Eng. & Technology, Vol. 1, No. 24, 2005

IR-Blind Visible Silicon Detector

Khalid Z. Al-Ta'ai*
Received on: 10.06.2004
Accepted on: 09.11.2004

Abstract

In the present paper, silicon p-n junction detector of 600 ± 25 nm peak response has been characterized. This peak was obtained by depositing high purity Au thin film onto sensitive side of the p-n junction (donor-side), this film reduces the responsivity in the near-IR region (800 – 1100) nm and leads to peak response at 600 nm. The white light photovoltaic characteristics, spectral responsivity, and quantum efficiency are greatly depended on the photon transmission of Au film. Experimental results showed that the detector responsivity in the near IR region was reduced to about 18.5% from its initial value after depositing 30 nm Au film.

تصنيع كاشف سليكوني يعمل في المنطقة المرئية من الطيف ولا يعمل في المنطقة تحت الحمراء

الخلاصة

في هذا البحث، تم تصنيع ودراسة خصائص كاشف سليكوني نوع ثنائي الوصلة يمتلك قمة استجابة عند المنطقة المرئية (600 ± 25 nm) وجرى تقليل استجابة الكاشف عند المنطقة تحت الحمراء القريبة (800 – 1100) nm من خلال ترسيب غشاء رقيق من الذهب عالي النقاوة على المنطقة الحساسة (المنطقة المانحة) للضوء الكاشف السليكوني. إن نتائج كل من الفولتائية للضوء الأبيض، الاستجابة الطيفية، والكفاءة الكمية تعتمد بشكل كبير على ظاهرة النفاذية لغشاء الذهب. لقد أوضحت النتائج العملية إن استجابة الكاشف للمنطقة تحت الحمراء القريبة قد انخفضت إلى 18.5% من قيمتها الأصلية بعد إجراء ترسيب غشاء الذهب وبسمك 30 nm.

Keywords: Visible photodetector, Au/p-n Si.

1. Introduction

p-n junction silicon detectors are widely used in many applications of the 300 – 1200 nm range detection, this comes from the silicon band gap (1.12 eV) [1 – 4]. Previous researches on Si p-n junctions approved that peak response of these detectors lye in the 900 ± 25 nm wavelength [2 – 6]. In certain applications (e.g, spectrometer detectors, flame sensors, satellite applications, and visible lasers detection), it is required to use detectors operate in the 400 – 700 nm wavelength (i.e, visible spectrum). In this range, conventional Si detectors with interference filters or IR-cutoff filters are used, these additions will rise the cost [4].

In the present work, p-n Si detectors were coated by a metal on the sensitive surface. This technique is based on the fact that most metals have good reflection in the IR region as compared with there reflection in the visible region. The used metal in this work was gold (Au).

2. Experimental Procedures

Single crystal (111) Si wafers of p-type conductivity, 3 Ω.cm resistivity and 500 ± 15 μm thick grown by 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 0.25 μm diamond paste. CP-4 etchant was used to remove native oxides [7], then the

* School of Applied Sciences/ University of Technology

https://doi.org/10.30684/etj.24.1B.6
2412-0758/University of Technology-Iraq, Baghdad, Iraq

wafer was thoroughly cleaned and degreased. The p-type silicon was doped with donor impurities (phosphor) by thermal diffusion to produce p-n junction Si detector. In this technique, the samples are immersed in $POCl_3$ solution and then are put into evacuated furnace (10^{-3} Torr) at 880^0 C for 8 min. After this process, the diffused samples were rinsed by HF acid for about 1 min to remove phosphor residuals from Si surface. High purity Au ultra-thin film was deposited on sensitive area of the detector (n-type) by thermal resistive technique. The thickness of this film was 30 nm. Ohmic contacts were made by depositing Al and Au electrodes on n-type and p-type of the detector respectively. Cross sectional view of the final detector is presented in Figure 1. 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 Au-metal thin film was measured with the help of spectrophotometer for samples prepared at glass substrates. Reverse I-V characteristics under illumination were characterized.

3. Results and Discussion

Optical transmittance of the Au thin film that was prepared on glass substrate 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. This result reflects that Au film should act as a good visible and UV filter. The figure shows that transmittance decreases to 3% at 1100 nm wavelength when the thickness is 30 nm, this indicates that Au film can be considered as ideal filter, particularly at this thickness.

Reverse current of uncoated and gold-coated detectors in the dark and illumination conditions is illustrated in Figures 3-a and 3-b. For the uncoated detector (Figure 3-a), it is noted that dark current increases with bias voltage shows soft break-down behavior. This behavior is not obeyed to the Schokley's diffusion model of p-n junction [8]. On the other side, the photocurrent in this figure shows significant increase as compared with dark current. After Au-deposition (Figure 3-b), no observed variation is registered on dark current but significant decreasing in photocurrent is observed.

Shown in Figure 4 is the spectral current responsivity (S) of Si detector before and after Au deposition. The figure demonstrates that peak response of this detector is shifted from 900 ± 25 nm wavelength (the peak response of uncoated detector) to 600 ± 25 nm wavelength (the peak response of Au-coated detector). Peak response is essentially related with the type of deposited film by the following equation [9]:

$$\lambda_P = \frac{4nt}{2k+1} \quad \text{............ (I)}$$

where n is refractive index of the deposited film, and k = (1, 2, ….).

The present shift in peak response that occurred after Au-deposition can be elucidated on the base of the optical properties of Au thin film that are explained elsewhere in Figure 2. The Au thin film has high optical reflectivity at near IR region as compared with its reflectivity at visible and UV regions [9, 10]. Therefore, Au thin film can act as a filter with narrow bandwidth about 200 nm, which calculated from FWHM (Full Width at Half Maximum).

Figure 5 depicts the quantum efficiency (Q.E) as a function of wavelength of uncoated and Au-coated Si detector where Q.E displays similar influence to that mentioned in the paragraph of responsivity.

4. Conclusions

On the base of the results that have mentioned before, one can conclude that Au 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. Au-coating of passivated Si detectors is currently under progress.

References

[1] F. Zhn & J. Singh, "Study of Optical Amorphous Silicon Solar Cells Using Admittance Source", J. Non-Crystalline Solids, 152 (1993) 75.

[2] M. A. Green, "Silicon Solar Cell, Advanced Principles and Practice", New South Wales, 1995, p. 15.

[3] J. Zhao, A. Wang, M. A. Green, "Double Layer Antireflection Coating for High Efficiency Passivated Emitter Silicon Solar Cell", IEEE Trans. on Electron. Dev., 4 (1994) 312.

[4] C. L. Joseph, "UV Technology Overviews", Internet Paper, File///C/Nadia/Space Detectors/ Joseph.htm(1-8)[8/21/2001].

[5] S. M. Sze, "Semiconductor Devices Physics and Technology", John Wiley and Sons, 1985, p. 282.

[6] A. Hadeed, "Efficiency Enhancement of Single Crystal Silicon p-n Junction Solar Cell", M.Sc. Thesis, UOT, 2000, p. 72.

[7] N. Ikarash, T. Akimoto, K. Ishidas, Phys. Rev. Lett., 72 (1994) 3198.

[8] S. M. Sze, "Physics of Semiconductor Devices", John Wiley and Sons, 1981, p. 90.

[9] L. E. Klyachrin, L. B. Lopatina, A. M. Malyarent, V. L. Sukanou, "Spectral Characteristics of Selective Photodetector for the Visible and UV Regions", Sov. Tech. Phys. Lett., 11 (1985) 146.

[10] F. Ready, "Industrial Applications of Laser", Academic Press, 1997.

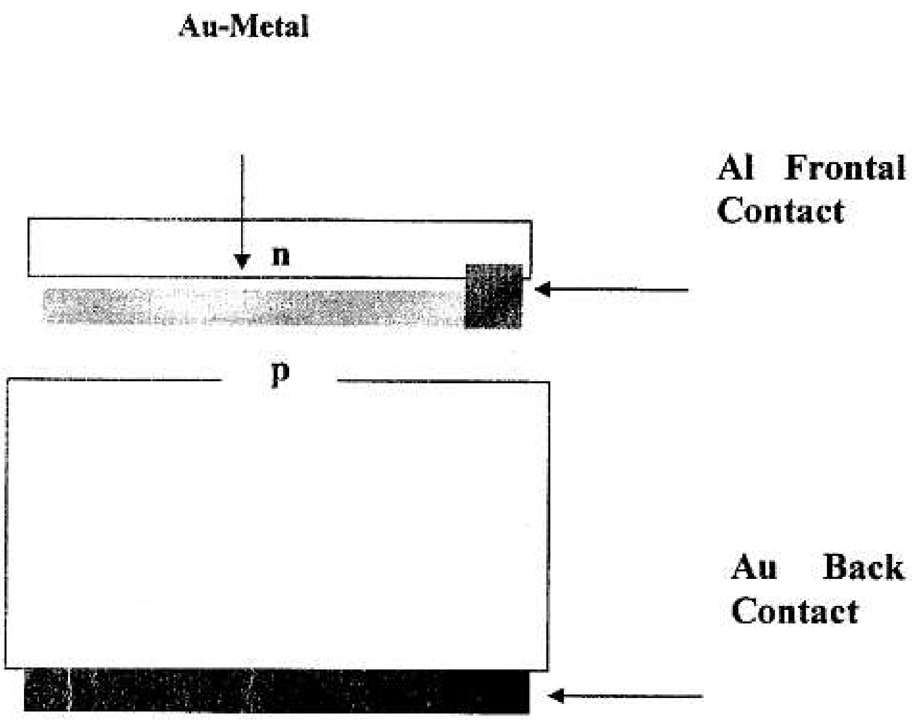

Figure 1. Sectional View of the Final Detector.

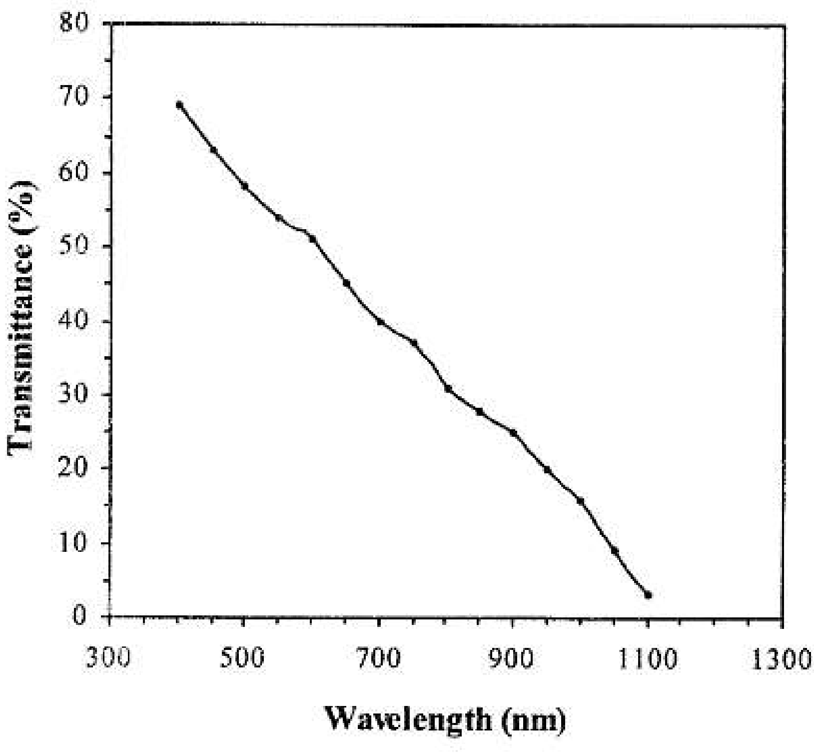

Figure 2. Spectral Transmittance of Au Thin Film.

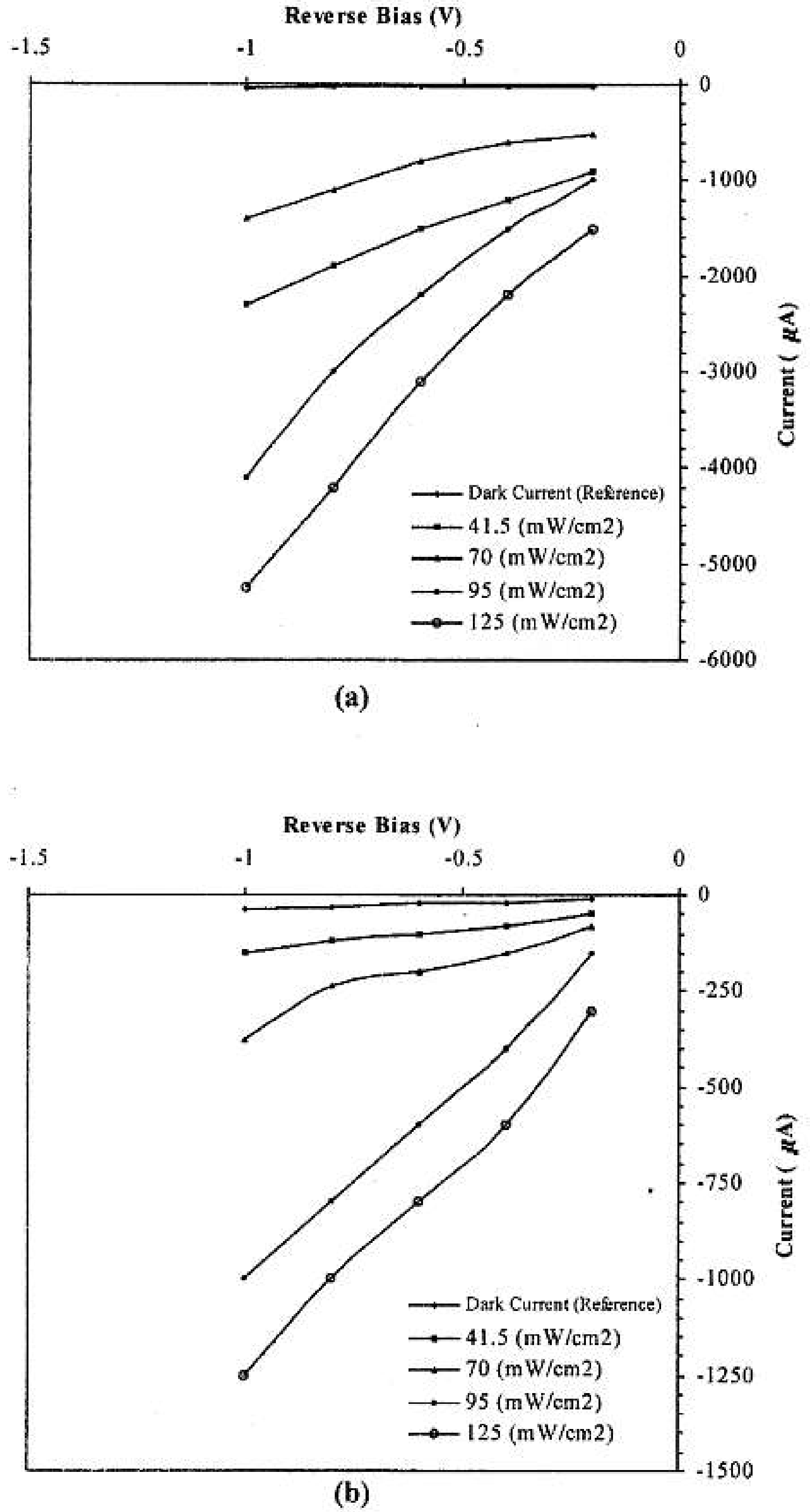

Figure 3. Photocurrent under reverse bias for uncoated (a), and Au-coated (b) detectors.

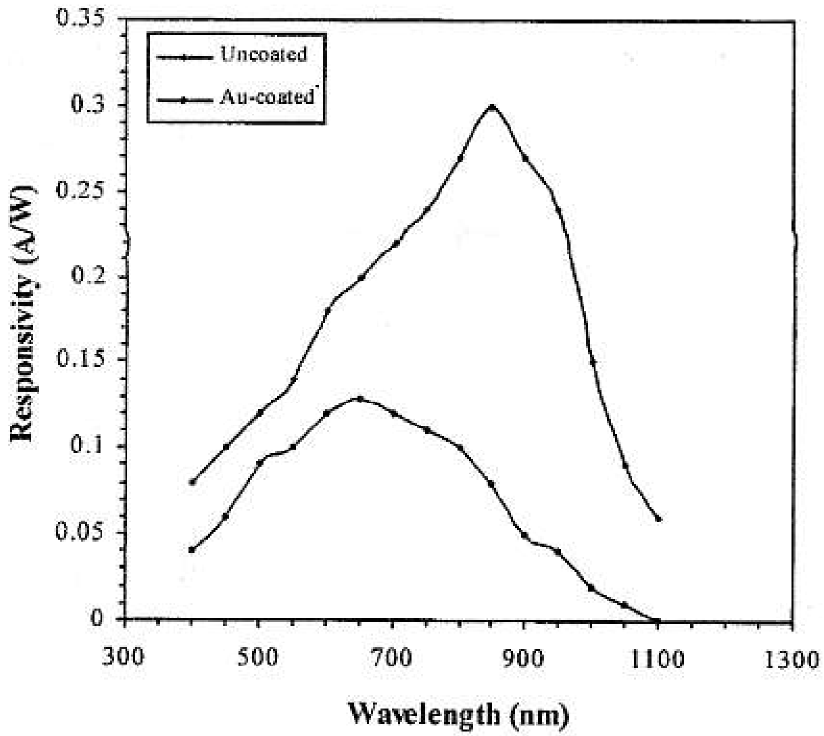

Figure 4. Spectral Responsivity of Si Photodetector before and after Au deposition.

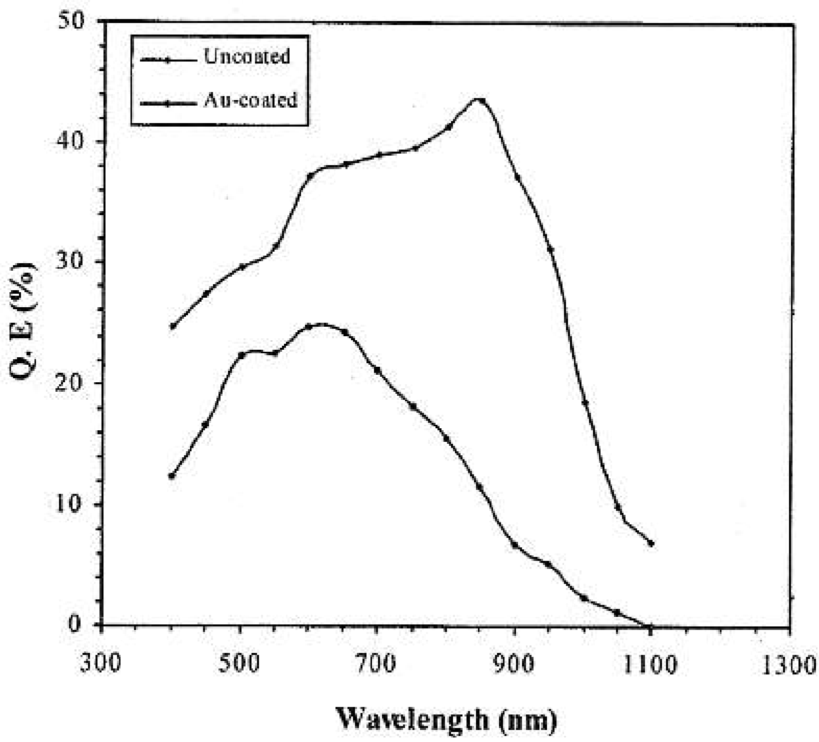

Figure 5. Quantum Efficiency of Si Photodetector before and after Au deposition.