Dark and Light Characteristics of Sb-Se Heterojunction Formed on Silicon Substrate

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ABSTRACT

In this work, the dark and light characteristics of Se/Sb thin film heterojunction deposited on a p-type silicon substrate were studied. Reasonable enhancements in electrical and spectral characteristics of the achieved structure were indicated throughout I-V and C-V measurements in dark and light. These results are compared to the cases of Se/Si or Sb/Si individually.

خصائص الظلام والإضاءة لتركيب ثنائي الوصلة الهجين أنتيمون-سيلينيوم على قاعدة سيليكونية

الخلاصة

في هذا البحث، جرى دراسة خصائص الظلام والإضاءة لتركيب الأغشية الرقيقة من السيلينيوم والأنتيمون على قاعدة من السيليكون القابل. لوحظ تحسناً ملحوظاً في الخصائص الكهربائية والطيفية لهذا التركيب من خلال قياسات تيار-جهد وسعة جهد في حالتي الظلام والإضاءة. جرت مقارنة النتائج المستحصلة مع حالة الأنتيمون على السيليكون أو السيلينيوم على السيليكون كل على حدة.

Keywords: Heterojunctions, Silicon-based devices, Selenium-Antimony devices

1. Introduction

There are many available techniques for the fabrication of heterojunctions those are the base of most photoelectric devices such as detectors, solar cells and semiconductor lasers. Such heterojunctions are prepared by growing epitaxially one semiconductor material onto a different semiconductor material. The most common preparation techniques are chemical-vapor deposition (CVD), solution

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growth, alloying, sputtering and vacuum evaporation.

In vacuum evaporation, direct evaporation of the semiconductor or co-evaporation of the constituent elements of the compound semiconductors are the main employed processes and subsequent condensation on single crystal substrates in high vacuum can be used principally for growing hetero-epitaxial layers of any semiconductor material. Usually, the films grown by this technique are polycrystalline [1-9].

The most common compounds formed from II-VI, IV-VI or III-V groups are important semiconductors. The main necessary requirements of such structures are parity and equivalence. Due to previous works, structures made of V-group elements (As, Sb and Bi) combined with VI-group elements (Se, Te and Po) are not common to form compound semiconductors. Extensively studied in order to achieve good semiconducting properties, the chalcogenides of antimony (Sb) are interested. They have rather complex lattices and prepared by direct reaction of elements at 500-900°C. Both n-type and p-type materials can be obtained by appropriate doping [1,10].

2. Experiment

A 150nm-thickness thin film of antimony was deposited on a 1x1cm^2 p-type (111) silicon substrate using 10^{-6}Torr vacuum evaporation system. Then a 150nm thin film of selenium was deposited upon the Sb film by the same system. Hence, a 300nm-thickness region of n-n isotype Selenium-Antimony (Se-Sb) heterojunction was formed. The deposition rate was ~30nm/min and the tolerance of such process does not exceed 5%. The aluminum top contacts were deposited on the selenium layer while nickel contact was deposited on the silicon backside. Fig. (1) explains the structure formed in this work.

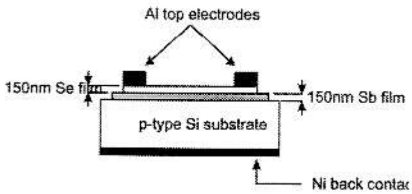

Figure 1. The Se/Sb-on-Si structure formed in this work.

Measurements included reverse and forward I-V characteristics, C-V characteristics and I-V characteristics in dark and under illumination by a halogen lamp in case of individual (Sb/Si and Se/Si) and Se/Sb-on-Si structures.

3. Results and Discussion

Results of the current-voltage measurements are shown in Figs. (2-5). The current-voltage measurements were carried out for the three cases at different intensities (90-210)mW/cm^2 of incident light. The generated current in case of Sb/Si was little more than 2.5mA at 5V bias and maximum power density of illumination (210mW/cm^2) while it was 3.5mA in case of Se/Si at the same level of bias and illumination. The value of generated current was increased to about 5mA in case of Se/Sb-on-Si that reveals the improvement of photoelectric conversion of this structure. The I-V measurements in both forward and reverse biases validate uniformity of the diode characteristics as shown in Fig. (5).

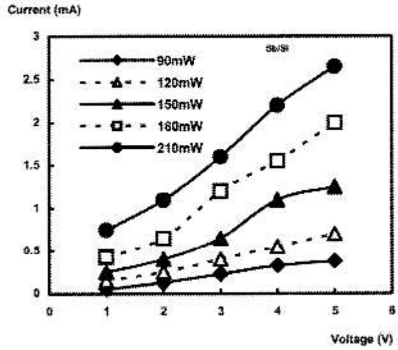

Figure 2. I-V characteristics of Sb/Si structure at different incident light intensities.

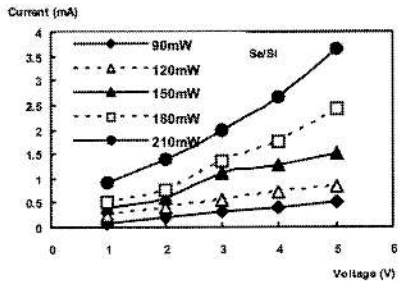

Figure 3. I-V characteristics of Se/Si structure at different incident light intensities.

Results of the capacitance-voltage measurements in reverse biasing shown in Fig. (6) reveal that the heterojunction of this work is linearly graded. From this figure, the value of built-in potential (V_{bi}) is about 0.8V.

There are two interpretations for the enhancement performed in the characteristics of the Se-Sb structure. The first one proposes formation of $Sb_{1-x}Se_x$ intermediate layer. The enhanced characteristics are attributed to the new properties of $Sb_{1-x}Se_x$ layer (much probable Sb_2Se_3). This structure is already a compound semiconductor of 1.3eV band-gap and 612°C melting point.

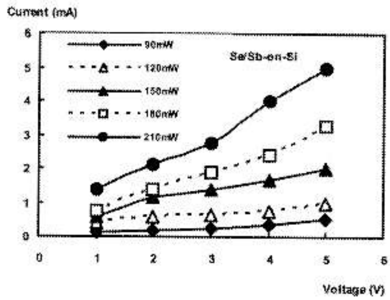

Figure 4. I-V characteristics of Se/Sb-on-Si structure at different incident light intensities.

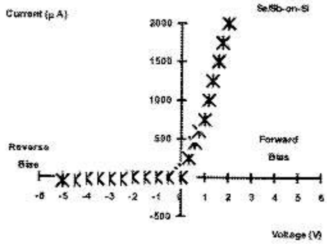

Figure 5. I-V characteristics of Se/Sb-on-Si in forward and reverse biasing.

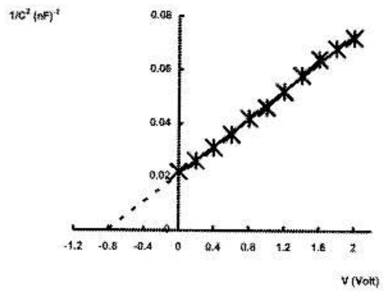

Figure 6. C^{-2}-V characteristics of Se/Sb-on-Si in reverse biasing.

The second interpretation is the combination of Sb/Si and Se/Si layers, individually, to the characteristics of the thin-film structure. In this case, the characteristics of the upper layer (Se) support those of the lower layer (Sb) producing more sensitive and less transparent structure. As the thin-film structure is formed on a semiconductor substrate (in this work it is silicon), two effective regions are formed. The first region is formed between the substrate (silicon) and the lower layer (antimony) while the second one is formed between the two deposited thin films themselves, which in turn includes two probabilities as mentioned above.

4. Conclusions

According to the results of this work, an isotype (n-n) Se/Sb heterojunction was formed on a p-type silicon substrate. Results expressed reasonable enhancement in I-V and C-V characteristics compared to both cases of individual elements (Sb and Se) on silicon substrate. The enhancement achieved can be interpreted by to two probabilities. The formation of $Sb_{1-x}Se_x$ intermediate layer is possible. This layer possesses semiconducting properties better than both elements individually. The formation of two heterojunction regions (Sb/Si and Se/Sb) then each contributes to the overall characteristics of the structure. This is also possible. This work is an attempt to fabricate heterojunctions of enhanced characteristics from V and VI groups.

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