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A FABRICATION CONDUCTING POLYMER-SILICON AS A TYPICAL UV-PHOTODETECTOR

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Abstract:

We study the fabrication and characterization of a p–n of polyaniline–silicon as a photo detector for the ultraviolet (UV) region. The hybrid heterojunction consists of films (300 nm thick) of polyaniline deposited on the top of a silicon wafer through the spin-coating method, wherein the backside of silicon and on top of polyaniline, aluminium and silver were respectively deposited by evaporation to make the electric contacts. The electrical characteristics of the devices present excellent reproducibility and a high rectification rate. In addition, the spectroscopic and the photon response analysis of the devices strongly indicates that it can be used as a broadband photon detector, with good sensitivity in the UV region 2.0–3.5 eV, where it presents enhanced sensitivity (≈200%) when compared to commercial silicon diodes such as the OPT 301 UV detector.

Keywords: Conducting Polyaniline, porous, n-silicon, UV detector.

1.INTRODUCTION

The development of ultraviolet (UV) photodetectors has been driven by more applications in the defence, commercial, and scientific fields. Commercial applications include industrial flame sensors, jet engine sensors, and consumer sensors for UV dosing. The interest in developing UV- detection is that it may result in a lower rate of false alarms than infrared- detection [1,2]. Detection of structure discharges of high-voltage transmission lines and arcs, inspection of UV leakage, monitoring UV curing and drying, controlling UV sterilization, and monitoring UV exposure in phototherapy are also among the applications. In addition to ozone, many other organic and inorganic compounds have absorption lines or fluorescence lines in the UV region of the spectrum. If several different cut-off wavelengths of UV photodetectors are used, it is possible to determine the presence of individual spectral lines and to attempt to identify the presence of specific chemicals. This potential for attaining compact solid-state fluorescence spectroscopy is one of the most exciting applications. Current UV technology uses wide-bandgap materials. These include zinc oxide and magnesium zinc oxide materials and Schottky-type TiO UV photodiodes. The distinctive aspect of III-nitrides is that their bandgaps are tunable within the UV range. Other novel approaches include the use of organics and phosphors. Silicon-detection utilises silicon carbide materials [3] and amorphous silicon alloys [2,3].

Another approach consists of using conducting polymer–silicon–based devices, which offer an opportunity for the development of silicon-based integrated technology [4–11]. Recently, we reported developing and applying high-quality heterojunctions consisting of silicon and conducting polyaniline. Those devices proved to be excellent for the detection of chemical gases as well as ionising radiation [12]. Since polyaniline presented an optical response in UV regions, in this paper, we decided to investigate the heterojunction response as a UV detector.

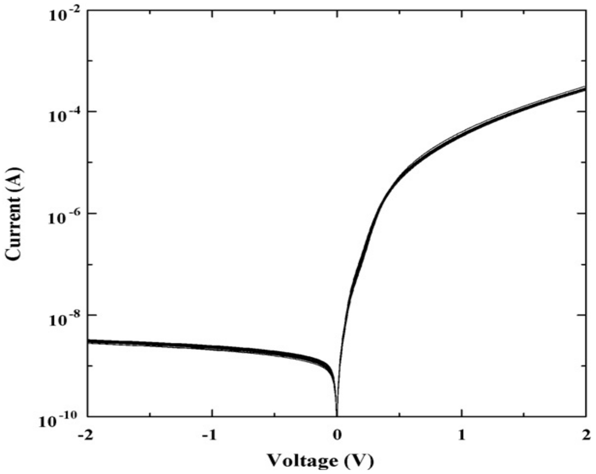
2. MATERIALS AND METHODS

Rectifying heterojunctions were formed by using the spin-coating method, where a highly uniform film of polyaniline of 300 nm was deposited onto a silicon (n-type, (1 0 0) orientation, 1 Ω cm resistivity. All procedures were done in a clean room (class 1000). Electronic grade chemicals were used in a modified RCA cleaning of silicon wafers [13], and for the polymer fabricate. Aniline was three times distillated at atmospheric pressure and stored in dark at low temperature. The structure devices were stored in vacuum before electrical characterization. The polyaniline synthesis was made following the procedure of MacDiarmid et al. [14]. The emeraldine salt (PANi ES), obtained was treated with 0.1 M NH_4OH to form emeraldine base (PANi EB) soluble in organic solvents. The solution obtained was used to form the polyaniline thin film over silicon substrate by spin coating. This film was treated with 1 M HCl solution to form the emeraldine salt (PANi ES). The thickness of polyaniline film was measured by ellipsometry. An evaporation vacuum deposited electrical contacts at a pressure below 10^{-6} Torr. A circular gate contact (area = 0.0036 cm^2) 450nm thick was obtained by silver evaporation on polyaniline film and a large area backside contact (50 nm thick) was obtained by aluminum evaporation. The backside contact was not optimized to be perfectly ohmic and has a low barrier height, resulting in increased series resistance. However, experience showed that this increased series resistance was acceptable at this stage of device development. Power loss is not necessarily a concern, since these devices are to be used as photo detector and this type of devices are usually polarized at low forward bias, so that the effect of an increased series resistance is not so important. The current–voltage (I V) characteristic curve of the device was measured using a low noise probe station and a (HP 4155A) Semiconductor Parameter Analyzer, and the photo response was measured using a high intensity xenon lamp and monochromator, with a reference calibrated UV enhanced silicon response photodetector.

3. RESULTS AND DISCUSSION

Fig. 1 shows the forward and reverse current–voltage characteristics of polyaniline–silicon heterojunction diodes. The reproducibility of characteristics is apparent. Measurements of the main heterojunction properties indicate high uniformity of electrical characteristics with a variation in the parameters of less than 5%. Average reverse current at —1.0 V is 3 nA and the rectification ratio is typically 60,000 at 1.0 V.

Fig. 1. Diagram view of the structure used for n-type Si formation.



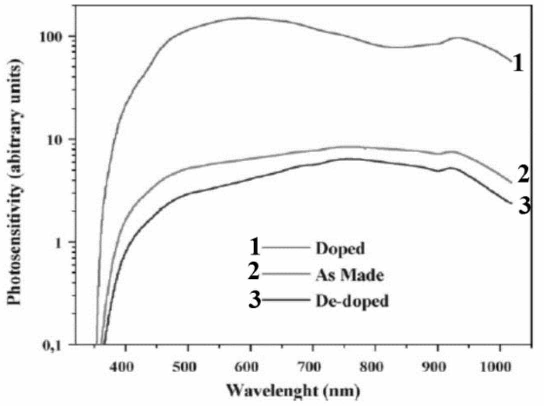


Fig. 2. Comparison between photosensitivity (photocurrent response) for the polyaniline–silicon diodes (a) undoped, (b) as made and (c) doped.

The achievement of such values on polymer based strongly indicate the high quality of the polymer film as well as the excellent characteristics of the silver–polyaniline and polyaniline–silicon interfaces. Preliminary results obtained by atomic force microscopy and spectroscopy (not shown) points to a surface roughness on the upside of the polymer film of less than 4 nm and an abrupt polyaniline–Si interface formation. Certainly, the care taken at the silicon substrate preparation and spin coating has contributed for the substantial improvements of the electrical properties.

Fig. 2 shows the spectral response for polyaniline–silicon diode as a function of the doping state of the polymer. In this paper we used different samples: (a) undoped, (b) as made and (c) doped. From these results we can see that the heterojunctions present a broad band response in the region 300-1000 nm, with a maximal response at 500 nm. Also, these results clearly show that in doped diode is more sensible than the undoped and the as made diode, meaning that for device development the doped polymer will be the most right. The comparison of the optical response in the spectral range from 300-1000 nm between the doped and a commercial photodiode OPT 301 is shown in Fig. 3, from these results we can observed that both diodes, presents a broad band response in this region, however the doped diode presents a better response in the UV region. A more detailed analysis can be performed in Fig. 4, where drawing the photo absorption efficiency ratio between the polyaniline–silicon diode and the commercial diode OPT 301. We can see that in the UV region the efficiency of the doped diode is almost 200% higher than the commercial type. This result strongly suggests that our structure PANi-Silicon has a strong potential to be used as a UV detector.

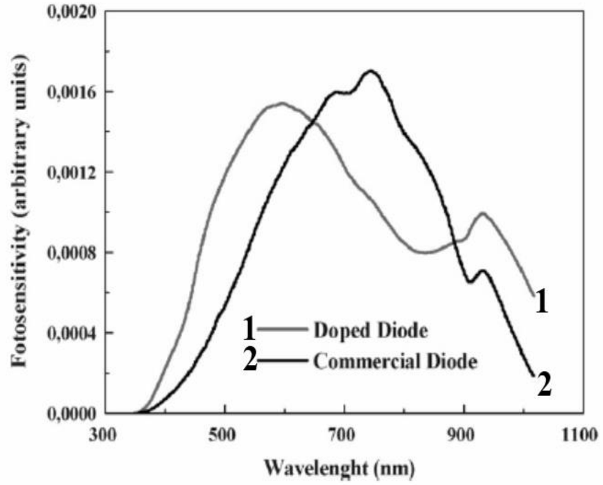


Fig. 3. Photo-current response of the PANi–Si doped diode and the commercial.

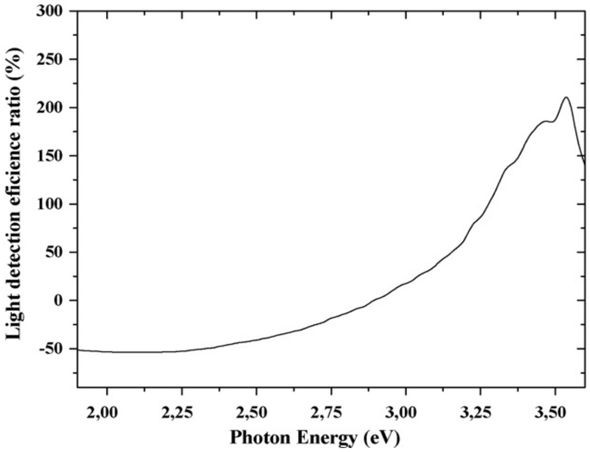


Fig. 4. Absorption efficiency between the PANi–Si diode and the commercial diode OPT 301.

4. CONCLUSION

A new way of fabricate to produce good quality conducting polyaniline and control its degree of doping was attained. The polymer, in the form of thin films (300 nm) was integrated in a microelectronic process to yield good quality polyaniline–silicon heterojunction diodes. The produced diodes are highly sensitive to light, in particular in the UV region of the spectra, indicating its potential to perform as a UV diode photodetector. A comparison with a widely known commercial homo-junction diode indicates that the polyaniline–silicon heterojunction diode, in doped polymer, presents an enhanced performance (~200%) in relation to the commercial diodes in certain regions of the UV spectra.

REFERENCES

1. M. Krause, M. Topic, H. Stiebig, H. Wagner, Phys. Stat. Sol. A 185 (2001) 121.
2. J.M. Pimbley, G.J. Michon, IEEE Trans. Electr. Dev. ED-34 (1987) 294.
3. D.M. Brown, E.T. Downey, M. Ghezzo, J.W. Kretchmer, R.J. Saia, Y.S. Liu, J.A. Edmond, G. Gati, J.M. Pimbley, W.E. Schneider, IEEE Trans. Electr. Dev. 40 (1993) 325.
4. P. Ball, Nature 409 (2001) 974.
5. L. Fletcher, P. Mitchell, Nat. Biotechnol. 20 (2002) 351.
6. M. Green, J. Zhao, A. Wang, P. Reece, G. Weedon, S. Harris, Nature 412 (2001) 805.
7. W. Ng, M.A. Lourenco, R.M. Gwilliam, S. Ledain, G. Shao, K.P. Homewood, Nature 410 (2001) 192.
8. European commission technology roadmap-optoelectronics interconnects for integrated circuits, Office for Official Publications of the European Communities, Luxemburg 1998.
9. M. Krause, M. Topic, H. Stiebig, H. Wagner, Phys. Stat. Sol. A 185 (2001) 121.

10. J.M. Pimbley, G.J. Michon, IEEE Trans. Electr. Dev. 34 (1987) 294.
11. J.M.G. Laranjeira, H.J. Khoury, W.M. de Azevedo, E.F. da Silva Jr., Appl. Surf. Sci. 190 (2002) 390.
12. J.M.G. Laranjeira, H.J. Khoury, W.M. de Azevedo, E.F. da Silva Jr., Phys. E 17 (2003) 666.
13. E.F. da Silva Jr., Y. Nishioka, T.P. Ma, IEEE Trans. Nucl. Sci. 34 (1987) 1190.
14. A.G. MacDiarmid, J.C. Chang, A.F. Richter, N.L.D. Somasiri, J. Epstein, in: L. Alcacer (Ed.), Conducting Polymers, Reidel, Holland, 1987, p. 105.