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ELECTRICAL AND PHOTOELECTRICAL MEASUREMENTS IN p-Si/$Cd_{0.3}Zn_{0.7}S_{0.8}Se_{0.2}$ HETEROSTRUCTURES WITH INTERMEDIATE BUFFER LAYER OF CdS.

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Məhluldan elektrokimyəvi çökdürmə üsulu ilə p-Si/CdS/$Cd_{0.3}Zn_{0.7}S_{0.8}Se_{0.2}$ heterostrukturları hazırlanmışdır. Açıq havada 400°C-də 7 dəqiqə ərzində termik emal olunmuş strukturların elektrik və fotoelektrik xassələri CdS nazik təbəqələrinin qalınlığından ($150 \le d \le 250$ nm) asılı olaraq tədqiq olunmuşdur. Muəyyən olunmuşdur ki, strukturların həcmi yüklər oblastına çökdürülmüş təbəqələr defektlərin konsentrasiyasını azaldır. 100 mVt/sm^2 işıqlanmada və 300 K temperaturda boş gediş gərginliyinin, qısa qapanma cərəyanının və effektivliyin qiymətləri uyğun olaraq V_{bg} = 0.6 V, J_{qq} = 22.8 mA/cm^2, η = 10.3 % olmuşdur.

Методом электрохимического осаждения изготовлены гетероструктуры p-Si/CdS/$Cd_{0.3}Zn_{0.7}S_{0.8}Se_{0.2}$. Электрические и фотоэлектрические свойства структур, термически обработанных на воздухе при 400 °C в течение 7 мин, изучены в зависимости от толщины пленок CdS ($150 \le d \le 250$ нм). Установлено, что пленки, осажденные в области пространственного заряда структур, уменьшают концентрации дефектов. При освещении светом мощности 100 мВт/см^2 и при температуре 300 К, значение напряжения холостого хода, тока короткого замыкания и эффективности достигают до V_{xx} = 0.6 V, $J_{кз}$ = 22.8 mA/cm^2, η = 10.3 % соответственно.

p-Si/CdS/$Cd_{0.3}Zn_{0.7}S_{0.8}Se_{0.2}$ heterostructures were fabricated using an electrochemical deposition method. The electrical and photoelectrical properties of annealed in air at temperatures 400 °C for 7 min structures were investigated for various thicknesses of the CdS ($150 \le d \le 250$ nm) films. It is established, that films CdS that are deposited in the space charge region of structures reduce the concentration of defects. Under illumination 100 mVt/cm^2 and temperature 300 K, the maximal values of open-circuit photovoltage, short-circuit photocurrent and efficiency reached V_{oc} = 0.62 V, J_{sc} = 23.7 mA/cm^2, η = 10.3 % respectively.

INTRODUCTION

It is known that, one of the problems Si/CdS solar cells is the lattice mismatch between silicon and CdS structure [1]. The use of $Cd_{1-x}Zn_xS$ films permits relatively the creation of layers remaining lattice matched to the silicon substrate (p-Si/$Cd_{0.3}Zn_{0.7}S$) [2, 3].

During the investigations carried out by us, it is established, that addition of selenium to films $Cd_{1-x}Zn_xS$ is significant small amount though results in reduction of dark current, but due to effective division of electron-hole pairs the fill factor of heterojunctions p-Si/$Cd_{1-x}Zn_xS_{1-y}Se_y$ considerably increases in comparison with the structures of p-Si/$Cd_{1-x}Zn_xS$ [4]. But all the same, defects stayed in junction region limit the achievement of maximum efficiency. Therefore for the manufacture of good device structures, between a substrate and buffer layer were grows an intermediate buffer layer [5, 6]. In the present work, it is offered to build in the space charge region of heterostructures p-Si/CdS/$Cd_{0.3}Zn_{0.7}S_{0.8}Se_{0.2}$, high-resistance and less defective thin films of CdS (~ 0.05 ÷ 0.15 μm) for blocking tunnel currents originated because of defects with various natures.

EXPERIMENTAL

Thin films of CdS were deposited at room temperature on p-Si substrates from an aqueous solution containing cadmium chloride ($CdCl_2$) and sodium thiosulfate ($Na_2S_2O_3$). The thickness and resistivity of the monocrystalline p-Si substrates were 0.6 mm and ρ = 8 Ohm·cm, respectively. Before a deposition process, the surfaces of Si substrates were etched in an aqueous solution of hydrochloric acid (HCl) and KOH-KNO_3 (1:3) mixture and further washed in distilled water, which it was maintained at high temperatures (≥ 300°C). The deposition potential and current density during the deposition were varied at values between – 0.42 V and 6 mA/cm^2. Depending on the deposition time and the individual system, CdS films of thickness up to 0.15 ÷ 0.25 μm was obtained from a solution.

Electrodeposition of the $Cd_{0.3}Zn_{0.7}S_{0.8}Se_{0.2}$ films onto the p-Si/CdS substrates was carried out at room temperature from aqueous solution containing cadmium ($CdCl_2$), zinc ($ZnCl_2$), sodium ($Na_2S_2O_3$) and selenium (SeO_2 or $Na_2Se_2O_3$) salts. The deposition potential was controlled at– 0.82 V. The thickness of the films was 0.5 ÷ 1 μm.

As ohmic contacts we used Al for the silicon and ZnO for the films $Cd_{0.3}Zn_{0.7}S_{0.8}Se_{0.2}$. The active area of heterostructures was 0.4 ÷ 0.8 cm^2.

RESULTS AND DISCUSSION

The current-voltage characteristics on log scale of the annealed in air at temperatures 400 °C for 7 min heterojunctions p-Si/$Cd_{0.3}Zn_{0.7}S_{0.8}Se_{0.2}$ and p-Si/CdS/$Cd_{0.3}Zn_{0.7}S_{0.8}Se_{0.2}$ depending on the CdS films thickness are shown in Fig. 1.

The pass direction corresponds to negative polarity of the external bias on the $Cd_{0.3}Zn_{0.7}S_{0.8}Se_{0.2}$ films. All the characteristics can be described by dependence of

$$I \cong \exp(eU / nkT)$$

From this dependence the factors of imperfection n, have been calculated. From calculations follows, that in an applied voltage region of U = 0.1-0.67 V, for structures without an intermediate layer n = 1.75. As in all investigated structures 1<n<2, it is possible to draw a conclusion, that a current through transition, include both diffusion, and recombination-tunnel components. As the density of defects in junction region of structures without an intermediate layer is higher, that on it the great value of imperfection factor testifies. It can be seen that the presence of high-resistance thin films of CdS in the space charge region of heterostructures reduce the concentration of defects. Apparently, with increase of CdS films thickness the imperfection factor sharply decreases, reaching the minimal value (n = 1.42) at d = 220 nm.

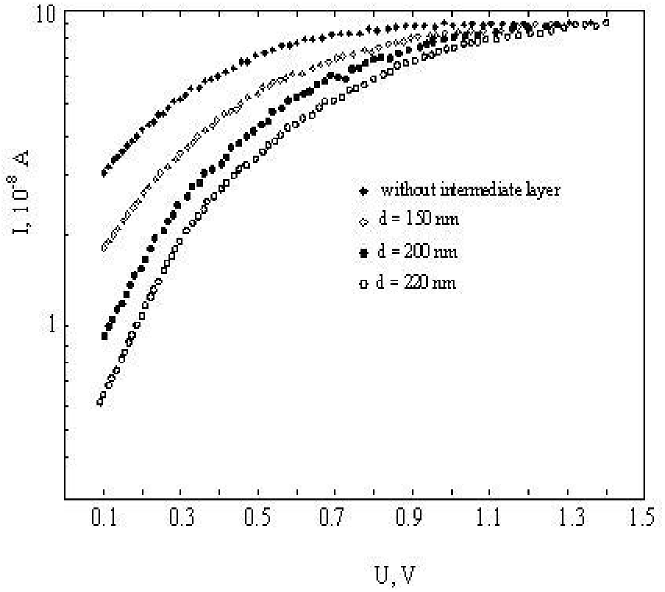

Fig.1. Dark *J-V* characteristics for p-Si/$Cd_{0.3}Zn_{0.7}S_{0.8}Se_{0.2}$ heterostructures without and with intermediate buffer layer of CdS.

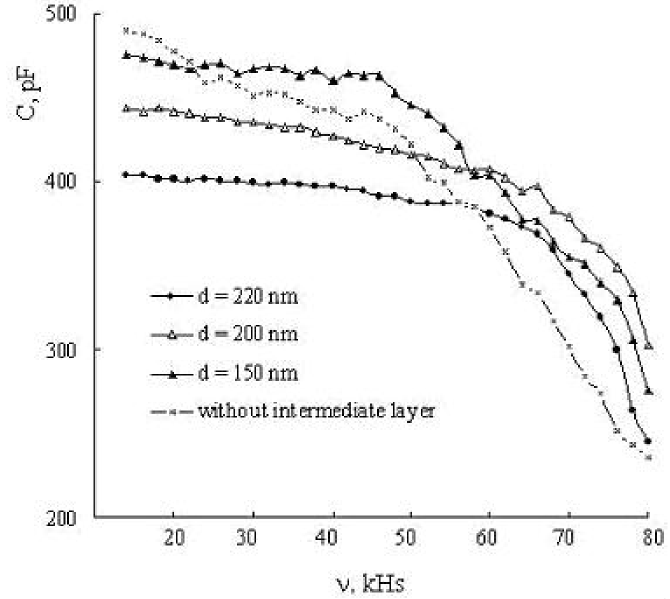

Fig.2. Capacitance-frequency dependences for heterostructures p-Si/$Cd_{0.3}Zn_{0.7}S_{0.8}Se_{0.2}$ without and with intermediate buffer layer of CdS.

The capacitance-frequency measurements carried out on the annealed in air at temperatures 400 °C for 7 min heterojunctions heterostructures p-Si/$Cd_{0.3}Zn_{0.7}S_{0.8}Se_{0.2}$ give further insight into the junction properties and the role of the intermediate layer of CdS. C(f) curves drawn in Fig. 2 show significant differences between structures without and with intermediate layer of CdS. The low frequency capacitance is much higher in the structures without intermediate layer. With increasing thickness of films CdS up to 220 nm, the value of capacitance decreases and weakly depends on the frequency till 60 kHs. This indicates a change of the density of states in the junction region, i.e. a decrease in the density of defects.

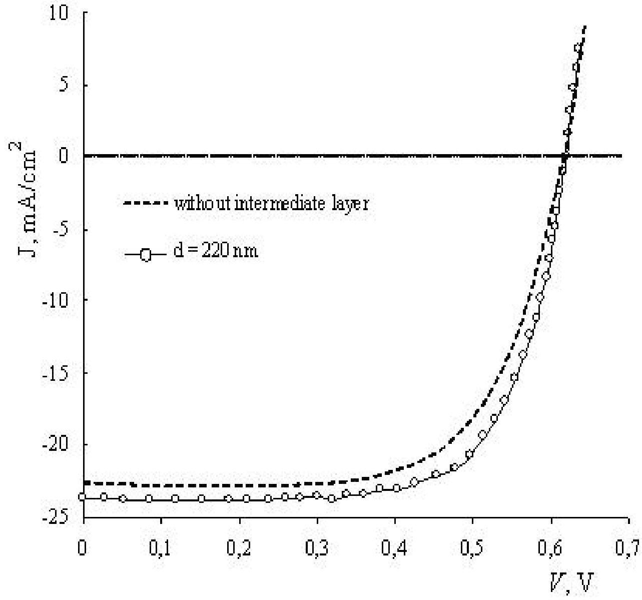

Fig.3. Light *I-V* characteristics of the p-Si/$Cd_{0.3}Zn_{0.7}S_{0.8}Se_{0.2}$ heterostructures without and with intermediate buffer layer of CdS.

Additional information on the effect of thin films of CdS in the space charge region on the parameters of the investigated heterostructures could be obtained by investigating the photoelectric properties of the structures. Fig. 5 shows the light current-voltage characteristics of the annealed heterojunctions p-Si/$Cd_{0.3}Zn_{0.7}S_{0.8}Se_{0.2}$ and p-Si/CdS/$Cd_{0.3}Zn_{0.7}S_{0.8}Se_{0.2}$ at illumination 100 mVt/cm^2 and temperature 300 K. It is clearly seen that efficiency of structures with intermediate buffer layer of CdS is high than in usual structures. The maximum open circuit photovoltage, short circuit photocurrent and efficiency values for the heterojunctions were V_{oc} = 0.62 V, J_{sc} = 23.7 mA/cm2, η = 10.3 % respectively.

CONCLUSION

p-Si/CdS/$Cd_{0.3}Zn_{0.7}S_{0.8}Se_{0.2}$ heterostructures are prepared by the electrodeposition method. Their base characteristics were studied depending on the thickness of CdS films. The films CdS that are deposited in the space charge region reduce the concentration of defects. It is established that heterostructures possess the high photosensitivity with intermediate CdS layer thickness of d = 220 nm.

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