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Influence of rapid thermal oxidation process on the optoelectronic characteristics of PSI devices

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Abstract

The morphological properties of the freshly and oxidized porous silicon at oxidation time (60, 90) sec were studied. Eyes, can see a blue emission from PSi after thermal oxidation, we can obvious increasing energy gab, that due to decrease silicon column (nano particles).Pore size and shape of n-type wafers are estimate and correlated with optical properties before and after rapid thermal oxidation (RTO).

Key words: Porous silicon; Oxidation; Optical properties.
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1. Experimental

Crystalline wafer of n-type Silicon with resistivity of (1.5-4.5Ω.cm), 508 μm thickness, and (111) orientation were used as starting substrates. The substrates were cutting into rectangles with areas of (1×1.5 cm2). The native oxide is cleaned in a mixture of HF and ethanol (1:4) to obtain 10%HF concentration. Photo-electrochemical etching then performed in HF 47% concentration and Ethanol (1:1) at room temperature the electrical circuit is completely after putting a Pt electrode in parallel way to achieve the homogenous PSi layers. Current density of about (20 mA/cm2) applied for (15 min), light source is consisted of one commercially available CW diode laser with power (2 W) and wavelength (810 nm), (fig.1) shows the schematic diagram of Photo electro chemical etching (PEC) system.

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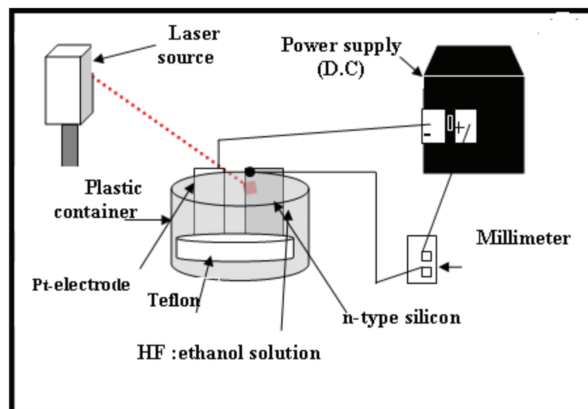


Fig.1: schematic digram depicts the PEC process.

The RTO system is consisted of the following: (1) a tungsten halogen photo optic lamp type (OSRAM 64575) with power 1000 W based on ceramic base. We put parabolic reflector like half circuit under the lamp to increase the heating efficiency. (2) A quartz tub with a 2cm diameter, the tube opens from two sides for allowing air to input (dry oxygen source). Oxidation treatment occurs at atmospheric pressure. The like mirror surface which etched, has been put directly above the tungsten halogen lamp. The quartz tube attached with halogen lamp to obtain the temperature of about 750 Ċ, (Fig.2) shows the photographic image for oxidation system.

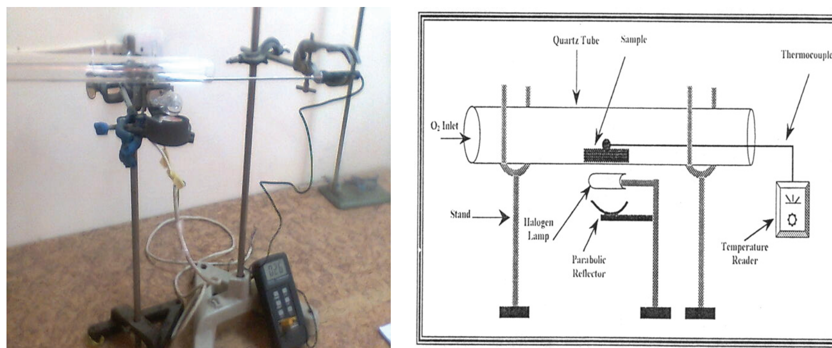


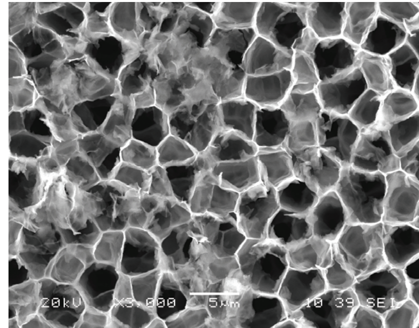
Fig. 2: RTO system for the (a) photographic image for oxidation system (b) Schematic diagram.

The samples characterizes by scanning electron microscopy (SEM). Measurements were carried out in the School of Physics / Nanostructures and Optoelectronics Research Center (NOR)-lab, University Sains Malaysia (USM).

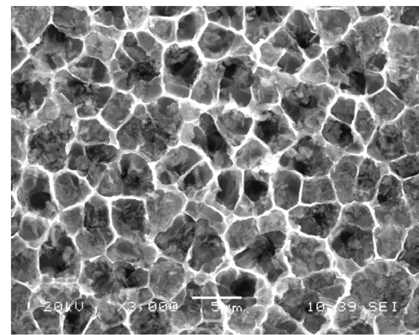
2. Result and discussion

Fig.3 shows the scanning electron microscopy (SEM) of the as prepared and oxidized porous silicon etched from n-type crystal silicon sample .Fresh sample A represented in (Fig.3a), sample B represent after oxidation time 60 sec in (Fig.3b) and (Fig.3c) represent sample C for oxidation time 90 sec. These micrographs allowed the size and density of porous to be estimated .In fact these values contained an estimate error because of the micrograph contrast. The pore size was measured directly from these

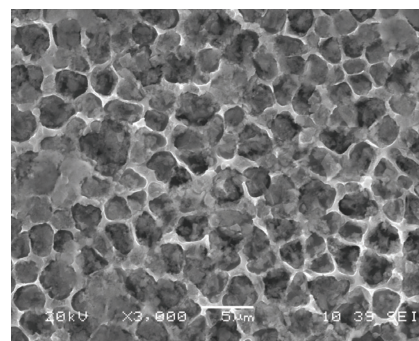
micrographs and its distribution was deduced (Fig.4) it could be seen that the porous layer is composed of a pore net work (in black) separated by silicon crystallites (in white).For sample A, pore size was varied from (1.6-5.3) μm center around a mean value equal to (3.3),this distribution was almost symmetrical due to Gaussian distribution for the laser beam ,where the laser intensity at the center larger than at the edge[12].



(a)



(b)



(c)

Fig. 3: Scanning electron microscopy for fresh sample (a), oxidation time 60 sec. See (b) and Oxidation time 90 sec. See (c).

Fig.3 shows that distribution with allow root mean squire the revealed an homogeneity in pore size values. This distribution was almost symmetrical for sample B and C but different in mean value , the value corresponding to maximum after oxidation pore size decreased and become (3 μm) for sample B and (2.6 μm) for sample C, from SEM image in (Fig.3) ne can see that after oxidation the value of roughness are always lower. This decrease in roughness after oxidation was also observed by papetal et al. 13] and chrrier et al. [14]. The wall size, which separate porous, also can be evaluate, that mean the energy gap increased after oxidation according to [15]:

$$Eg^{*}=Eg+ 88.34/L^{1.37} \quad (1)$$

where Eg* is the energy gap (eV) for PSi layer, Eg is the energy gap(eV) for silicon substrate and L is the nano crystallite size(nm). Porous did not collapse because of the initial porosity which define as a fraction of voids inside the PSi layers [16] the density was nearly the same before and after oxidation and it was about 16×10^{6}pore/cm^{2},the pore density the same and pore size decreased, so the porosity after oxidation of course lower than the porosity before oxidation, because the decreasing in a fraction of voids after oxidation due to oxide growth inter PSi layer.Table 1 shows pore morphology estimated from SEM micrograph of porous silicon before and after thermal oxidation. The difference in band gap after rapid thermal oxidation caused to change the optical and electrical properties [17]. Fig.5 shows the electrical behavior for as prepared and after thermal oxidation of porous silicon. The J-V curve of fresh hetrojunction show the rectification behavior due to the formation of an isotope hetrojunction with low rectification factor (about 5 at 5 V), since PSi is reported to be n-type when it is fabricated from n-type substrates [18].

The J-V characteristics of Al / porous silica/n-silicon/Al sandwich structure which contain PSi such as shottky diode generally is determine depending on the forward current –voltage characteristics, Table 2 shows the J-V characteristics after oxidation. We can obvious that the dark current is increased with oxidation time, it could be from a defects formed by no sympathy silicon –oxygen structure in a very thin oxide and they would act as tunneling centers [19]. The rectification factor is increased to 13.5 after 60 sec of oxidation, this increase in rectification factor is attributed to the formation of a thin oxide layer between Al metal and Si. This interfacial layer introduces a MIS structure, which is in turn leads to a decrease in reverse saturation current and hence increases the rectification factor after the time 60 sec rectification ratio will be decrease, it could be from the defects.

Fig.6 shows the photo current at reverse bias voltage (0.2-5) V, we observed increase the photocurrent with increasing oxidation time when it shorter than 60 sec that because after 60 sec of RTO treatment, surface states will replace unstable hydrogen-passivated surface. Therefore, the photo carriers generated in Si wires are greatly increased resulting into increasing the photocurrent. For the oxidation time 90 s photo carrier will be decreased resulting thinner wire size and therefore longer energy band gap of PSi, the absorption energy of the PSi layer is further away from the main portion of tungsten lamp, where the wave length of tungsten lamp is in the range of 400-3000nm with the main portion at around(875nm) [18]. The contribution of Al/PSi contact is not significant for fresh junctions, because the barrier height which is calculated from the semi-log J-V curve (not shown here) is (0.7742eV), with neglect of series resistance. The barrier height is raised to (0.7769 eV) at 60 sec of oxidation time. This increasing in barrier height attributed to the formation of metal isolation semiconductor (MIS) structure at Al/PSi contact by producing an oxide interfacial layer after thermal oxidation. The increasing in the barrier corresponds to an increase in rectification characteristics with bit-by-bit Lessing in the current values due to the increase in series resistance of the junction [19]. The existence of the oxide layer and the increase of the PSi resistivity (due to band widening) will result in an increase in series resistance, i.e., which is indicated by an increase in the slope of the forward current. Balagurov et al. [20] exhibited similar results for their Al/PSi/c-Si heterojunction after oxidation, in which they attributed the improvement in the J -V characteristics of the oxide samples to the substrate potential barrier.

4. Conclusion

We studied the physical characteristics of porous silicon layers before and after oxidation. The pore size and column size decreased after oxidation. However, the pore density conserved, the porosity decreased after oxidation ,photo current will be increased about 7 order after oxidation we can suppose that the oxidation of PSi layers is a good way to obtain lower optical loss of PSi photo detector by reducing both volume scattering and absorption in the near infrared wave length range.

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