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Effect of SiO_2 and SiN_x Passivation on CdTe based Solar Cells

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***Abstract* — Back passivation of CdTe solar cells was done using silicon di oxide (SiO_2) and silicon nitride (SiN_x) and its effect was seen on dark I-V, light J-V and C-V characteristics. We also did the annealing of solar cell which further changes the performance of solar cell. Solar cells show enhancement in performance with SiO_2 passivation and annealing after SiO_2. There is no enhancement in performance with SiN_x but it improves by doing annealing after SiN_x.**

I. Introduction

The presence of defects on CdTe degrades [1-3] the performance of CdTe solar cells. One possible way to improve the performance of solar cells is the passivation of CdTe and its effect has been studied by different research groups. Hydrogenation of CdZnTe improved the sample quality and affected the physical properties of material [4]. The results were observed by photoluminescence which tells that there is an enhancement of excitonic photoluminescence intensity and reduction of transition involving defective bonding in the $Cd_{1-x}Zn_xTe$ (CZT) alloy after hydrogenation. The passivation of $Cd_{1-x}Zn_xTe$ (CZT) was also tried with oxidation in low energy atomic oxygen [5]. Exposure of oxygen makes the grain size to be more homogenous but does not change the surface roughness. The experiments were done on metal-semiconductor–metal devices after oxidation of CZT. The oxidation of CZT increases the resistivity thus the leakage current reduces. Even though some enhancement were shown in results but change in performance was not much significant. Thermal and wet oxidation of CdTe can also passivate [6] the surface of CdTe but its effect was shown on MOS structures. Consonni et. al. [7] investigated the effect of polycrystalline chlorine doped CdTe layer. The chlorine atoms appear to compensate unintentional impurities and give rise to levels within the bandgap. Kang et. al. [8] did the surface passivation by sulfur treatment of CdTe and observed the change in photoluminescence intensity which relates with the minority carrier life time of CdTe. Kim et. al. [9] also showed the change in photoluminescence intensity by doing surface preparation with ZnS and CdZnTe. Nelson et. al [10] reported in situ H_2S plasma processing of CdTe and observed reduction in surface recombination velocity through passivation of surface states.

In this study we are also passivating the back side of CdTe on the structure of CdTe solar cells. Silicon di oxide (SiO_2) and silicon nitride (SiN_x) were used for passivation. The deposition of SiO_2 increases the value of cell parameters by reducing the surface states and by improving the interface properties. The samples were annealed and further improved the performance of CdTe solar cells. The deposition of SiN_x did not show as much enhancement as SiO_2 on solar cells.

Fig 1. shows the structure of CdTe solar cells. Fig 1a. shows the structure of CdTe solar cells without passivation and Fig 1b and c. shows the structure of CdTe with SiO_2 and SiN_x passivation respectively.

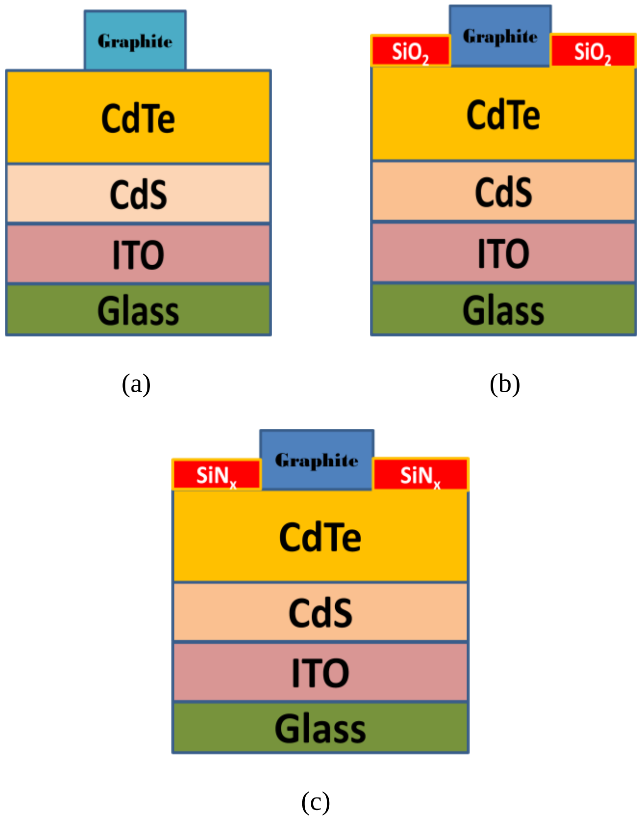


Fig 1. Structure of CdTe solar cells; (a) without; (b) with SiO_2 passivation and (c) with SiN_x passivation

II. EXPERIMENTAL DETAILS

The fabrication of planar structure of CdTe/CdS/ITO was done using standard techniques. The deposition of CdTe on CdS/ITO/Glass was done using close space sublimation. Finally graphite paste was used for contact. The samples were characterized after the fabrication of the structure shown in Fig 1a, using light and dark I-V and C-V. A layer of 200nm of (i) SiO_2 and (ii) SiN_x was deposited using Plasma enhanced chemical vapor deposition in different structures. Samples were again characterized after the deposition of SiO_2

and SiN_x Solar cells were annealed at 200°C for 30 minutes and again characterized.

III. RESULTS

Fig 2. shows the light J-V characteristics of CdTe solar cells under six conditions: (i) without SiO_2 (structure of Fig 1a), (ii) with SiO_2 (structure of Fig 1b), (iii) annealing after SiO_2 deposition, (iv) without SiN_x (structure of Fig 1a), (v) with SiN_x (structure of Fig 1c) and (vi) annealing after SiN_x deposition. Although there is small change in V_{oc} with the deposition of SiO_2, Jsc and fill factor improves significantly with the deposition of SiO_2. J_{sc} further improves after annealing. In the case of passivation with SiN_x the performance of solar cell first reduced and enhances after annealing.

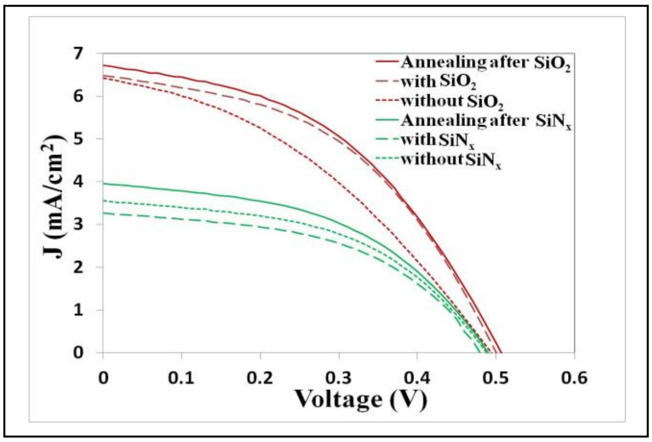


Fig 2. Light J-V characteristics of CdTe solar cells under six conditions.

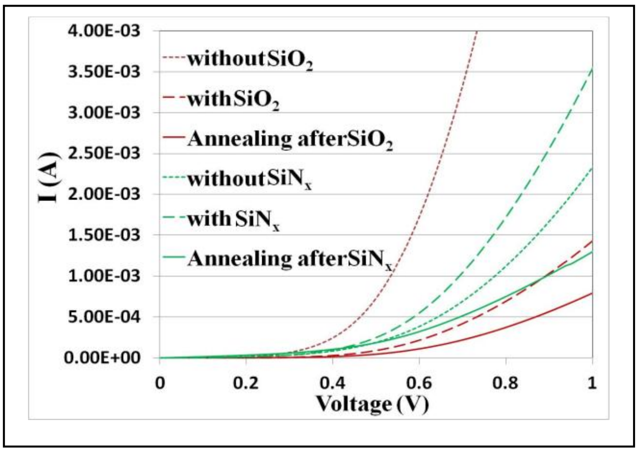
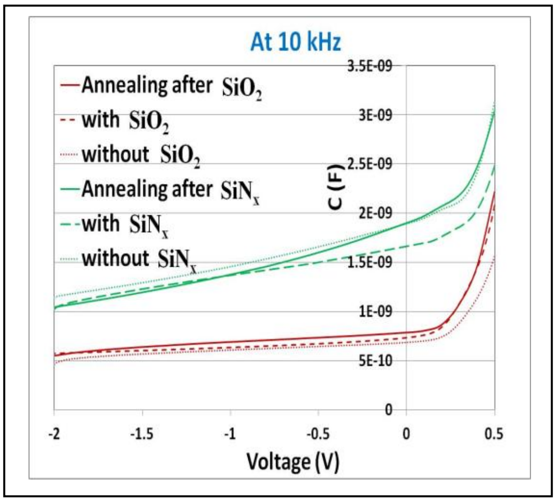


Fig 3. Dark I-V characteristics of CdTe solar cells under six different conditions.

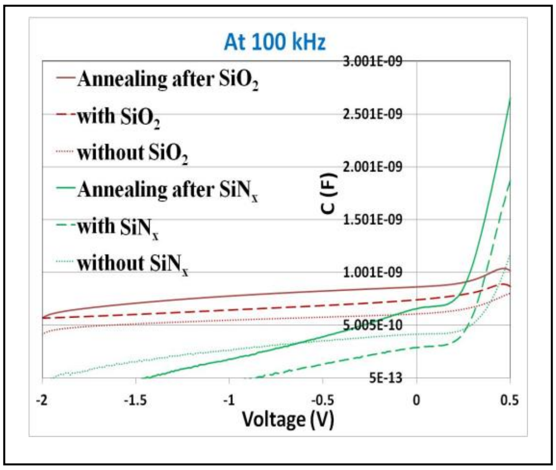
The improvement in J_{sc} and fill factor is due to the fact that surface states reduce with deposition of SiO_2 and it also reduces surface recombination by passivating bonds at the surface. The deposition of SiN_x cannot reduce the recombination and create defect in CdTe which passivate after annealing.

Fig 3. shows the behavior of dark I-V under above mentioned six conditions. There is decrease in dark forward current on the samples having the deposition of SiO_2 which means that the saturation current density will reduce with the deposition of SiO_2. Series resistance will be lower for samples having SiO_2 deposition. The curve further shifted downward for the samples on which annealing was done after SiO_2. This shows that annealing further passivate the defects present on CdTe which is responsible for enhanced performance.

Fig 4. shows the C-V characteristics of CdTe solar cells under above mentioned six conditions.



(a)



(b)

Fig 4. C-V characteristics of CdTe solar cells under six conditions, (a) at 10 KHz and (b) at 100 KHz

Fig 4 tells that both depletion and diffusion capacitance show its effect with the deposition of SiO_2 and after annealing. In the case of CdTe solar cells as fabricated (without SiO_2) the recombination effect reduces the capacitance values at different frequencies. The similar study of defects using C-V characteristics on CdTe solar cells has been reported by Poonam et. al. [11].

In the case of SiN_x the deposition of SiN_x increases the trap density which is responsible for the reduced value of depletion capacitance (Fig 4b) but after annealing depletion capacitance again increases which tells that traps get filled and reduce the trap density. That is why the deposition of SiN_x does not fully passivate the back surface of CdTe solar cells.

IV. CONCLUSION

The back passivation of CdTe solar cells were studied using the deposition of SiO_2 and SiN_x. The samples were characterized three times after fabrication of planar CdTe solar cells (without dielectric), after dielectric deposition and annealing after dielectric deposition. The changes were observed in dark and light I-V and frequency dependent C-V characteristics.

The results clearly tell that the performance of CdTe solar cells improve with the deposition of SiO_2 and after annealing. There are defects present on back surface of CdTe which get passivated after the deposition of SiO_2 and with annealing. With respect to SiN_x passivation there is not much enhancement in the performance of solar cells. The deposition of SiO_2 reduces the surface recombination and enhances the performance of solar cells. The effect of back surface recombination cannot be neglected in CdTe solar cells because of the less thickness of solar cells [12].

The scope of this work is extended to the possibilities of other dielectrics also like Al_2O_3 and HfO_2.

V. ACKNOWLEDGEMENT

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