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Effect of temperature on the current-voltage characteristics of an nSi/pCdTe heterostructure grown by thermal evaporation in vacuum

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ABSTRACT: This study delves into the exploration of the electro-physical attributes of nSi-pCdTe heterojunctions formed through the Vacuum Thermal Evaporation (VTE) technique. The choice of n-type polycrystalline silicon as the substrate material was pivotal. Under deposition conditions of approximately 1.3×10^{-4} Pa and a temperature of roughly 500°C, a CdTe thin film was laid down. Throughout this process, the substrate temperature was rigorously maintained at 590°C. This deposition spanned 30 minutes, yielding a CdTe film thickness measuring 10 µm, thereby affirming the generation of a p-type layer. The Volt-Ampere characteristics of the resulting heterojunction were meticulously gauged across varying temperatures. The findings illuminated a consistent alteration in the opposite direction with ascending temperature, a phenomenon referred to as VAX. Experimental scrutiny disclosed a peculiar non-monotonous shift in behavior during forward biasing. Furthermore, the sample underwent scrutiny to assess the mobility and electrical conductivity of both electrons and holes.

KEY WORDS: Vacuum thermal evaporation, CdTe, heterostructure, p-n junction, thin film, I-V characteristics, polycrystall.

I.INTRODUCTION

In recent times, there has been significant interest in semiconducting thin films, both in academic research and commercial sectors, due to their potential in optoelectronic devices. A noteworthy category of such films is the II–VI chalcogenides, known for their suitability in thin film optical devices owing to their high optical absorption capabilities. Additionally, they can be produced as high-quality polycrystalline films from cost-effective raw materials using various methods [1-8]. Among these, cadmium telluride (CdTe) thin films have garnered substantial attention for their versatile applications in optoelectronics and photovoltaics, such as in solar cells, detectors for infrared and gamma rays, and field effect transistors. CdTe polycrystalline films, in particular, show promise for photovoltaic solar cells due to their high absorption coefficient (10^{-4} cm^{-1}) and optimal band gap of 1.5 eV.

The construction of heterojunctions between CdTe and Si has attracted a lot of scientific attention lately because heterostructures based on these materials can provide an alternate method for converting solar energy into electricity. In this work, we have grown a CdTe compound on a polysilicon substrate by VTE method and aimed to study the effect of temperature on the I-V of the sample.

II. MATERIALS AND METHOD

CdTe films with a thickness of 10 µm were prepared on a polysilicon substrate with a thickness of 400 µm using the thermal evaporation technique in a vacuum of 10^{-4} Torr. The growth method and the optimal mode of thin film growth were determined in previous works [9]. Inside the vacuum chamber, the distance between the source and the substrate was about 20 cm, and the thickness of the thin film was measured using a micrometer. In this work, we increased the base temperature to 590°C and the CdTe temperature to 500°C. The morphology and initial dimensions of the sample were presented in a previous work [10]. The grown sample was in contact with indium in a vacuum.

III. RESULTS

To assess the electrical characteristics of thin films, Hall Effect experiments are performed in air at room temperature to ascertain the semiconductor material's form of charge carriers as well as concentration, mobility, and conductivity. CdTe film was discovered to be p-type with corresponding $6.5 \cdot 10^{13}$ cm^{-3}, 130 cm/V·s), and $1.01 \cdot 10^{-4}$ $(\Omega \cdot cm)^{-1}$ values.

Figure 1 shows current-voltage characteristics measured with and without a Si-CdTe contact, as well as without a thin CdTe polysilicon layer.

Fig. 1 - I-V characteristics of Si-CdTe and Si

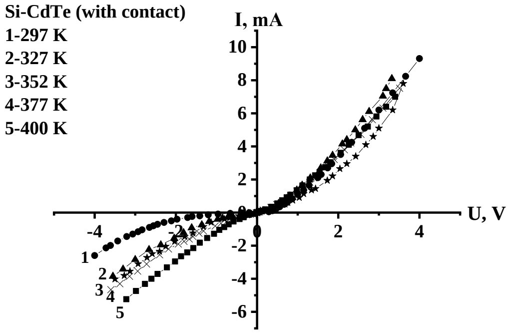

Fig. 2 - I-V characteristics of Si-CdTe at different temperature

In Fig. Figure 2 shows the current-voltage characteristics of the sample, taken at various temperatures from 297 K to 400 K.

IV. DISCUSSION

Fig. 3 shows lnI vs V plots for (n)Si/(p)CdTe heterojunction in the dark at different temperatures. The straight fitting of lnI vs V shows that current, carrying mechanism over the heterojunction barrier, is dominated by the thermionic mechanism, current density–voltage relation is given by the relation [11]

$$I = I_s\left[\frac{qV}{nkT}\right] (1)$$

where V is the applied voltage and J_s is the saturation current density given as

$$I_s = \frac{qA^R T V_{bi}}{k} exp\left(\frac{-qV_{bi}}{kT}\right) (2)$$

where A^R is the Richardson constant, V_{bi} is the built-in potential, k is the Boltzmann's constant and T is the temperature.

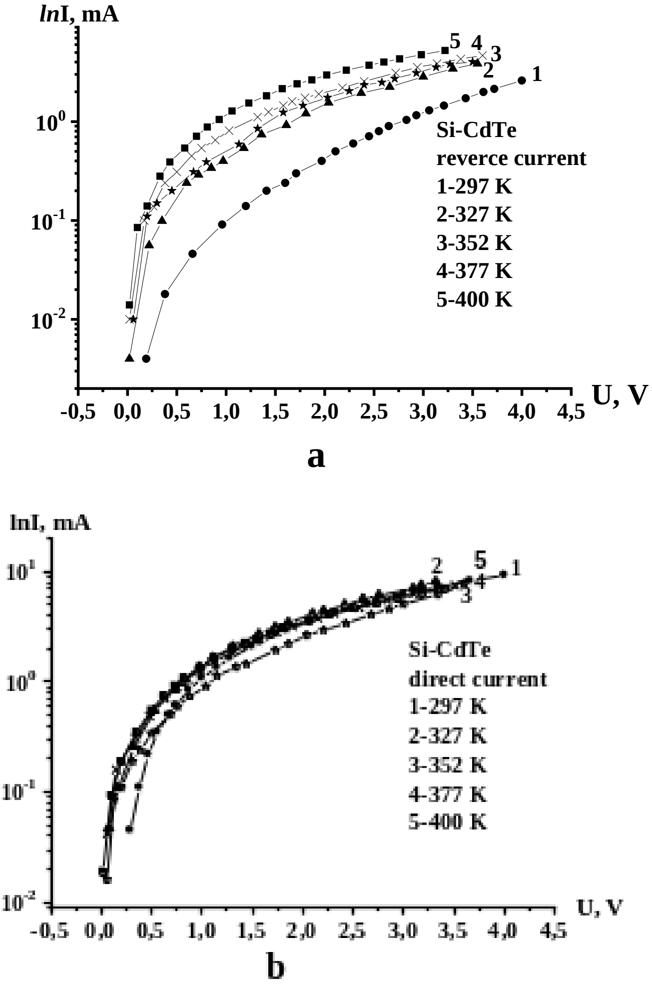

Fig.3 - lnI vs V plot of (n)Si/(p)CdTe heterojunction: revercce (a) and direct (b) transition

From Figure 3 it can be seen that the VAX line changed monotonically during the reverse transition with increasing temperature. We see that the transition is non-monotonic. From this example, we can conclude that in the mechanism of current transfer, the recombination mechanism plays a larger role than the diffusion mechanism.

In Fig. Figure 4 shows the current-voltage characteristics of Si-CdTe without a contact (1), with an indium contact (2) and silicon (3) (without a CdTe film) in logarithmic form. After contact with Si-CdTe, we see that the current increases when measuring the current-voltage characteristics of the sample without contact and the Si material itself (without a thin layer of CdTe).

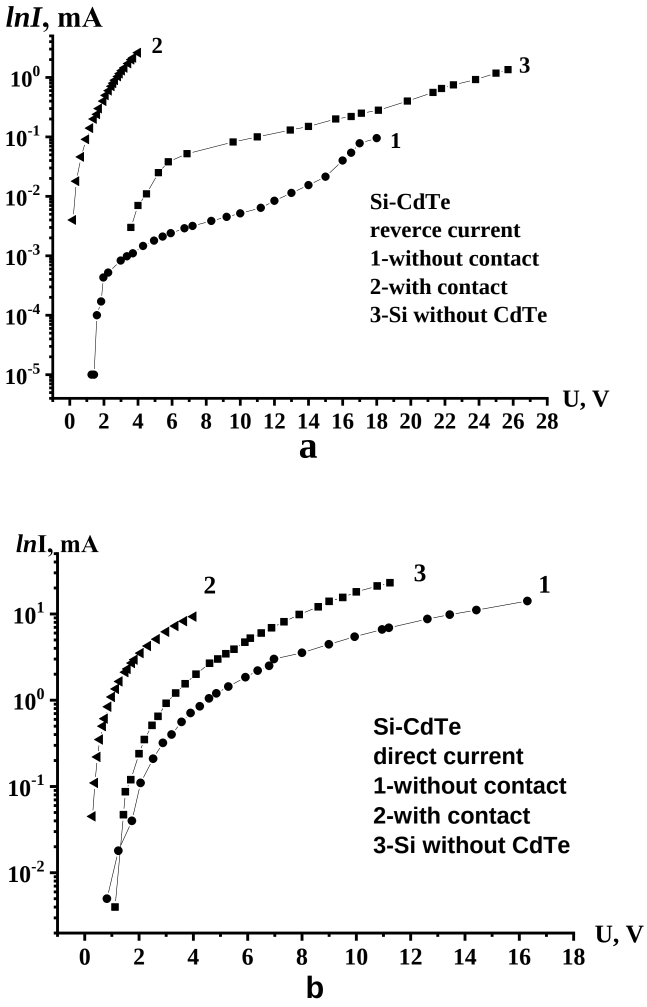

Fig. 4 – lnI vs V plot of Si-CdTe and Si

V. CONCLUSION

In conclusion, the p-type CdTe film was grown on a polysilicon substrate. Sample concentration, carrier mobility, and conductivity were measured. They were respectively:
$6.5\cdot10^{13}$ cm^{-3}, 130 cm/V·s), and $1.01\cdot10^{-4}$ $(\Omega\cdot\text{cm})^{-1}$
With increasing temperature, the current-voltage characteristic changed monotonically during the reverse transition and non-monotonically during the forward transition. After contact with the sample, the current transmission mechanism improved.

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