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Physical Properties of MOS Porous Silicon Detector Fabricated under RTO Method

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Abstract

In this research we studying the sensitivity of a porous silicon photo detector, we found it improved through rapid thermal oxidation processes. Under our optimum preparation conditions, photocurrent can reach about 3408 µA (under power density 100 mW/cm^2 tungsten lamp illumination) and dark current is about 300µA (at reverse bias of 5V).

Keywords: Photo detector, porous silicon, rapid thermal oxidation.

الخصائص الفيزيائية لكاشف السليكون المسامي MOS المحضر بطريقة الأكسدة الحرارية السريعة

الخلاصة

في هذا البحث تم دراسة التحسسية الضوئية لكاشف للسليكون المسامي حيث وجدناها تحسنت بعد المعالجة الحرارية السريعة ،تحت أفضل شروط تحضير ،التيار الضوئي ازداد من (1783 إلى $3408µ\ m/cm^2$) (عند كثافة قدرة $200mW/cm^2$ لمصباح التنكستن) و تيار الظلام قل من 3750 إلى $300µ\ \ m/cm^2$) عند فولتية انحياز عكسية (5V).

Introduction

SCHOTTKY barrier photo detectors fabricated from porous silicon (PS) are few active devices. It has been shown that PS is a very useful antireflection (AR) coating due to its extreme porosity [1]. *Tsai* et al. brought forward a typical Si *P-N* junction photodiode with a rapid thermal oxidation (RTO) PS cap layer to be an AR layer [2].

Zheng et al. [3] reported Schottky barrier photo detectors fabricated with as-anodized PS.

From these studies, the PS layer in the photo detector hardly acts as an active region to absorb light and leads to a low quantum efficiency in short wavelength region, In this paper, RTO were used to improve the characteristics of Schottky barrier PS photo detectors[4].

Experimental:

The substrate is (100) oriented, 20Ω.Cm, P-type, 300µm thick silicon wafer. The porous layer was prepared by electro_ chemical etching process as shown in fig (1). The preparation conditions of PS layers are anodic current density of 20 mA/cm^2, HF: Ethanol solution (1:1) the concentration of HF (48%) and anodic time of 15 min in dark. The thickness of the as anodized PS layer is 6µ.Rapid thermal oxidations shown in fig (2). The rapid thermal oxidized occur at 750Ċ by using lamp (OSRAM 64575) , with 1000W power at different oxidation times(15-150 s) in O_2 atmosphere to form a thin $Sio_{2\ -\ layer}$ above the porous layer . The structure of the MOS photo detector is Al $_{(thin)}$/O PSi /P-Si/$AL_{(ohmic)}$ was achieved by thermal evaporation technique.

The heating cycle of RTO system were shown in Fig (3). Where its appear from figure three regains [heating reign, equilibrium reign (oxidation region), and cooling reign].

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Results and Discussion:

Fig.(4) show the dark current of PS before and after ROT process.

From (fig.4) we can observe that the dark current decreases with increasing oxidation time when it is shorter than 90 s. It could be from the oxide decrease the dangling bond which is trapping the carrier after the 90 s the dark current is come back to increased that is formed by the nonstoichiometric silicon-oxygen structure in a very thin oxide and they would act as tunneling centers[4].

We measure saturation current density directly from dark forward current density ,were carried out at different forward bias voltage at temperature 750 Ċ and plotted in semi-log graphs as shown in fig.(5).

We can observed that the saturation current decreased with increasing oxidation time and have minimum value at 30 sec that mean the barrier height have large value at this point according to the relations between Js and the barrier height[5] :

$$f_{Bp} = \frac{kT}{q}\ln\frac{A^{**}T^2}{J_s} .....(1)$$

$$f_{Bp} = \frac{kT}{q}\ln\frac{A^{**}T^2}{J_s} + \frac{kT}{q} c^{1/2} d .....(2)$$

Where ΦBp is the barrier height in (eV), k is the Boltzman constant (J/K), T is the room temperature in (K), q is the electron charge in (c), A** is the effective Richardson constant, which equals 32($A/K^2.cm^2$) for p-type silicon. After oxidation the oxide thickness effected on the transport mechanism and manufacture to difference in Fermi level, we get to addition limit in barrier height equation and it becomes [6]:

Where χ is the average barrier height due to oxide layer and δ is the oxide layer thickness in Å. Barrier height after oxidation represented in fig.(6)

Other reason for increasing barrier height is due to the inter face layer between Ps/c-Si has large amount of pinning ,which acts as a defect in the interface and caused to increase saturation current density, so lead to decreasing barrier height of PS [4]. With increasing oxidation time we can observed decreasing in barrier height that due to increase oxide thickness.

Fig.(7) shows the photo current before and after RTO process .The photocurrent is excited by a 100 mW/cm^2 tungsten lamp illumination which it's at 15 cm distance from the samples .

Fig.(7)Shows the photocurrent increases with oxidation time when it is shorter than30 s. The photocurrent of photo detector (3408 µA) is twice as great as that of an as-anodized PS photo detector (1783 µA). It is from that imperfect native oxide [7] or unstable hydrogen-passivated surface of as-anodized PS [8] provide 1arge amounts of surface states which act as recombination centers in the PS layer (the surface state density of a PS layer has to be multiplied by a factor of 200 - 800 according to the ratio of surface area to volume [9]. After 30 s of RTO treatment, surface states will be saturated or the stable oxygen-passivated surface will replace unstable hydrogen-passivated surface [10]. Therefore, the photo carriers generated in Si wires are greatly increased and so is the photocurrent. Curve As the oxidation time is longer than 90 s, the oxide layer is thicker than the tunneling probability of photo carriers and the thermally generated carriers through the oxide layer are reduced, and hence the photocurrent and dark current are reduced. The oxide thickness is estimated to be 50 °A [10]. Another possibility is that the longer oxidation time results in thinner wire size and therefore a larger energy band gap of PS [11]. The absorption energy of the PS layer is further away from the main portion of the tungsten lamp spectrum (the spectrum

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of a tungsten lamp is in the rang ~ of 400 - 3000 nm with the main portion at around 875 nm).the larger the energy band gap of PS is, the fewer the thennal1y generated carriers are. So the conductivity and dark current are reduced. It is because: 1) the RTO process saturates surface states of as-anodized PS and life time of photo carriers is long enough to go across the PS region; 2) the top of the PS layer can absorb short wavelength photons like a Si Schottky photodiode; and 3) energy band gap of the PS layer has a wide direct-band distribution (1.6 – 2.5 eV) and hence photons with energies from 1.6 to 2.5 eV or above will be absorbed efficiently by the PS layer[4-12].

Conclusion:

In this paper, the treatments of RTO have been used to enhance the photo responsivity and reduce the dark current significantly. The device is very stable and the reproducibility is good due to a stable surface on the PS layer. The optimized RTO-PS photo detector has the performance of photocurrent ~ 3408μA (under 100 mW/m^2 illumination) and dark current ~ 300μA.

Acknowledgment:

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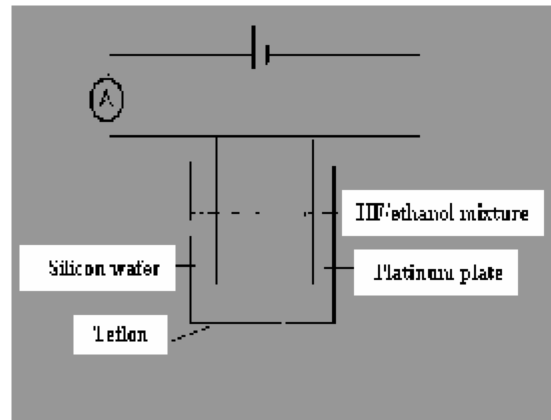

Figure (1) Electrochemical Etching set up.

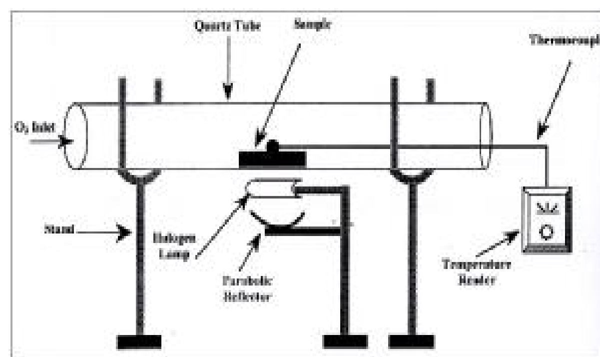

Figure (2) shows the manufactured system of rapid thermal oxidation.

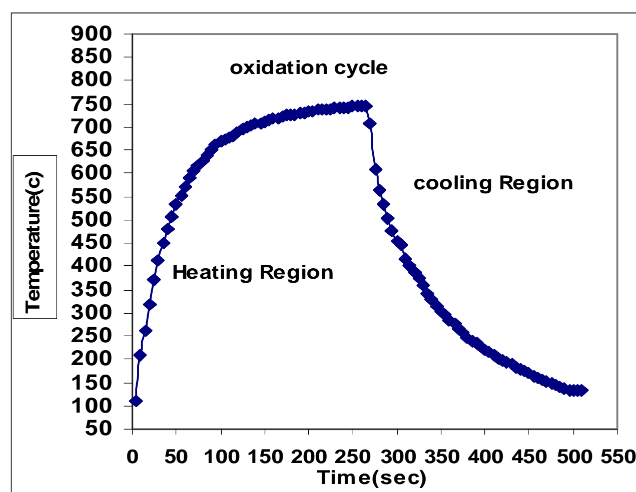

Figure (3) Shown the characteristics of RTO system.

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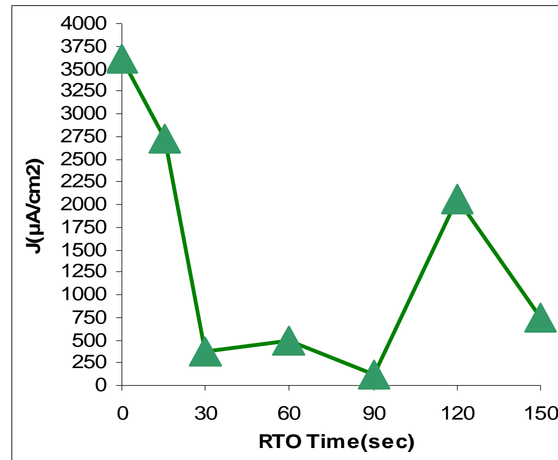

Figure (4) Shows the dark current of a PS before and after RTO process.

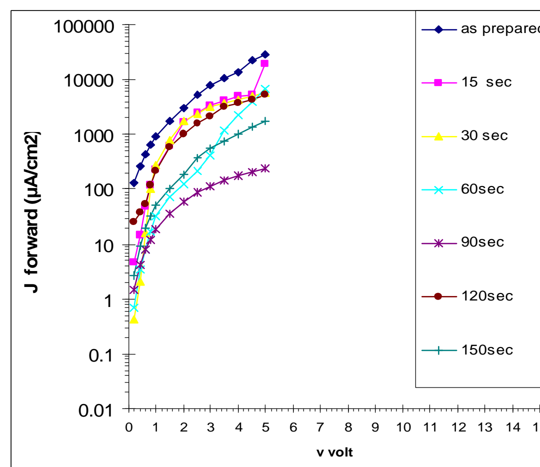

Figure (5) shows forward current at different oxidation time.

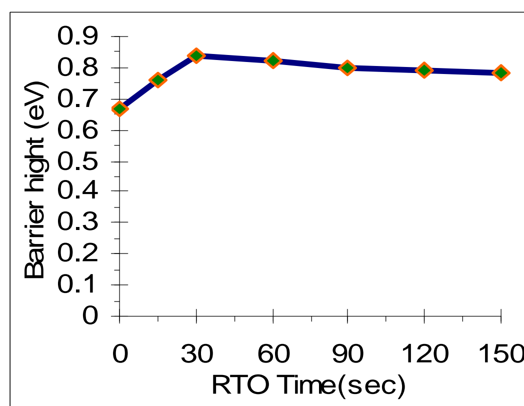

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Figure (6) Shows the barrier height with oxidation time

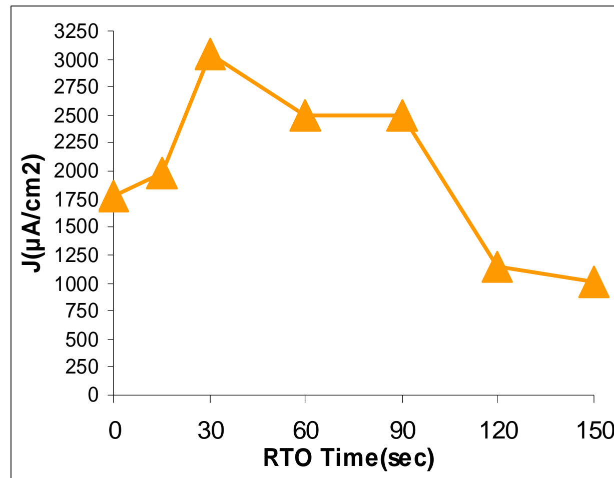

Figure (7) Shows the photocurrent of a PS photo detector versus oxidation time at the reverse bias of 5 V.

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