Optical And Electrical Properties Of P-Type Si<100> Modification In Visible Region For Silicon Based Microphotonics

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Abstract: The development of Silicon surface texture would revolutionize the growing field of Microphotonics and its applications in different fields .The objective of this study is to modify the Optical and Electrical properties of Silicon in visible region at room temperature. So, for that purpose, we have used thermal treatment method with applied M-field “1000G.”. We have found that p-type Si is more response to this method. Optical and Electrical study were carried out using CW photoluminescence emission technique (Ar+ Laser emitting at 514.5 nm), Ellipsometry (632.8nm), AFM and IV. We were obtained increasing emission intensity in band [~ (2.0-1.6) eV] and an improvement in PL emission profile. We were recorded irregular behaviors in extinction coefficient values of treated samples. In this study, we recorded at the first time different behavior in IV and change in surface texture which provides new surface profile for improvements of Si technology.

Index terms: surface texture studies, spectroscopy studies, Optical & Electrical properties of indirect energy gap materials, size-dependent absolute quantum yield, Nano- laser active medium & thermal effect on material behavior.

1 INTRODUCTION

Sililicon has a band gap of 1.12 eV that is ideal for room temperature operation. The continuous improvements of Silicon technology is one of aims in recent years for different applications such as Light emitting diodes (LED) or a Si Lasers [1]. Much of the information about the optical and electrical properties of Silicon is obtained when it interact with Laser radiation using PL, Ellipsometry technique and IV measurements. The intensity of PL signal provides information on the quality of surfaces and interfaces. Si- photoluminescence emission is generally in the red-green region [2-3]. Ellipsometry used to investigation of surface and interface phenomena. Also, it uses to determine both the refractive index (n_s) and extinction coefficient (κ_s) of a substrate or dielectric [4]. In this paper, will demonstrate and discussion the PL, Ellipsometry, AFM and IV results of treated p-type Si samples.

2 EXPERIMENT RESULTS

This study was carried out to change monocrystalline Silicon surface texture for enhancing the visible emission and its surface quality. Thermal treatment with applied M-field (1000 G.) was used to modify the optical and electrical properties of Silicon. Nevertheless we got satisfied results as shown in PL, Ellipsometry, AFM and IV results as shown in Figures (1-6). This method was influential way to change surface quality. In this work, optical properties, electrical properties and surface texture were studied at room temperature using PL spectroscopy (514.5nm excitation wavelength of Ar+ Laser, hv=2.4eV>EgSi) , Ellipsometry (single wavelength, 632.8nm),AFM technique and IV measurements system . In our measurements, we noted very important topic, results varied with Si-orientation (100,111) and types. In this paper, we present p-type Si<100> results only of treated and untreated Si samples because showed more response to this treatment.

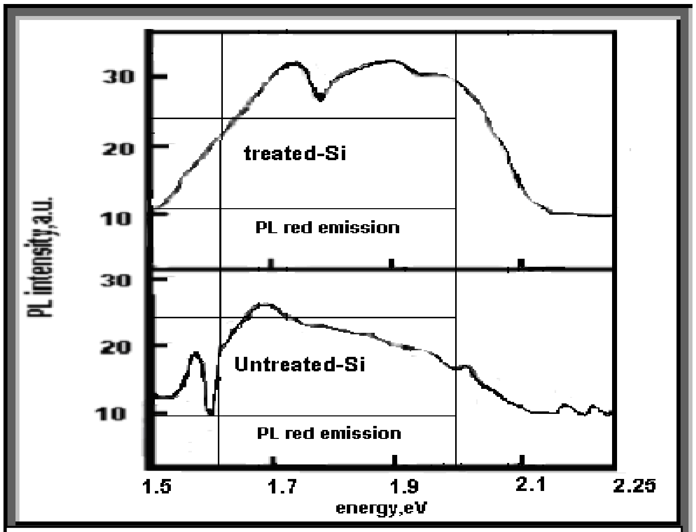

Fig. 1 .PL visible emissions of treated and untreated p-type Si at room temperature

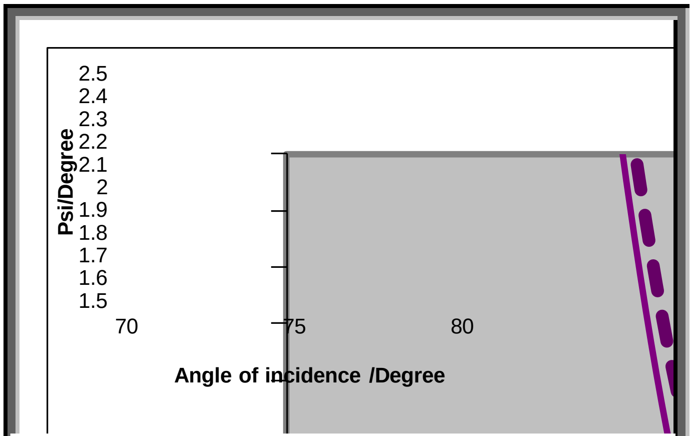

Fig. 2. Ellipsometery results, psi versus angle incident, dotty line indicates to untreated Si sample.

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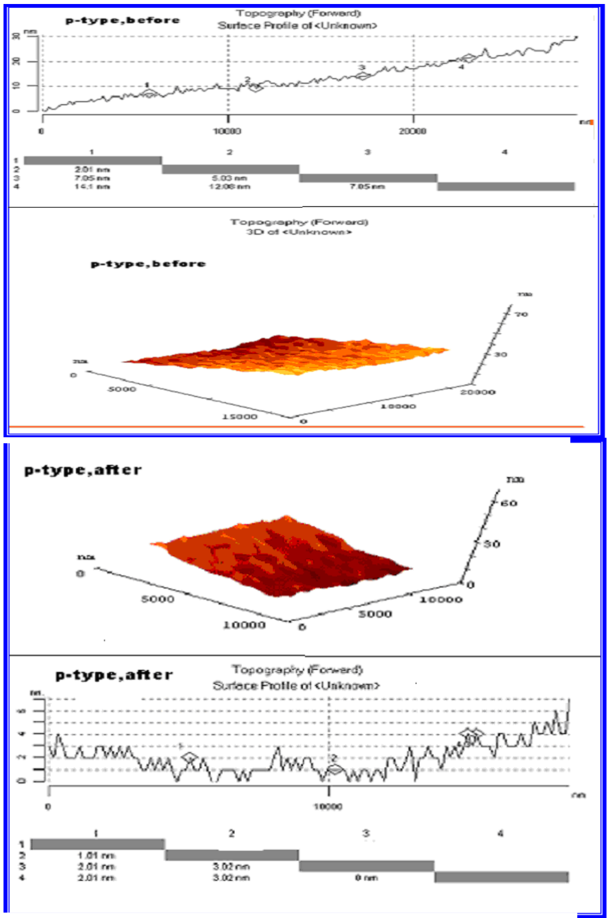

Fig. 3.AFM results of treated and untreated p-type Si

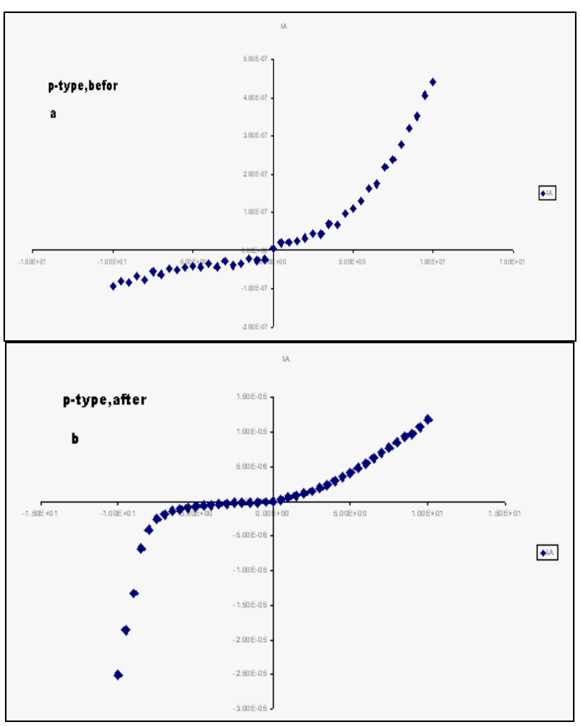

Fig. 4. IV measurements of treated and untreated p-type Si

3 DISCUSSION

Ellipsometery , PL and IV results of treated Si samples explain the effect of this treatment. Figure (2) shows the irregular effect on psi versus incident angle related to untreated-Si (dotty line). That irregular effect will affect on the others parameters as shown in the equation below [5, 6]:

$$\sigma / c = n \kappa / \lambda_o \qquad (4)$$

Where λo is the wavelength in vacuum, σ is the optical conductivity. κ has relation with skin depth δo as given in equation below[5,6]:

$$\boldsymbol{\delta_o = \lambda_o / 2\pi \kappa} \qquad \mathbf{(5)}$$

Figures (1) and (2) illustrate the effect of this treatment on visible emission band intensity and surface quality. After treatment the treated-sample turned in to good material for red emission because Si has a high absorption coefficient to (514.5 nm) and this probability increases when surface quality increasing or radiative recombination rate increases with 514.5nm wavelength interaction for treated p-type Si samples. Radiative recombination tends to dominate the relaxation of excited populations . Radiative recombination can increase by high surface quality and grain size/particle size . PL with above –gap excitation is very sensitive to surface effects and its quantum yield and lifetime also as a function of size. [7]. We expected that the particle size of samples have changed after that treatment. The PL for large particles (>9nm) can be attributed to the surface states effect in the near-surface region or the oxidized layer, these states have a direct energy gap and yield visible luminescence.PL for particles larger than 9nm is surface state-induced, while the PL for those smaller than 9nm is ascribed to quantum confinement effects [8]. The temperature dependence of the PL indicates the origin of the emission is from an exciton in the nanometer-sized Silicon structure [9] but our study carried out at room temperature. In Fig. (1), some dips appear related to quenched luminescence during photo excitation. That is attributed to an enhanced growth of the surface oxide in to the substrate due to the Laser exposure or of damaged area.PL is dominated by bulk recombination. So, treated-Si PL red emission is better than untreated-Si PL red emission. All those results give good measurements in IV .

4 CONCLUSION

This method gave optimistic results to change the optical and electrical properties of p-type Si in visible emissions region and to manage some problems in the way of Micro or nano laser based Si materials. Improvement of Silicon properties is the aim of this work to support its different applications such as Light emitting diodes (LED) or a Si Lasers .From results, Dielectric Function is good indication of our aim because this factor affects on a gain of materials especially radiative and non-radiative transitions (optical energy gap).

References

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