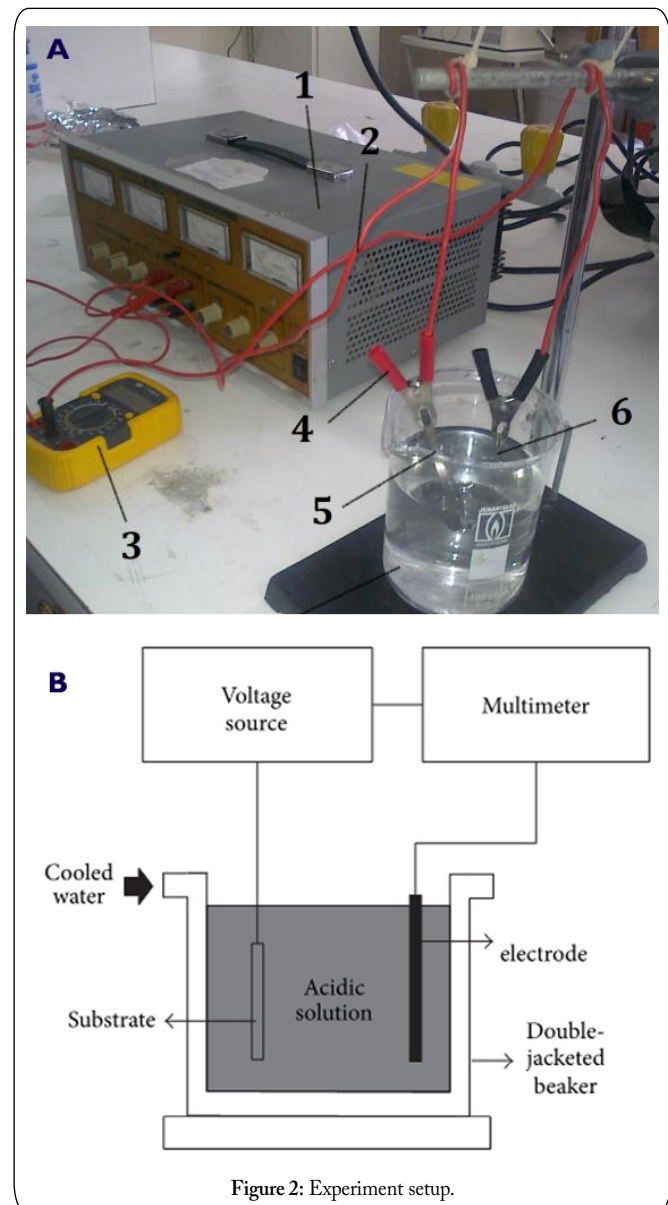


The article described mainly the first step of study through studying the production and optimizing of anodic porous alumina and the definition of silica pillar that will be used for solar cell applications as next step. Several experiments were performed with the aims to produce anodic porous alumina as support to favorite the growing of APA. This matrix will be used to define pillar of silica following a crystallization process. The anodizing process parameters will be optimized on aluminum foils and also on silicon wavers coated by thin film aluminum layers which will be used later as base substrate to produce silicon nano wires for the solar cells.

Experiment Procedure

Figure 2 shows the components of the experiment setup where a Titanium ring (100 × 10) mm diameter and thickness is connected at the cathode and aluminum foil at the anode. For each experiment, samples from (10 × 3 cm, 30 × 12 cm)

aluminum foils and aluminum thin film layer deposited on a silicon wafer by sputtering process are degreased with acetone in ultrasonic cleaning bath for few seconds, then degreased in ethanol for another few second in ultrasonic cleaning bath then dried in air. The sample is anodized at a constant temperature of (20 °C ± 1° C) which we achieve by cooling the anodizing beaker in cold water bath filled with circulated cold water with temperature less than 10 °C from water refrigerating system.



Ammeter is connected in series with the circuit. Voltage, electrolyte acid and time are set as in table 1.

Table 1: Experiment parameters.

Exp.	Electrolyte (acid)	Anode	Voltage	Time (min)	Temperature (°C)	Cathode	Concentration (M)
1	Oxalic	Al	45	9	20	Ti	0.3
2	Sulfuric	Si-Al	30	30	20	Ti	0.5
3	Oxalic	Al	50	4	20	Ti	0.3
4	Oxalic	Al	25	2	20	Ti	0.3
5	Sulfuric	Si-Al	30	30	20	Ti	0.5

Table 2: Time current relation for sample no. 2.

Time (sec)	Current (μA)	Current Density (10^{-3} A/m^2)
10	0.1	0.33
20	0.2	0.67
30	0.8	2.67
40	0.6	2.00
50	0.3	1.00
60	0.3	1.00
70	0.4	1.33
80	0.3	1.00
90	0.3	1.00
100	0.3	1.00

acts as steady state, this indicates the end of reaction, as time goes the thickness of layer grows. **Figure 4** shows SEM output of the sample with porosity.

In sample 3, the nanopore structure of aluminum oxide is identified very clearly as it is observed in **figure 5**. The structure seems to be consisting of identical ordered nanopores accompanied with the appearance of smaller pores in some places all over the area. The ordered distribution of pores proves that lower oxalic acid concentration (specifically 0.3 M) is an excellent concentration to be used in one step anodizing processes. The fascinating structure is shown in **figure 6**. The average pore diameter in this sample is about 29 nm, which is larger than it in sample no. 2. This may be due to increase in voltage, which indicates that voltage has a significant effect on the pore diameter. Another worthy observation is that interpore distance in this sample is larger (about 107 nm) than

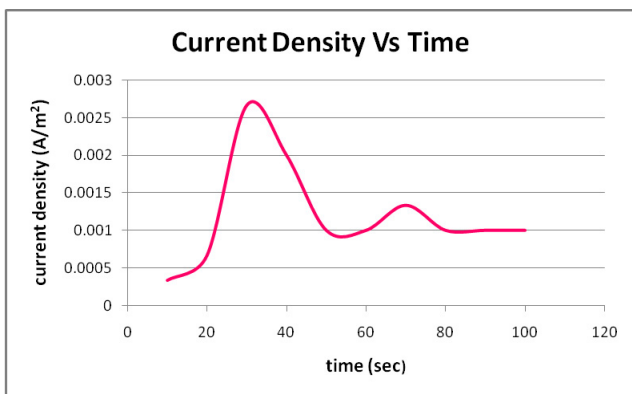


Figure 3: Current density- time curve for experiment no. 2.

In experiment 2, a current versus time was measured as seen in **table 2** and current density was calculated and graphically described the formation of anodic alumina in **figure 3**.

It is seen from **figure 3** that the first appearance of current value is the warning of the beginning of the reaction, as the current rises with time it is known that the layer is growing proportionally, as the curve goes down, that means that the growing rate is increasing, it also informs that the barrier layer has grown completely. As the curve seems to settle down and

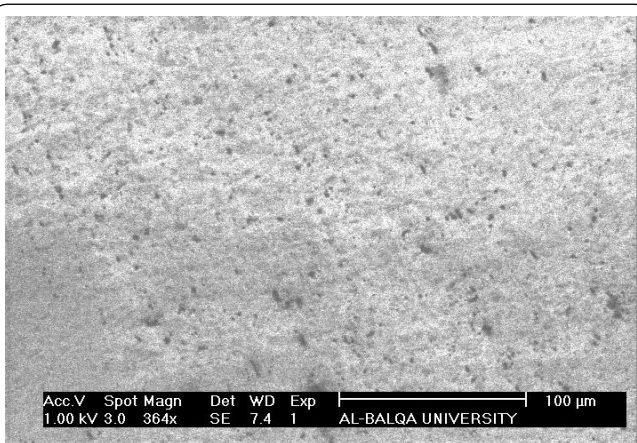


Figure 4: Porosity in aluminum foil prepared in 0.5 oxalic, 55 v, and 1.5 min as indicated by SEM.

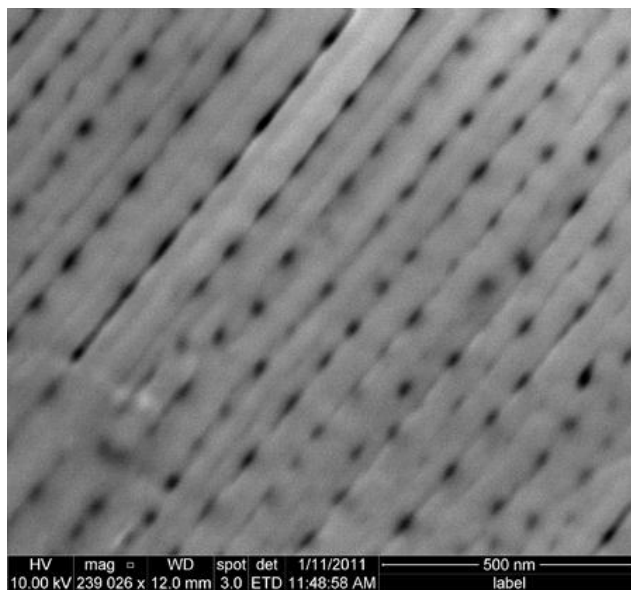


Figure 5: Larger pore diameter and interpore distance as indicated by SEM.

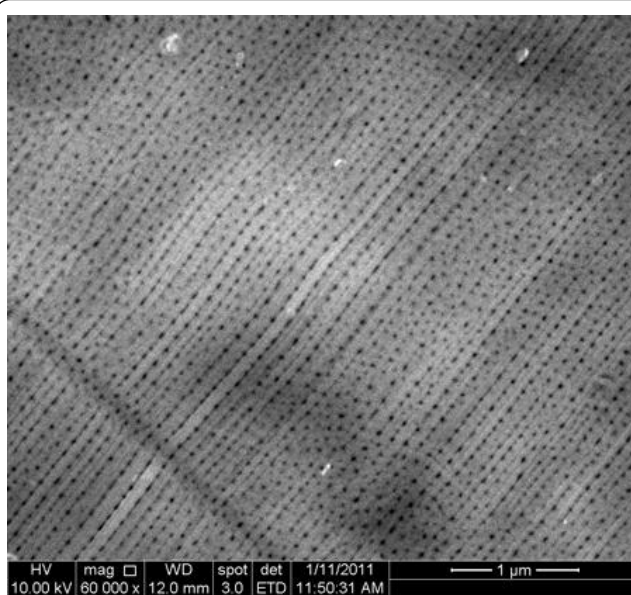


Figure 6: Ordered pore distribution and a high pore density of sample no. 3 as indicated by SEM.

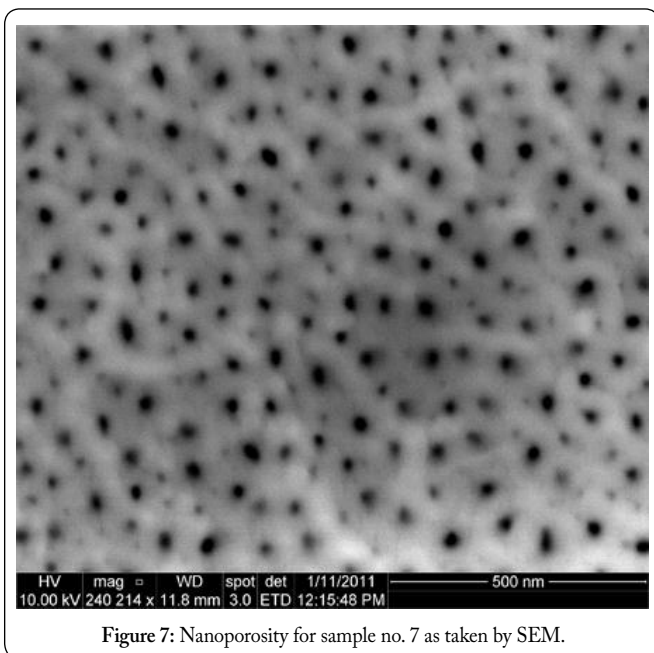


Figure 7: Nanoporosity for sample no. 7 as taken by SEM.

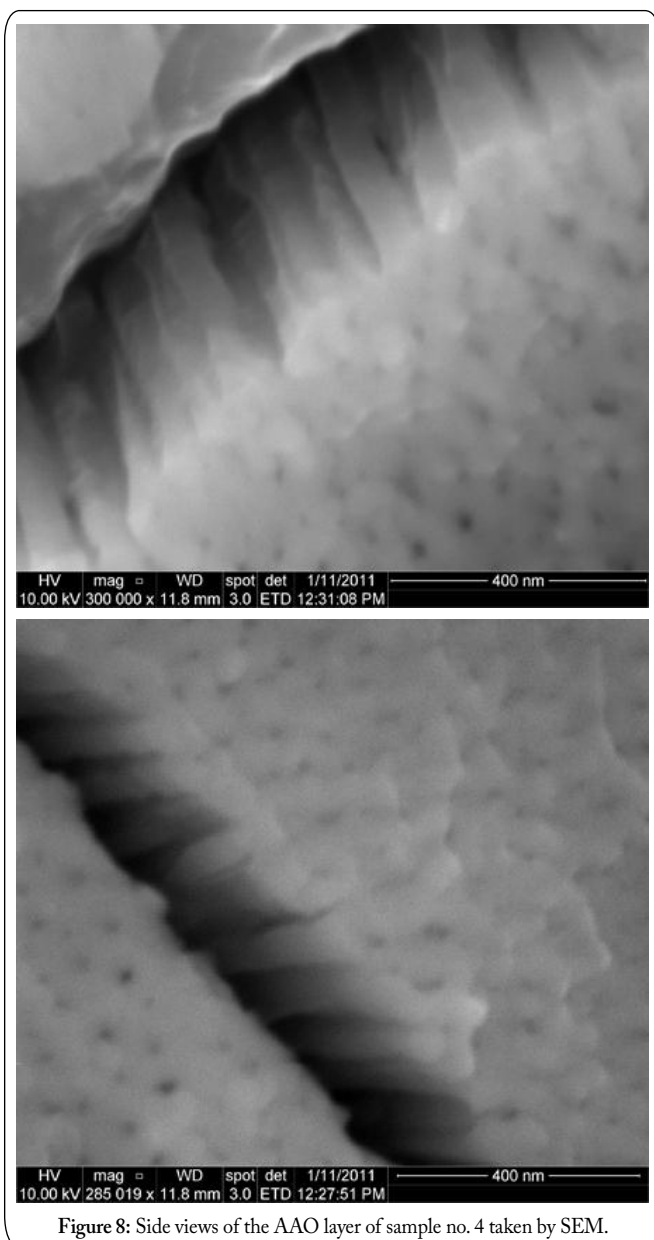


Figure 8: Side views of the AAO layer of sample no. 4 taken by SEM.

it in sample no. 2 (about 57 nm). This may be due to increase in voltage too. Pore density in this sample is less than it in sample no. 2.

For sample no. 4 the current vs time plot is shown in figure 7, it is seen that as time increases, pore density decreases. This was observed from visually comparing sample no. 4 and sample no. 3. Moreover, comparing sample no. 7 and sample no. 3 illustrates similar results. Figures 7 and 8 show nanoporosity and thickness of the AAO layer for samples 7 and 4, respectively. An estimated value of layer thickness is given to be more than 250 nm.

Conclusions

From experiment results we can draw the following:

- One step anodizing is a simple process to achieve a good pore distribution,
- Pore diameter increases significantly with voltage and electrolyte's concentration. Electrolyte type has a small effect on pore diameter,
- Interpore distance increases slightly with voltage, increases as time passes. Electrolyte type is found to have an important effect on the interpore distance,
- Pore density is found to be a function of time and electrolyte type essentially, so pore density in a sulfuric acid path is more than it in oxalic acid. Also, pore density decreases with time,
- Layer thickness is found to be a function of time and current density, an estimated layer thickness is found to be in harmony with that found in literature, and
- The uniform pore ordering in characterized samples calls for more focus on one step anodizing as a simple method to fabricate Anodic alumina layer,
- Result from this work will be used to produce silicon nano wire on silicon wafers for solar cell applications.

References

1. Cui Y, Duan X, Hu J, Lieber CM. 2000. Doping and electrical transport in silicon nanowires. *J Phys Chem B* 104(22): 5213-5216. doi: 10.1021/jp0009305
2. Cui Y, Zhong Z, Wang D, Wang WU, Lieber CM. 2003. High performance silicon nanowire field effect transistors. *Nano Letters* 3(2): 149-152. doi: 10.1021/nl0258751
3. Li F, Zhang L, Metzger RM. 1998. On the growth of highly ordered pores in anodized aluminum oxide. *Chem Mater* 10(9): 2470-2480. doi: 10.1021/cm980163a
4. Diggle JW, Downie TC, Goulding CW. 1969. Anodic oxide films on aluminum. *Chem Rev* 69(3): 365-405. doi: 10.1021/cr60259a005
5. Thompson GE, Wood GC. 1983. Anodic films on aluminium. In: Scully JC (ed) *Treatise on materials science and technology*. Elsevier, USA, Volume 23, pp 205-329. doi: 10.1016/B978-0-12-633670-2.50010-3
6. Wernick S, Pinner R, Sheasby PG. 1987. Anodizing of aluminium: general notes and theory. In: *The surface treatment finishing of aluminium and its alloys*, 2nd edtn, Finishing Publications Ltd., Teddington, Middlesex, UK, pp 289.
7. Report of the research group for functionalizing of aluminum and its surface films. 1988. Light Metal Educational Foundation, Osaka, Japan.

8. Despic A, Parkhutik VP. 1989. Electrochemistry of aluminum in aqueous solutions and physics of its anodic oxide. In: Bockris JOM, White RE, Conway BE (eds) Modern aspects of electrochemistry. Springer US, Boston, USA, pp 401-503. doi: 10.1007/978-1-4684-8762-6_6
9. Eftekhari A. 2008. Nanostructured materials in electrochemistry. Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim, Germany. doi: 10.1002/9783527621507.fmatter
10. Zaraska L, Sulka GD, Jaskuła M. 2010. The effect of n-alcohols on porous anodic alumina formed by self-organized two-step anodizing of aluminum in phosphoric acid. *Surf Coat Technol* 204(11): 1729-1737. doi: 10.1016/j.surfcoat.2009.10.051
11. Thompson GE. 1997. Porous anodic alumina: fabrication, characterization and applications. *Thin Solid Films* 297(1-2): 192-201. doi: 10.1016/S0040-6090(96)09440-0
12. Cui Y, Lieber CM. 2001. Functional nanoscale electronic devices assembled using silicon nanowire building blocks. *Science* 291(5505): 851-853. doi: 10.1126/science.291.5505.851