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Study of The Process usedfor Evaluation high - Efficiency $Al_X\ Ga_{1-x}\ AS$ - Ga As Solar Cells

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Abstract

The effects of chemical etching and temperature treatment on the optical Properties of $Al_x\ Ga_{1-x}$ As/GaAs solar cells are reported . Two structures are Investigated to isolate surface and interface effects, and to determine the effects of each layer on the resulting sample and device properties .

1.Introduction :

The use of Al_x Ga1- $_x$As/GaAs as semiconductor material in solar cell structures have been receiving increasing interest as one of the best ways to a achieve high solar energy conversion – efficiency . Enhanced performance is observed with the interesting structure by Hovel ane wood [1] , who suggested use of a "window" layer obtained with a heteroepitaxial system, P($Al_x\ Ga_{1-x}$ As) - p(GaAs) – n (GaAs) which reduce the Iosses due to surface recombination, and increase the collection efficiency. The purpose of this paper is to gain additional information on the internal efficiency of the $Al_x\ Ga_{1-x}$ As/GaAs solar cells prior to device processing and to determine the characteristics of each of the individual layers by using anew technique employing step etching and photoluminescence (PL) measurements .

2. Experimental Detailes :

The heavily doped p – type Al_x Ga1-x As layer with Al composition (x~ 0.87) and 0.5 μm thick was grown on n - -type GaAa substrates by Metal – Organic Chemical Vapour Deposition (MOCVD) .The growth temperature was 750 c^o , and The free carrier concentration of $2X10^{17}\ cm^{-3}$ .The substrates was doped with Si

to a carrier concentration of 1.5 $X10^{17}$ cm^{-3} . In the first sample a 0.6µm Sn –doped n+ -GaAs buffer layer was initially grown on the GaAs substrates ,The last of the device fabrication steps was Chemical Vapour Deposition (CVD) of a thin anti – reflection (AR) coating of S_i3 N4. Therefore , the two structures used in this study are :

S_{i3} N4(AR) – P(Al_x Ga_{1-x} As) – p(GaAs) – n+(GaAs buffer layer)- n+ (GaAs subst.),

and

Si3N4(AR) – P(Al_xGa1-$_x$As) – p(GaAs) – n+ (GaAs subst .) ,

These were selected in order to isolate the interface reactions and effects (i.e. to observe the change of surface recombimation velocity from employing the n+ -GaAs buffer layer).

The eteching process was performed using two chemical etch systems :

First: A solution of HF(98%)and H2O (de-ionized) in the ratio 1:300 used to

remove the AR coating .

Second : A new solution system prepared by mixing 60ml of (5 gm K2 Cr2O7

+500ml H2O) and 260ml of (20gm CrCI3 + 10ml H3PO4 +400ml H2O) which has

been found useful for etching of Al_xGa1 - $_x$As and GaAs layers [2] .

The two samples were analyzed before and after processing in the following areas :

Microscopic topography and morphology, scaaing electron micrograph (SEM),

Composition, minority – carrier and PL measurements. PL data are presented

Using the method previously reported [3] .

3 . Results and Discussion :

The PL measurements were carried out on the two samples in the temperature range 8 - 300°K . Due to the high Al composition (x) in the Al_xGa_{1-x} As window layer (giving indirect gap material) , and the small thickness , only GaAs PL signals were obtained. The PL spectra of the two samples after and before AR coating and Al_xGa1-$_x$As window layers were etched off are plotted in Fig's . (1) and (2) for comparison. We can see the PL emission intensities were greater from the sample having an AR coating , removal of this layer cause the PL signal to be reduced .Two sources could account for this. The first is the presence of an AR coating on the Al_xGa_{1-x} As/GaAs solar cells should have the characteristic of passivating the surface (i.e. reduce the surface recombination). The second is indicates that the presence of an AR coating decreasing optical reflection, which

in turn, increasing the PL emission efficiency . as well as it has protected the chemically active $Al_xGa1\text{-}_xAs$ layer [4] . The analysis of the temperature dependence of the PL spectra of Al_xGa_{1-x} As – GaAs solar cells, (Fig ' s 3 and 4) , show that the PL emission intensity decreases with increasing temperature which indicates that the usual thermally activated nonradiative recombination mechicaism is becoming more effective, and giving rise to an reduction of the PL intensity. The correlation between the temperature dependence of the PL intensity and that of cell performance has been noted [5], and it was shown that the surface recombination at the p-n junction is principal nonradiative process that limits the PL intensity [6]. Thus the analysis the of results indicates that nonradiative killer centers are concentrated at the $Al_xGa1\text{-}_xAs$ – GaAs interface region , and the passivation process involves reduction of these recombination centers at the interface, which agreat effect on cell performance . To observe the chang of surface recombination velocity from employing the n+ - GaAs buffer layer, a PL study was carried out at 77^oK using the two samples and the result are show in Fig . [5], The PL emission intensity of the first sample is lager than that of the second sample and this indicates that the n+ - GaAs buffer layer improves the quality of the heterointerface of the the Al_xGa_{1-x} As window layer and GaAs layer . The incorporation of the the $Al_xGa1\text{-}_xAs$ and / or GaAs buffer layer in the cell structure associated in previous reports [7] which greatly improves the open circuit voltage of solar cells due to the so – called back surface field effect caused by the Al_xGa_{1-x} As and / or GaAs buffer layer (i.e. acts as amirror for photogenerated carriers and the minority carriers are reflected at the heterointerface).

In conclusion, the temperature dependence of the PL emission intensity of Al_xGa_{1-x} As – Ga As solar cells and step etching by chemical solutions provides a direct measure for the quantum efficiency of the the $Al_xGa1\text{-}_xAs$ – GaAs solar cells. The effects and / or contribution of each layer forming the cell to the overall PL emission intensity was evaluated, and the results gave evidence that the AR coated cell had input and output reflection lower than the bare cell , while the interface surface of the p – type $Al_xGa1\text{-}_xAs$ window layer with x ~0.87 had surface recombination much less than the bare GaAs emitter surface which is in good agreement with previous studies [8] .

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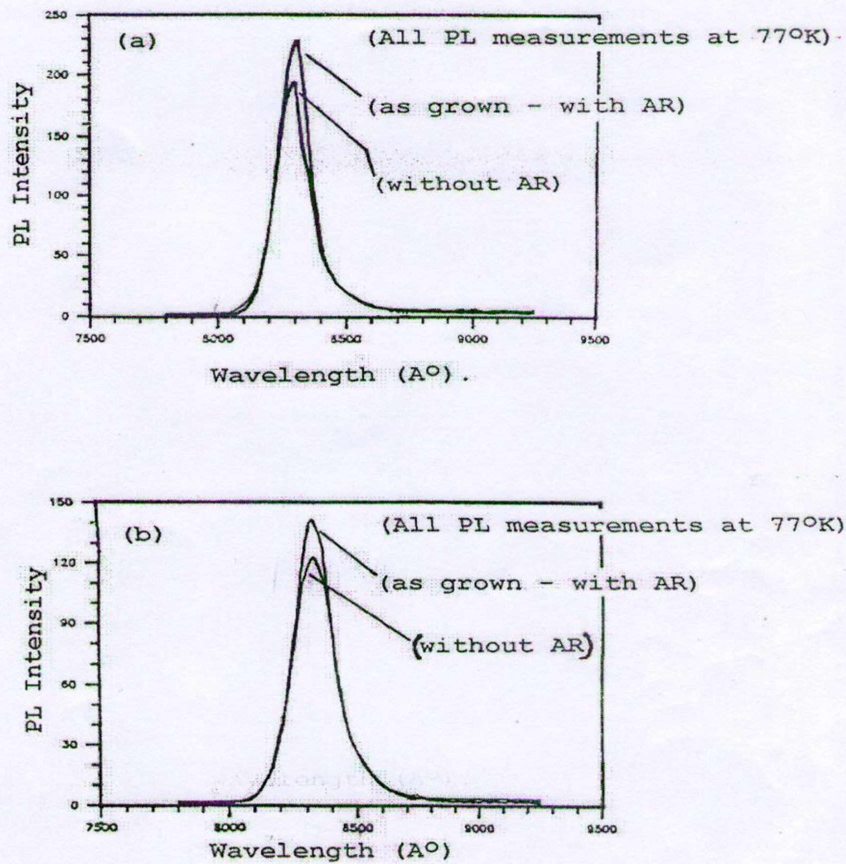


Fig (1): PL spectra of the two samples.

a - sample with n^+ — GaAs buffer layer.

b - Sample without n^+ — GaAs buffer layer

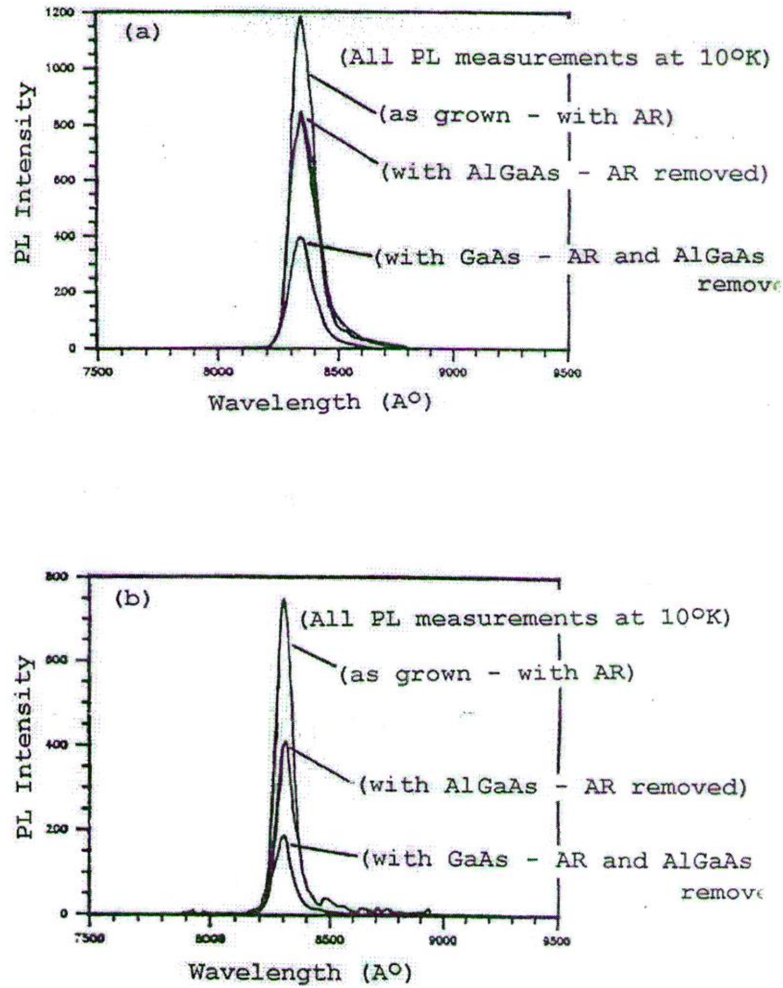


Fig (2): PL spectra of the two samples.

a - Sample with n^+ — GaAs buffer layer.

b - Sample without n^+— GaAs buffer layer.

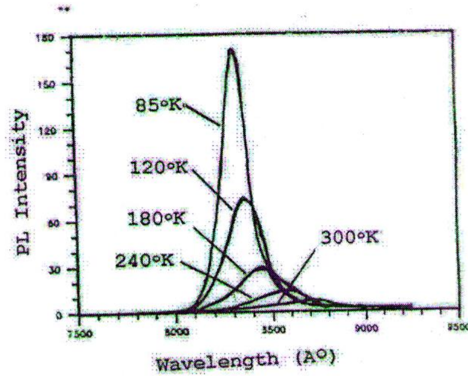
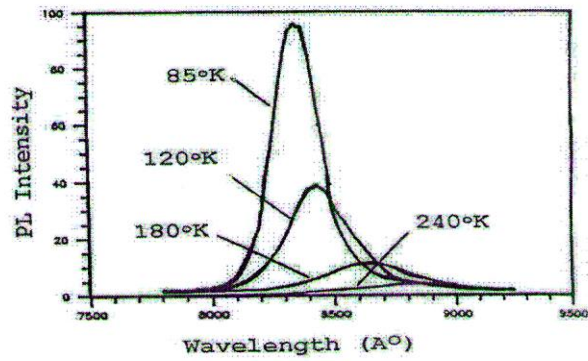


Fig (3): PL spectra of sample with n^{+}-GaAs buffer layer at different temperature in °K.

Fig(4): PL spectra of sample without buffer layer at different temperature in °K.



Fig(4): PL spectra of sample without buffer layer at different temperature in °K.

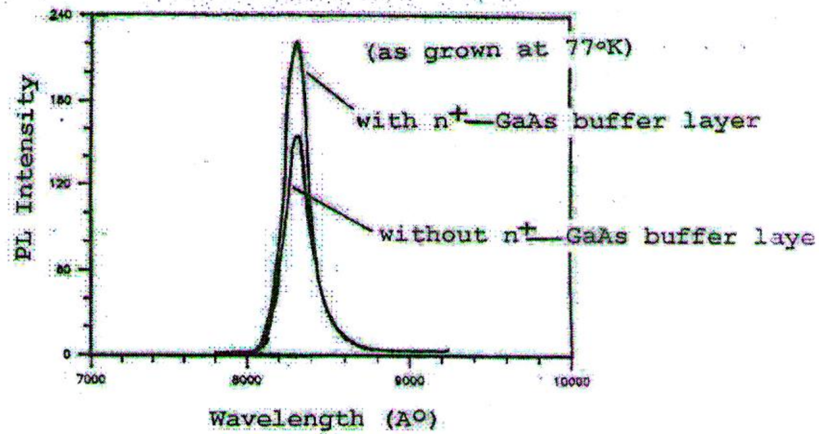


Fig. (5): PL spectra of the two samples (with and without n^+—GaAs buffer layer)

دراسة وتقييم الخلايا الشمسية ($Ga_x As_{1-x}$ As - GaAs) عالية الكفاءة

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الخلاصة:

في هذا البحث تم دراسة تأثير القشط الكيميائي ودرجة الحرارة على الخواص الضوئية للخلايا الشمسية من نوع (-As Ga_x Al_{1-x} GAas). لقد تم أختبار تركيبين مختلفين لغرض دراسة وتمييز تأثير السطح (surface) ودراسة و تحديد الـــ (interface) بالإضافة إلى أيجاد تأثير الطبقات المقشوطة (المزالة) (Etched layer) على صفات وخصائص النماذج المستخدمة .