Synthesis of Al/OPS/PS/Si/Al by RTO and its detection properties

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الخلاصة

تم تحضير السليكون المسامي المؤكسد بطريقة التأكسد الحراري السريع للسليكون المسامي الذي حضرعلى شريحة من السليكون بشروط منتخبة. المسامية كانت تقريبا ٦٥% وسمك الطبقة ٨ مايكرومتر. التألق الضوئي للسليكون المسامي بين بأن له قمة عريضة عند ٦٩٠ نانومتر (١,٧٩ الكترون فولت) مع اعلى شدة عند منتصف القمة ١٣٠ نانومتر بينما قياسات التألق الضوئي بالنسبة الى السليكون المسامي المؤكسد فبينت قمة عند ٦٧٠ نانومتر (١,٨٥ الكترون فولت) مع اعلى شدة عند منتصف القمة ١٤٠ نانومتر. قياسات المقاومية للسليكون المسامي المؤكسد وللسليكون المسامي هي ٩٥,٨ و١٨ كيلو اوم على التعاقب. زمن الاستجابة لكاشف السليكون المسامي هو ٩ ثانية وزمن الرجوع ٦,٥ ثانية بينما زمن الاستجابة لكاشف السليكون المسامي المؤكسد هو ٤ ثانية وزمن الرجوع ٨ ثانية. كاشف السليكون المسامي المؤكسد اظهر كشفية عالية للاشعة فوق البنفسجية مع او بدون انحياز.

Abstract

Porous silicon oxide (PSO) was prepared by rapid-thermal oxidization (RTO) of porous silicon that was formed on silicon substrate with optimum conditions. The porosity was approximately (65%) and layer thickness was (8μm). Photoluminescence (PL) observed a broad peak of porous silicon (PS) at 690 nm (1.79eV) with full width at half maximum (FWHM) of about 130 nm while the photoluminescence value of PSO located at 670 nm (1.85eV) with FWHM value of 140 nm. The lower values of resistances are 95.8 kΩ and 18kΩ of PSO and PS respectively. Response time of porous silicon detector about (9) second and the recovery time is about (6.5) second. The response time of UV detector for porous silicon oxide is (4) second and the recovery time about (8) second.

The (PSO) sample exhibited high detection for incident ultra-violet (UV) light with and without bios

Keywords: Porous silicon, Porous silicon oxide, Rapid-thermal oxidation, UV Photo detector.

Introduction:

PS is suitable for the development of sensors, photo detectors and solar cells [1, 2]. PS photodiodes with quite high photo-responsivity and quantum efficiency have been reported [1]. However, the photo-responsivity of these PS-based optical sensing devices is limited to the visible and near infrared ranges, and there are few studies using PS materials for UV detection. For effective UV sensing, the optical band gap energy (Eg) of a material has to be larger than 3 eV. The pore sizes must be reduced down to less than 2 nm for PS to reach this Eg value, and it is difficult to get such small sizes of uniform PS layers from traditional anodization methods [2].

Recently, silicon-rich oxide (SRO) had received much interest in the field of optical-sensing devices, because of its high UV photoconductive properties [3]. In order to obtain oxidized porous silicon (OPS), the PS multilayer's are oxidized to decrease the losses in absorption, after rapid thermal oxidation (RTO) or rapid thermal annealing treatments, surface states will be saturated and a stable oxygen passivated surface. The electrochemical technique used for the fabrication of PS allows the generation of lateral and vertical patterns of porosity, thus increasing the versatility of this material [4]. Patterned and textured surfaces at the micron- and nano-scales with very different chemical and topographic characteristics can be fabricated and used to control cell–substrate interactions and regulate/condition cell function [4]. Also replace an unstable hydrogen-passivated surface Photo-induced carriers transport this material by a multi-tunneling process between silicon and silicon-oxide nano-particles to generate a photocurrent. As a silicon-based oxide, the oxidized porous silicon (OPS) that forms from oxidizing PS layer has greater sensitivity to UV light than its un-oxidized [5, 6]. Unfortunately, the UV responses of these PSO-based devices are poor. It is thought that the pore sizes in these micro-porous structures of the PS are not small enough to get a large enough band gap to absorb UV light [7].

Nano-porous-silicon (NPS) is a wide-band gap semiconductor and is a good candidate for applications in short-wavelength photodetectors [8]. This nano-porous-silicon oxide (NPSO) is composed of silicon and silicon-oxide nano-particles in the PS structures.

In this work rapid thermal oxidation of PS was used to improve the photoconductivity of the UV detectors.

2. Experimental work

The porous silicon was formed by electrochemical anodization of p-type silicon wafer (100) with one side polished single crystalline and low resistivity ~0.01-1.5 Ω.cm. The anodization was carried out in the HF concentration (48%) and Ethanol concentration (98%) based solutions in the volumetric ratio 1:3. For performing anodization, the Si-wafer constitutes as the anode while a gold mesh as the cathode as shown in Fig. 1. For uniform porosity, the etching performed was done in current density 20 mA/cm² and etching time 15 minutes at room temperature. The cell has a circular aperture at the bottom that was sealed with a silicon wafer. The sample was rinsed in ethanol and dried in air after etching process. Porosity and thickness are determined by weighting the silicon wafer before anodization (m_1), then just after anodisation (m_2) and finally after dissolution of the whole porous layer in a molar NaOH aqueous solution (m_3). Uniform and rapid stripping in the NaOH solution is obtained when the PS layer is covered with a small amount of ethanol which improves the infiltration of the aqueous NaOH in the pores. The porosity is given simply by the equation [9].

$$p\% = \frac{m_1 - m_2}{m_1 - m_3} \quad \text{..... (1)}$$

The equation bellow is employed to determine the porous layer thickness d.

$$d = \frac{(m_1 - m_3)}{\rho \times s} \quad \text{..... (2)}$$

Where ρ , is the silicon density and s the etched surface area.

PSO layer was obtained from rapid-thermal-oxidation (RTO) of PS by using high efficient quartz tube furnace, the PS was introduced to the furnace when the temperature reach to 850 °C for 90 s in O_2 environment. The PSO-based photo-detector device was fabricated by screen printed silver (Ag) electrode (finger-finger) on the tops as front contact so that the back Si was coated by aluminum contact by thermal evaporation technique.

Dark and illumination I-V characteristic was recorded by changing the bias across the surface, in addition to the junction using Keithley 2430 source meter. The photocurrent of samples were measured using the set-up which consists of light source 150 Watt Xe lamp, its light passes through monochrometer to get the output light which incident in the device, therefore, the output current was measured by Keithley 2430 source meter which connected to computer to draw the results.

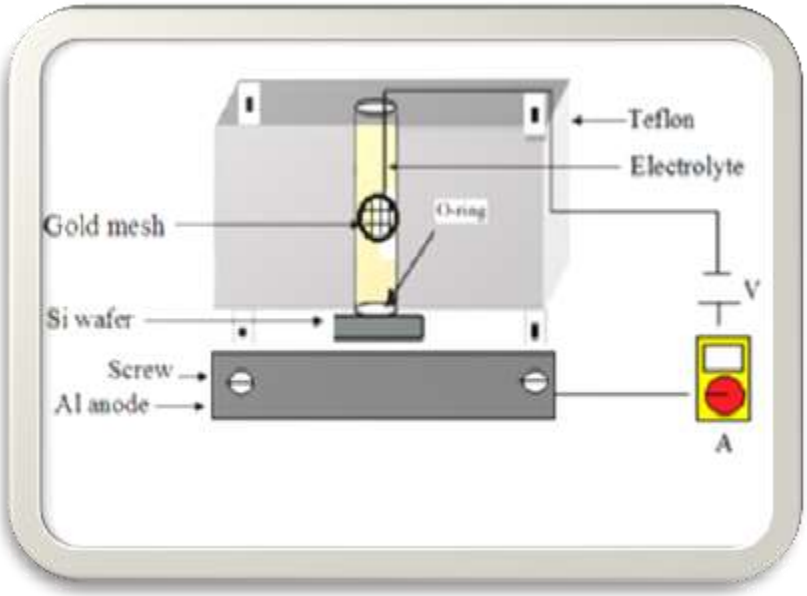


Figure 1: Schematic of electrochemical etching cell.

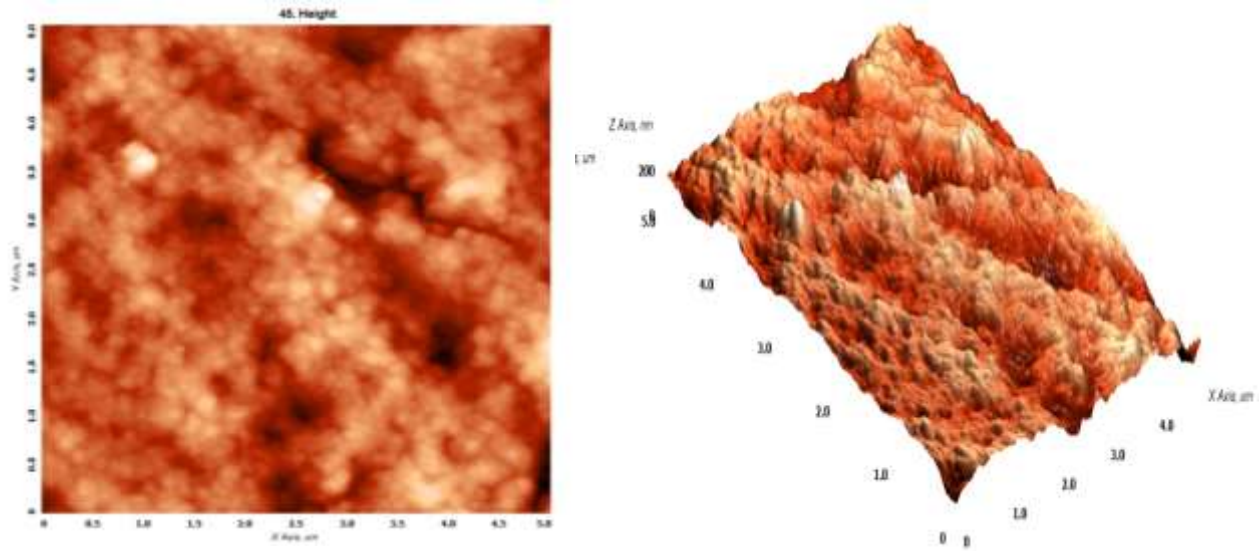
Results and discussion

The bright regions in fig.2 are the Si structure and the dark regions are the pores, the pore diameter is ranging from (0.7-1μm). By increasing the porosity of the PS layer, Si structure decreases while the size of the pores increases [4]. The pores evidently randomly distributed on the porous silicon surface, the high density of pores is observed with porosity approximately equals to (65%) and layer thickness is (8μm). After oxidation, the porosity decreases due to the transformation of silicon crystallite into silica which is accompanied by a volume expansion [4].

(a) (b)

Figure 2: SEM images in top view of (a) porous silicon (b) oxidation porous silicon.

It is observed that the morphology of PS structure is very rough like grooves and difference from topography of OPS sample as shown in figs 3 and 4 because the RTO treatment which effect on the grain size and make it smaller. The AFM images show that the roughness is decreased when the PS converted to OPS.



2D 3D

Figure 3: AFM images of PS surface of two dimensions (2D) and three dimension (3D).

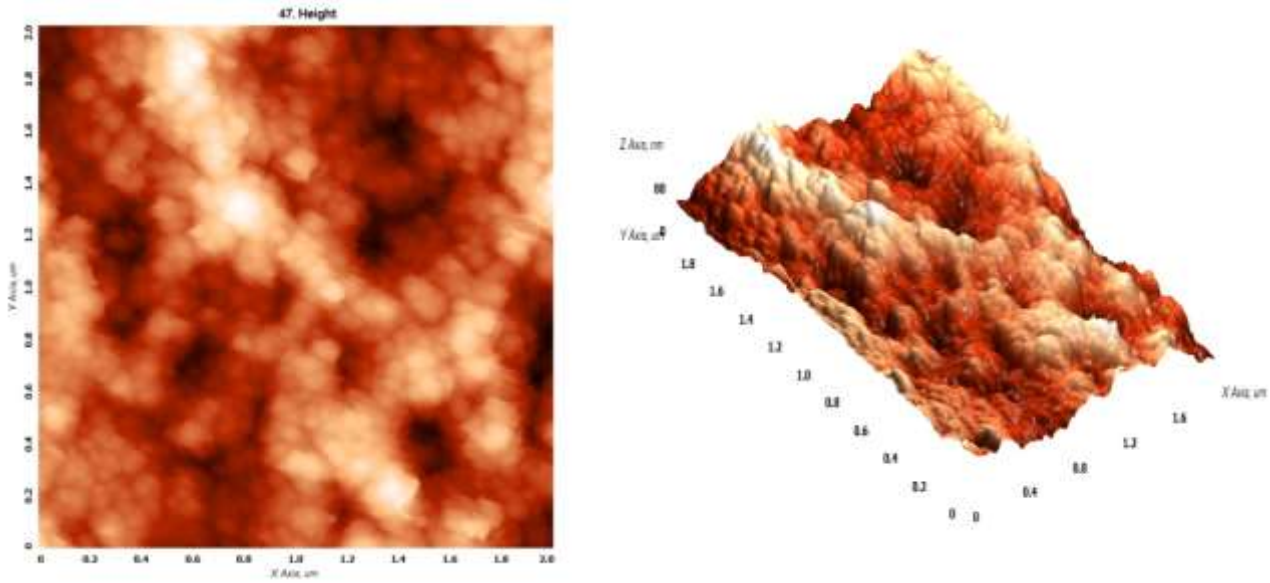


Figure 4: AFM images of PS surface after RTO at 850 ˚C temperatures and 90 S duration time.

Fig. 5 shows PL spectra of the PS p-type (100) and OPS, it is measured via excitation photon energy of 3.81 eV. PL spectra shows broad peak of PS centered at 690 nm (1.79eV) with FWHM of about 130 nm while the PL value of OPS located at 670 nm (1.85eV) with FWHM value of 140 nm.

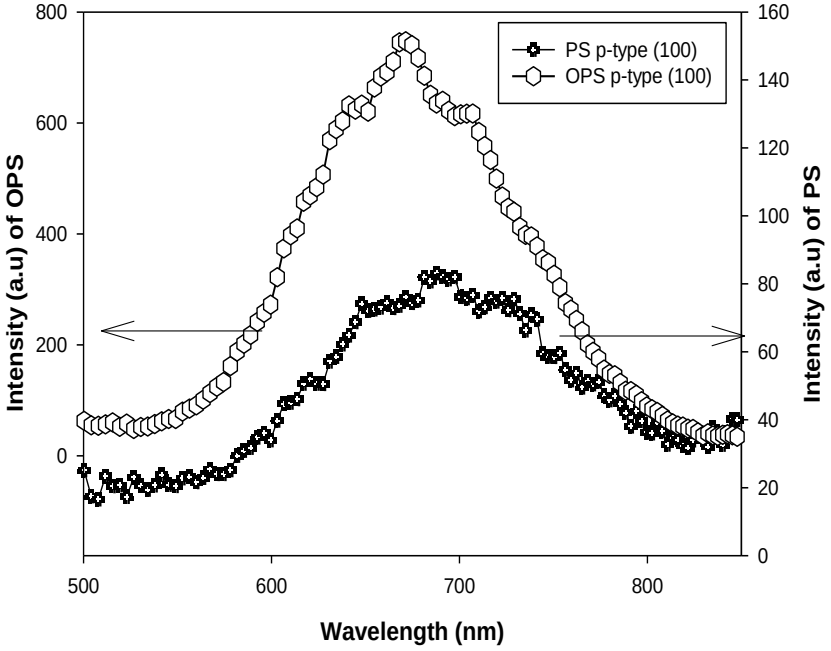


Figure 5: Photoluminescence spectra of porous silicon and porous silicon oxidation.

Figs 6 and 7 show the relation between resistance and wavelength for two substrates. In these figures it can see first the resistance decreases slowly with wavelength increasing then the curves gradient hardly towards the lowest point of resistances. The lower values of resistances are 95.8 kΩ and 18kΩ of PSO and PS respectively.

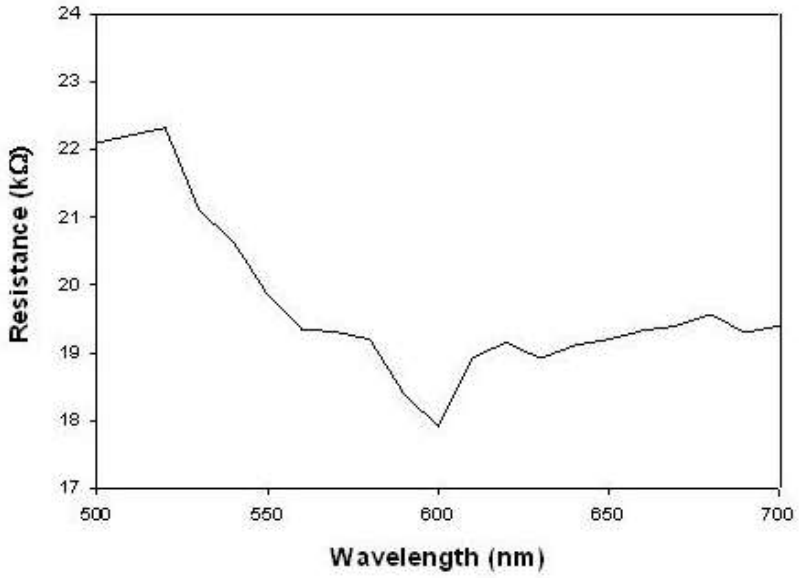


Figure 6: Relation between resistance and wavelength for P3 substrate.

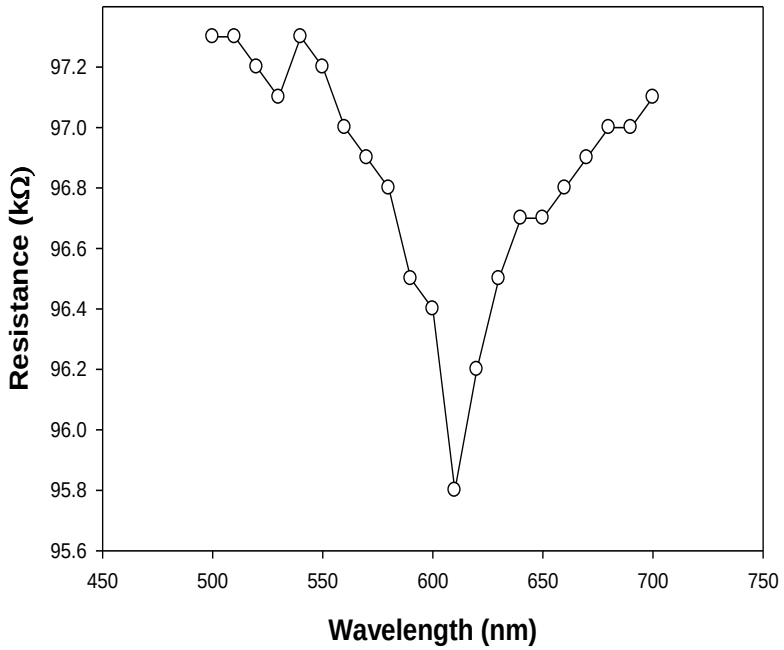


Figure 7: Relation between resistance and wavelength for PSO substrate.

Response time and recovery time

As shown in figures (8), (9) the response time of porous silicon detector is about (9) second and the recovery time is about (6.5) second. The response time of UV detection for porous silicon oxide is (4) second and the recovery time about (8) second. The response time of porous silicon oxide is better than in porous silicon but the recovery time in porous silicon reveal better than porous silicon oxide. The improvements in speed of response of the PSO UV detector gives indication that the oxidation is upgrade the detector properties.

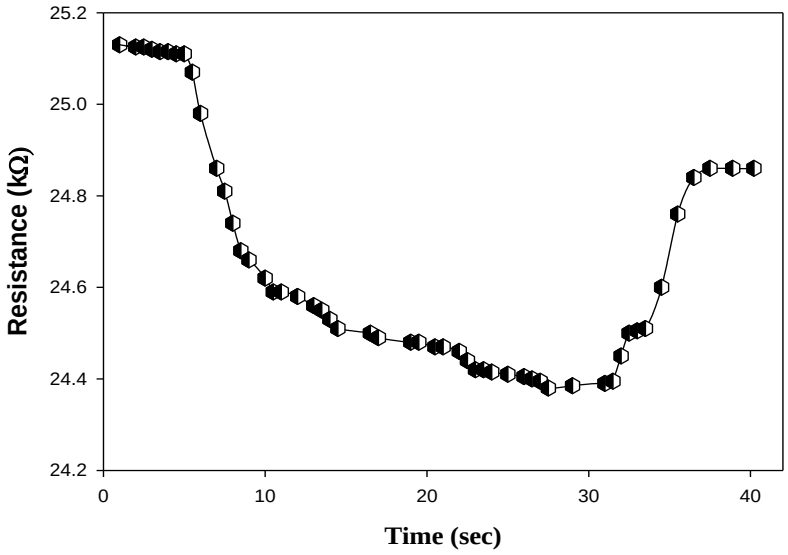


Figure 8: Response time and recovery time of PS detector.

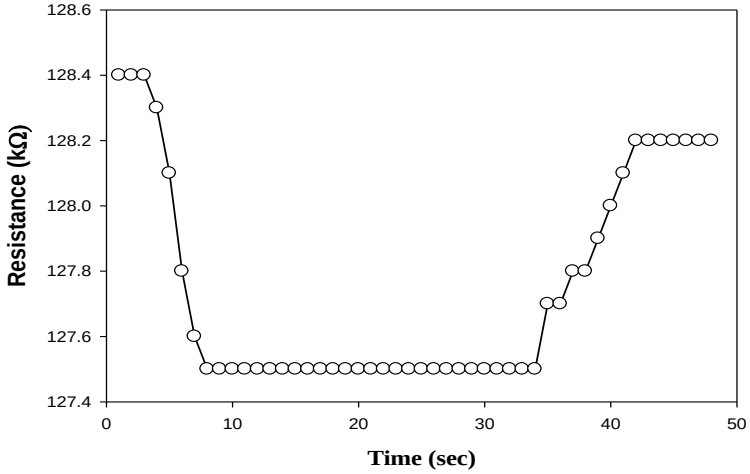


Figure (9): Response time and recovery time of PSO detector.

Conclusion

PS films with uniformly distributed Si nano-particles were obtained from p-Si substrates by an electrochemical anodization technique, in which a high HF concentration solution and low etching current density. The UV photo detector of porous silicon thin films that were prepared from electrochemical-etching silicon substrates in an anodization process had been greatly enhanced by rapid-thermal-oxidation (RTO) treatment. Experimental analysis demonstrated that the optical band gap energy of the formed microporous silicon (MPS) films increased from 1.79 eV to 1.85 eV after the RTO process. It was supposed that this band gap-widening effect resulted from the size shrinking of Si-nano crystals embeddedin the oxidized MPS films and led to the large increase in UV responses with RTO treatment. The response time of PS detector was (9) second and the recovery time about (6.5) second. The response time of UV detector for PSO was (4) second and the recovery time was (8) second. The oxidized MPS films exhibited high UV photo-responses for incident light than that of one fabricated without RTO treatment. Therefore, oxidized MPS materials prepared by RTO treatment after the electrochemical-etching of Si wafers have high potential for development of Si-based photo detectors.

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