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On the Influence of Metal Deposition on Responsivity Peak of Cleaned Silicon Photodetector

Raid A. Ismail, Khalid Z. Al-Ta'ai*, Manaf R. Ismail**

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Abstract

In the present work, p-type Si wafer of (111) orientation and 3 Ω.cm resistivity had been doped with phosphor by thermal diffusion process to fabricate p-n junction detector. The main optoelectronic properties of the fabricated detectors were studied. Thin films of ultrapure Cu, Bi, Ag, and Al were deposited on the sensitive area of the detectors (donor side). On the base of the transmission and absorption phenomena of the deposited films, peak response data of these detectors that conventionally at near IR (850-900 nm) before deposition was reduced and resulted in peak response at 600 ± 25 nm after deposition.

دراسة تأثير طلاء كاشف السليكون غير المؤكسَد بالمعادن على قمة الاستجابية الطيفية

الخلاصة

في هذا البحث، تم إشابة شرائح سليكونية قابلة ذات توجهية (111) ومقاومة نوعية Ω.cm 3 بمادة الفسفور المانحة وبطريقة الانتشار الحراري لتصنيع كاشف p-n السليكوني. جرى دراسة الخصائص الكهروبصرية الأساسية لهذه الكواشف. ثم رسبت بعد ذلك أغشية عالية النقاوة من مادة Cu و Bi و Ag و Al على المساحة الفعالة للكاشف (الجهة المانحة). استناداً إلى مبدئي النفاذية والامتصاصية لهذه الأغشية، انخفضت الاستجابية للكواشف المطلية في المنطقة تحت الحمراء القريبة لتنتج بدلا عنها قمة استجابية عند الطول الموجي ± 600 .25 nm

Keywords: Metals/p-nSi, Thermal Evaporation, Optoelectronic Properties.

1. Introduction

It is approved previously that Si p-n junction detectors

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* Dept. of Applied Science, University of Technology, Baghdad, IRAQ.

have a visible-NIR responsivity spectrum with peak response at 900±25 nm [1-3]. Silicon photodetectors of 200–700 nm responsivity régime is considered as imported detectors in many applications of the technology such as spectrophotometers, flame sensors, satellite communication, and detectors of UV and visible lasers [4]. In spite of Si detectors have sensitivity in the range of 700–1100 nm, this range is undesirable sometimes, several routes are available to reduce the sensitivity in the NIR region and produce detectors that operate in the visible-near UV spectrum. Some of these routes are using IR cut-off filters and interference filters [5]. In the present paper, economical and low-cost technique is used to produce visible-peak Si detectors by depositing materials of high reflectivity in the IR region respect to their reflectivity in the visible and UV regions. These materials are copper (Cu), aluminum (Al), silver (Ag), and bismuth (Bi).

2. Experimental Procedures

Single crystal (111) Si wafers of p-type conductivity, 3 Ω.cm resistivity and 0.5 ± 0.015 mm thick grown by Czocharlski (Cz) technique were used in this study. These wafers were cut into individual square shape pieces of 5 mm length. One side of the wafer was polished to mirror-like surface with aid of 25 x 10^{-5} mm diamond paste. CP-4 etchant was used to remove native oxides [6], then the wafer was thoroughly cleaned and degreased. The p-type silicon was doped with donor impurities (phosphor) by thermal diffusion. Thin films of Cu, Al, Ag, and Bi were deposited on the sensitive area of the detector with thickness of 30 nm using thermal resistive technique. Ohmic contact was made by depositing of Au and Al films onto p- and n-type respectively. Figure 1 shows a side sectional view of the final detector. Spectral responsivity was measured by using monochromator of the range 400–1100 nm after making a calibration with aid of power meter. Optical transmittance of the used metals was measured with the help of spectrophotometer for samples prepared on glass substrates.

3. Results and Discussion

Optical transmittance of the used materials that prepared on glass substrates is shown in Figure 2. It is obvious from the figure that transmittance is higher at short wavelengths (visible and ultraviolet) but it is decreased with increasing wavelength. It is also shown that Cu film exhibits best transparency at short wavelengths and good vanishing at long wavelengths against other used materials. This result reflects that Cu film should act as a good visible and UV filter. On the other side, Bi film exhibits undesired results. These results are in agreement with the previous published results [5].

Shown in Figure 3 is the spectral current responsivity of Si detector before metal deposition. The figure demonstrates that this detector has a peak response at 900 ± 50 nm which is in fair agreement with published results [7]. In the current work, the value of responsivity at peak response was 0.305 A/W, which is higher than that of the previous published data with a factor of 41%.

After metal deposition, responsivity waveform was altered and peak response became at 600 ± 25 nm as shown in Figure 4, this result can be elucidated as follows: since the used metals have low transmittance at near IR and relatively high transmittance at visible and UV wavelengths, then these metallic films will act as filters with narrow band width of 200 nm (measured at FWHM). Accordingly, the light will be attenuated in the IR region with a factor significantly greater than the attenuation in the visible and UV regions, and hence the peak response will be appeared at shorter wavelength. Moreover, the wavelength at peak response (λ_P) is essentially related with the refractive index (n) of the material by the empirical relation $\boldsymbol{\lambda_P=4nt/(2k+1)}$ [8] where t is the thickness and k=1, 2, …etc. On the other hand, the value of responsivity illustrates deep dependence on the value of transmittance that has previously mentioned (see Figure 2), that is to say, higher responsivity is corresponding to the metal of higher transparency. The histogram in Figure 5 depicts the peak response versus type of deposited film [9].

4. Conclusion

On the base of the results that have introduced before, one can conclude that metal coating of silicon detectors is a feasible technique to produce IR blind-visible detectors with peak response around 600 nm instead of 900 nm for conventional Si detectors. The prosperity of this technique is greatly depending on the type of used metal. Metal coating of passivated Si detectors is currently under progress.

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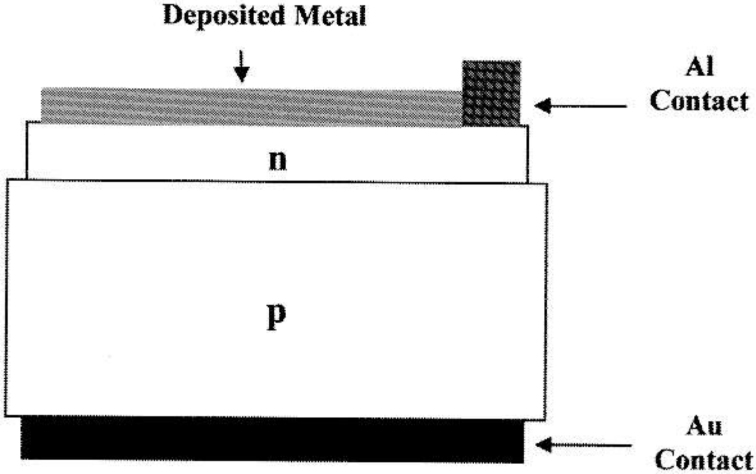

Figure 1. Sectional View of the Final Detector.

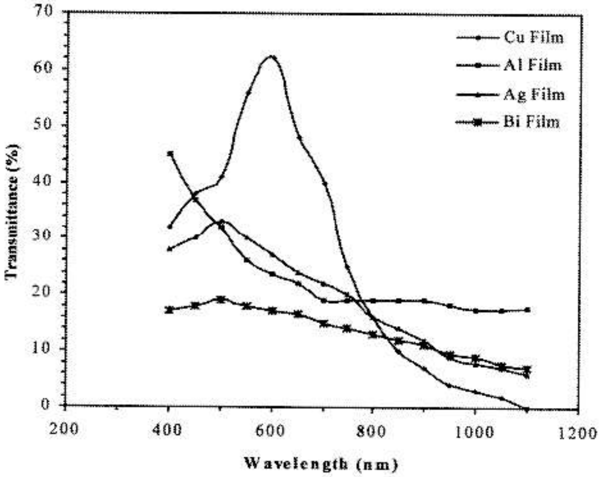

Figure 2. Spectral Transmittance of the Metals that had Deposited onto Glass substrates.

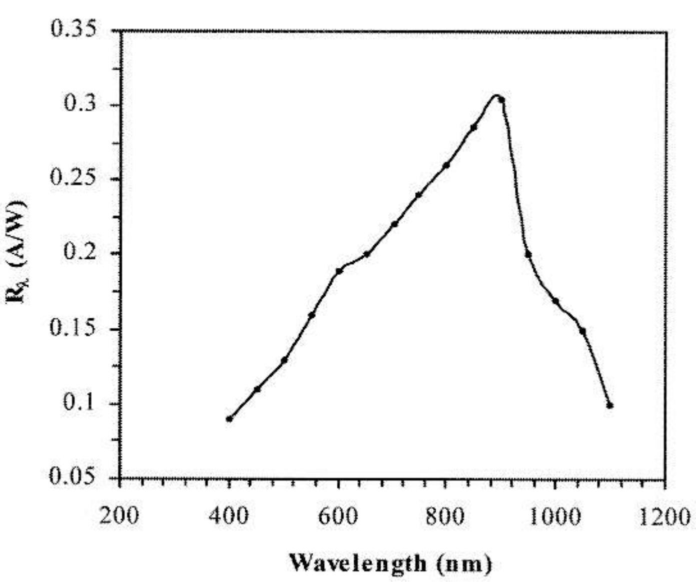

Figure 3. Spectral Responsivity of p-n Photodiode.

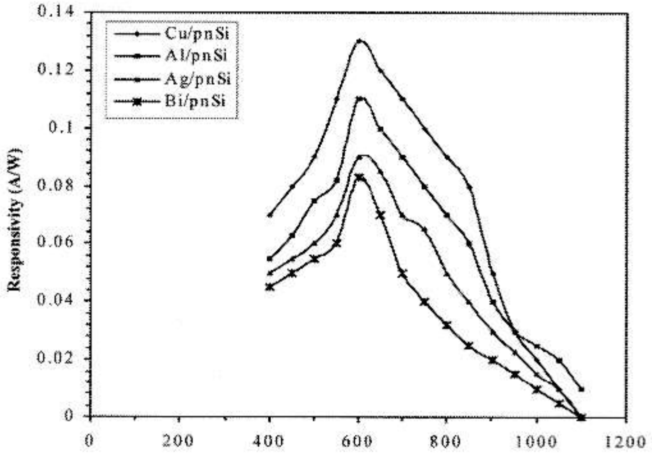

Figure 4. Spectral Responsivity of (Cu, Al, Ag, Bi)/p-n Si Detector.

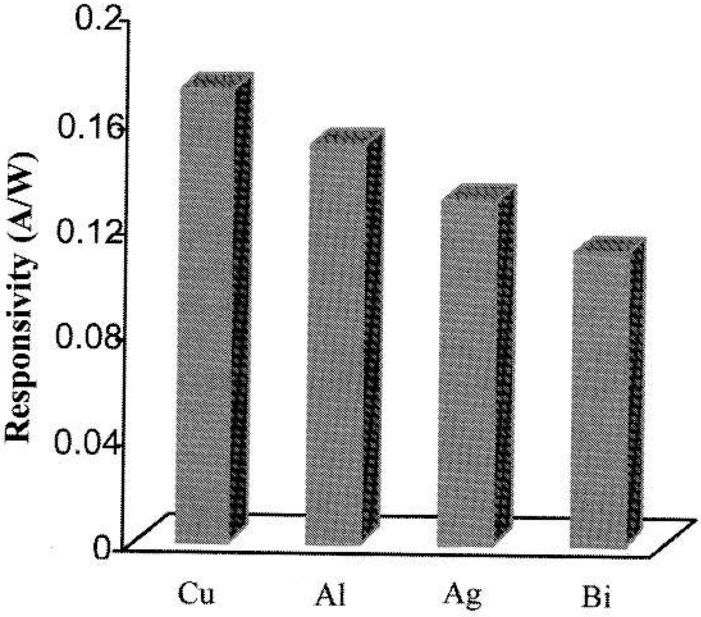

Figure 5. Histogram Explains the Peak Response against Deposited Metal Type.