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Low Cost of Preparation of Infrared PbS Detector Using Copper Electrodes of PCB

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Abstract: Low cost of preparation of an infrared detector using copper electrodes layer from commercialized PCB (Printed Circuit Board) was prepared. The PbS deposition layer was used as an active material deposited on the substrate of the etched PCB using an evaporation technique in a few micrometers of layer thickness. Electrical property of various deposition widths was investigated from 1.0 to 4.0 mm. The detector's parameters of drop voltage and sensitivity have been calculated. From the experiment, it has been found the encouraging result that shows relatively good sensitivity of infrared detector (1 – 3 μm) beside any advantages of inexpensive and easy for preparation.

Keywords: Detector, Infrared, PCB, Photoconductivity, Lead sulfide.

1. Introduction

PbS or lead sulfide is a semiconductor material that is commonly used as an active material for infrared detectors particularly in a short-wavelength infrared region. This material is also used for other optical devices based on photoconductive phenomenon in which the conductivity will change when any light or electromagnetic radiation of appropriate wavelengths introduced. The energy received by this material will generate free electrons from valence band to conduction band that produces any electrical current in the material. PbS material has a narrow band gap (0.41 eV) and a strong quantum-size effect has been observed in nanocrystalline form [1 - 4]. With this energy gap it

allows to radiate the electromagnetic wave at a short-wavelength region (1-3 μm). PbS polycrystalline thin films was grown using a substrate colloidal coating chemical bath depositions to study its structure characterization [5]. For an application, PbS material has been used for a near-infrared photodetector in the form of colloidal quantum dots/organic hole conductor [6]. Also, it was studied their IR photoconductive properties in thin film form [7] as this property was also observed for ZnS compound [8].

Preparation of infrared detector using PbS thin film needs a long process of deposition for electrodes and active material of detector. The detector is based on the photoconductivity phenomenon when any infrared radiation received by the detector. By using a copper layer of commercialized PCB (Printed Circuit Board), process of device fabrication could be inexpensive and shorter that leads any advantages. In this paper we report a strategy to use a copper layer of PCB to prepare infrared detector using PbS deposition based on photoconductive phenomenon of detection technique that introduces low cost and simple in preparation.

2. Materials and Experimental

Thin film PbS deposition from a pure material of PbS (Tianjin JinSheng Hong Xiang Chemical Co., LTD., purity: 99.999 %) was prepared using an evaporation technique. During deposition, the evaporator has been performed for a vacuum pressure of 10^{-6} Torr. Meanwhile, the distance between the crucible of material and substrate was fixed at 40 cm. PbS deposition was deposited on an etched area of a copper layer of PCB of a few micrometers of thickness. The active area of detector prepared was of 2.0 mm × 15.0 mm. The PCB used was of a commercial one using an insulating fiber glass material as a substrate. This substrate material is very insulating that introduces very low electrical current leakage that could improve the performance of detector. A complete process includes masking has been done prior the PbS deposition by covering the electrode surface using unreacted of $CuSO_4$ material following the pattern of the design. To study the characteristic of detector, an infrared radiation source of a Tungsten lamp (100 W) was used that has been confirmed its wavelength radiation spectrum covers 1.0 - 2.9 μm using a calibrated infrared detector (Hamamatsu). The detector was covered with a black color of cloth material to introduce no visible light spectrum detected by the detector during measurement. The measurement was carried out under dark environment while voltage bias of 1.5 Volts was applied to the photoconductive measurement set up used for a detector as shown schematically in Fig. 1.

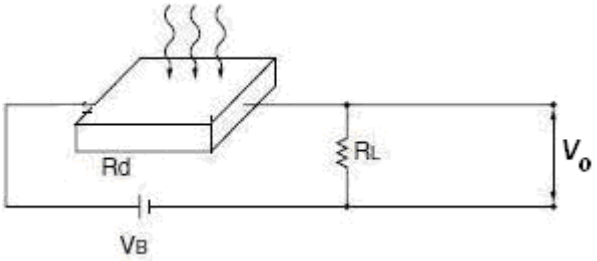

Fig. 1. Schematic diagram of a photoconductive measurement set up.

By referring to that figure, the output signal, V_O could be obtained by using the following equation.

$$V_O = \frac{R_L}{R_d + R_L}.V_B, \tag{1}$$

where, R_L, R_d, V_B are the load resistance, dark resistance and bias voltage, respectively. From the measurement obtained for the detector's resistance under dark and ambient environment, R_a, sensitivity of the detector, S could be calculated using the following equation.

$$S = \frac{R_d - R_a}{R_a} \tag{2}$$

3. Results and Discussion

The infrared detector prepared using copper electrodes from PCB is shown in Fig. 2 (top view). To introduce a convenient measurement, the electrode contact 1 and 2 were soldered with pins in the back side (not shown in this figure).

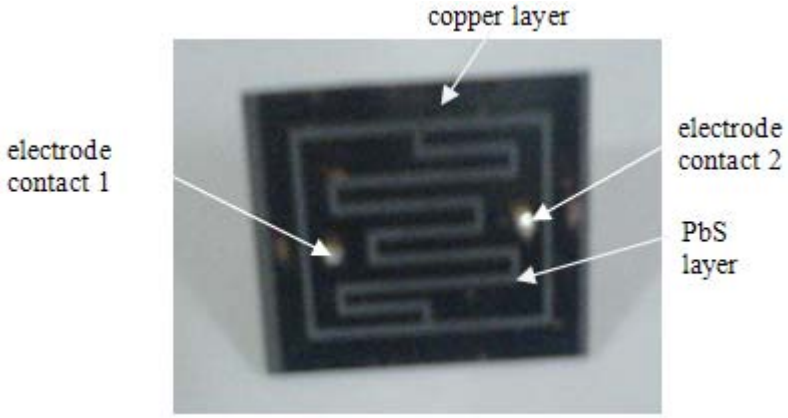

Fig. 2. Pictorial of a detector prepared using a PbS thin film (top view).

Initial experiment was done by observing the characteristic of IR radiation sources using Tungsten and Halogen lamps illuminated onto the calibrated IR detector. This was carried out by varying the optical power of sources and measuring the electrical current as the results are given in Fig. 3 for both light sources. From that figure, it was found that radiation produced by Tungsten lamp shows more linear curve characteristic over the optical power compare than that of the Halogen lamp that shows a non-linear curve. Therefore, this IR radiation source will be used for further characterization of PbS detector prepared using copper electrodes from PCB.

From the experiment, the drop voltage of detector has been calculated by using Eq. (2). From the result, the sensitivity of detector has been calculated as the result is given in Fig. 4 for a variation of distances between detector and infrared source from 20 to 80 cm. From that figure, the increase of distance is followed by the decrease of sensitivity. The curve is found linear that could be analysed further for a detector characteristic. From that linear curve, a slope of about - 0.6 has been found from the calculation that could be used to extrapolate the capability of detector. It is estimated that the detector could detect the distance of infrared spectrum source up to 2.20 m at room temperature. Experiment was also done at a distance of 10 cm that shows anomaly of the data point collected as at this distance, thermal effect is assumed to occur in the detector after 2 minutes (not presented in this paper). At sensitivity observed more than 100 %, the measurement was assumed to saturate due to close distance between IR source and detector.

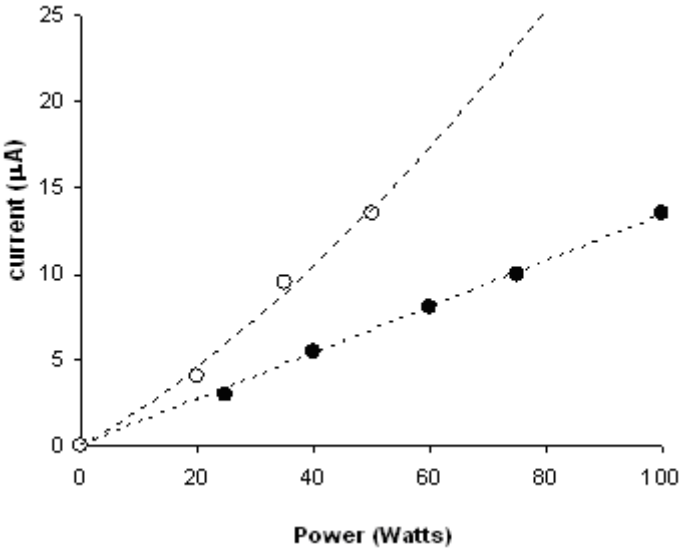

Fig. 3. Characteristic of IR radiation sources using Tungsten lamp (filled circle) and Halogen lamp (open circle) observed for their electrical current measured using a calibrated commercial detector.

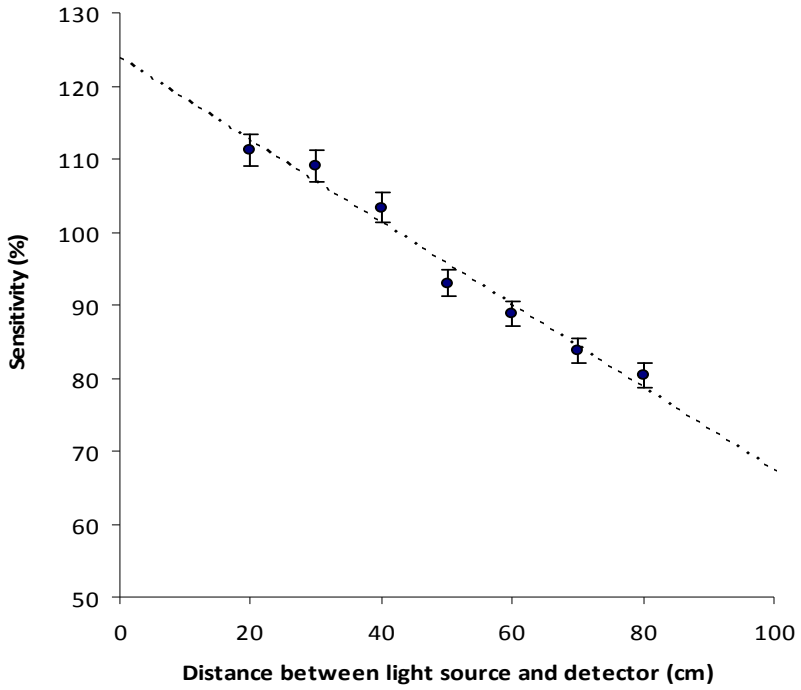

Fig. 4. Sensitivity calculated of the detector by varying the distance between source and detector.

PbS layer deposition was prepared by varying the widths of layer deposition from 1.0 to 4.0 mm as denoted in Fig. 5 with D31, D32, D33, and D34 for layer widths of 1.0, 2.0, 3.0, and 4.0 mm, respectively. From that figure, the dark areas show the surface of PbS depositions, meanwhile the light / grey areas show top view of the copper layer used as electrodes. This measurement was done to investigate the effect of width layer deposition of PbS respects to the detector sensitivity.

Measurement of electrical resistance has been done to various widths and the results are given in Table 1. From that table it is shown that the increase of layer width is followed by the increase of resistance. For sample D33, the infinity resistance found is due to poor preparation. The detector's

resistance has been measured in the ambient (environment light introduced) and found the resistanec is changed to the lower value compare than that of the measurement done in the dark room. This phenomenon could be explained that in the ambient environment, the appropriate energies received by the PbS material generates the electrical current that lead the decrease of the electrical resistance. This free electron generation does not occur in the dark room measurement.

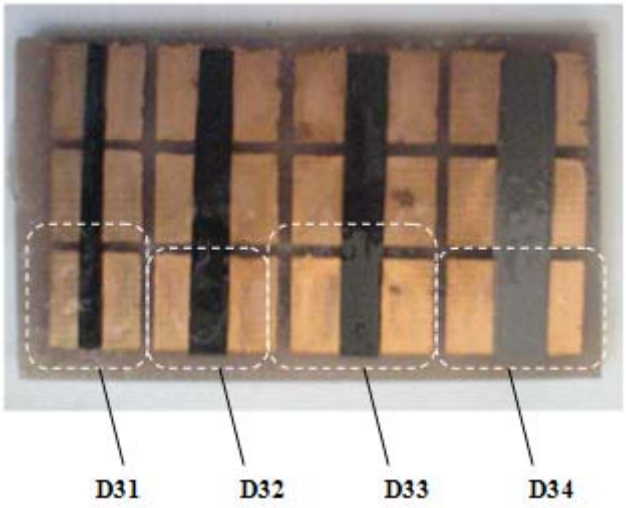

Fig. 5. Pictorial of PbS deposition of IR detector structures using copper electrodes for various widths of PbS layer deposition.

Table 1. Electrical resistances measured for various widths of PbS layer deposition.

Sample	Layer width (mm)	Resistance measured in dark room, (MΩ)	Resistance measured in ambient, (MΩ)
D31	1.0	0.479	0.368
D32	2.0	1.640	1.050
D33	3.0	∞	∞
D34	4.0	19.400	13.100

A measurement was done to the PbS thin film deposition using copper electrodes for a deposition layer width of 1 mm. As the PbS material is sensitive to a short wavelength region of infrared spectrum (about 1 – 3 μm), the result shows that the increase of load resistance (due to the decrease of radiation intensities received by the detector) followed by the increase exponentially (filled-circle data points) of the output signals measured as given in Fig. 6. This change could be used to investigate the drop voltage characteristic as shown in the curve (open circle data points) corresponds to the response of detector. As the infrared radiation intensities reduced (increase of R_L), this leads to the decrease of drop voltage rapidly and then decrease moderately. This drop phenomenon corresponds to the relatively fast response of detector respects to the change of radiation intensities.

For a film deposition with a layer width of 4.0 mm, the measurement was done as the result is given in Fig. 7. By comparing those two different widths of deposition layer, it shows that for layer width of 4.0 mm, the drop voltage is greater compare than that of the width of 1.0 mm. This phenomenon is considered due to a wider active area of PbS material that introduces more sensitive response respects to the radiation intensities.

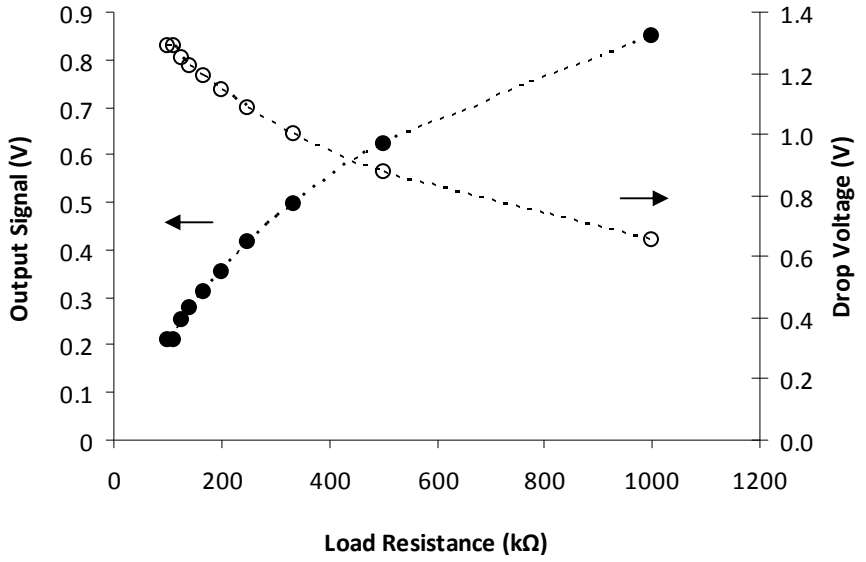

Fig. 6. Output voltage and drop voltage obtained from the PbS detector for 1 mm width of layer deposition.

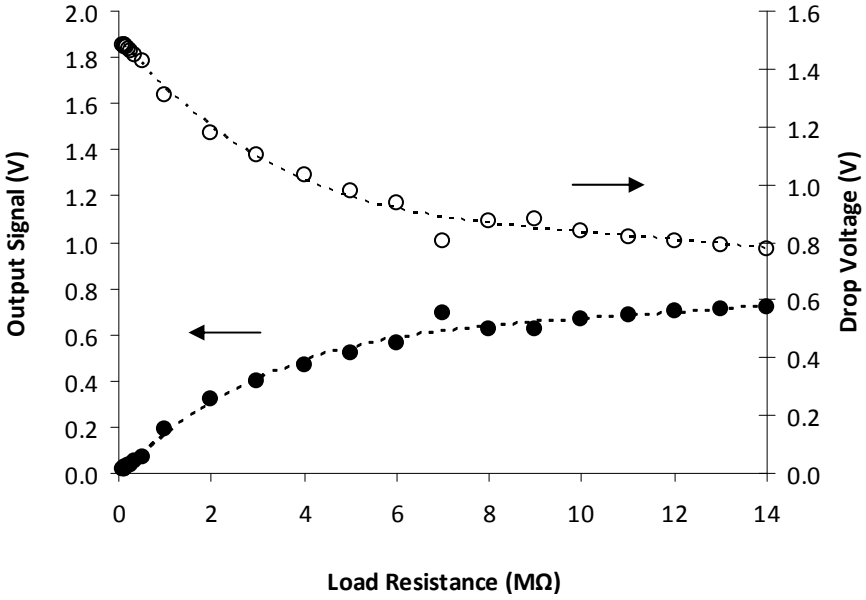

Fig. 7. Output voltage and drop voltage obtained from the PbS detector for 4 mm width of layer deposition.

4. Conclusion

Infrared detector of a short-wavelength spectrum (1- 3 μm) has been prepared successfully using an active material of PbS layer deposition using copper layer of PCB as electrodes. Photoconductive phenomenon has been observed from the detector structure. Various deposition widths of PbS material have been measured their resistances by illuminating infrared radiation, and it was found that wider area of layer deposition is followed by the increase of drop voltage associate with a greater sensitivity of detector. Good sensitivity of about 80 % was obtained from the detector at a distance of 80 cm that shows good percentage of a self-design of infrared detector. Use of copper electrode from a commercial PCB introduces low cost and simple preparation for the detector. This technique could be potentially applied for wide applications involved infrared spectrum detection.

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References

[1]. Z. Wang, S. Qu, X. Zeng, J. Liu., C. Zhang, M. Shi, F. Tan, and Z. Wang, The synthesis of MDMO-PPV capped PbS nanorods and their application in solar cells, *Current Applied Physics,* 9, 2009, pp. 1175-1179.

[2]. R. R. Hawaldar, K. G. Kanade, K. R. Patil, S. D. Sathaye, U. P. Mulik, and D. P. Amalnerkar, Self-assembly of nanostructured PbS for solar photovoltaic applications, *Materials Chemistry and Physics,* 91, 2005, pp. 447-453.

[3]. R. K. Joshi, A. Kanjilal, and H. K. Sehgal, Solution grown PbS nanoparticle films, *Applied Surface Science,* 221, 2004, pp. 43-47.

[4]. S. Jana, R. Thapa, R. Maity, and K. K. Chattopadhyay, Optical and dielectric properties of PVA capped nanocrystalline PbS thin films synthesized by chemical bath deposition, *Physica E: Low-dimensional Systems and Nanostructures,* 40, 2008, pp. 3121-3126.

[5]. F. A. Fernández-Lima, Y. González-Alfaro, E. M. Larramendi, H. D. Fonseca Filho, M. E. H. Maia da Costa, F. L. Freire Jr., R. Prioli, R. R. de Avillez, and E. F. da Silveira, O. Calzadilla, O. de Meloc, E. Pedrero, and E. Hernández, Structural characterization of chemically deposited PbS thin films, *Materials Science and Engineering, B,* 136, 2007, pp. 187–192.

[6]. S. H. Im, J. A. Chang, S. W. Kim, S-W. Kim, and S. I. Seok, Near-infrared photodetection based on PbS colloidal quantum dots/organic hole conductor, *Organic Electronics,* 11, 2010, pp. 696–699.

[7]. E. Pentia, L. Pintilie, I. Matei, T. Botila, and I. Pintilie, Combined chemical–physical methods for enhancing IR photoconductive properties of PbS thin films, *Infrared Physics & Technology,* 44, 2003, pp. 207–211.

[8]. H. Soetedjo and G. S. Prabowo, Photoconductive Phenomenon Observed from ZnS Layer Deposition for a Potential of IR Sensor Applications, *Sensors & Transducers,* 123, 12, 2010, pp. 100-105.

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- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors interfaces, buses and networks;
- Signal processing;
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- Nanosensors;
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