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Investigation of New Organic Photocathodes in Vacuum for Position Sensitive Gaseous Detectors

A.KhaliqueRajpar [1*], A.H Moghal[1], I.A Ismaili[2], J.V.Grazeulvacious[3], Fredrick C.Krebs[4], B.A Laghari[1], IftekharAhmed [1], Imran Ali Halepoto[1].

[1]Detector development Laboratory Institute of Physics University of Sindh Jamshoro Pakistan, [2]Institute of information technology university of Sindh Jamshoro Pakistan , [3]Department of Organic Technology Kaunas University of technology, Lithuania, [4]The Danish Polymer Centre Risø National Laboratory Denmark.*
[1]Corresponding Author: E-mail arajper1141@yahoo.com Cell: (+92) 300 3288486*

Abstract: *Position sensitive gaseous detectors with reflective photocathodes provide an attractive solution for photon localization over very large sensitive areas, under intense magnetic fields mainly due to their ease of construction. We report Quantum efficiency measurement of two new organic semiconductor photocathodes PEDOT/PSS and TECEB in spectral region 190-250nm, which are proposed for use in photosensitive gaseous detectors. Photocathodes were prepared by using resistive thermal vacuum evaporation technique. QE were measured in vacuum at about 10^{-4}Torr and both the photocathodes exhibit non-negligible quantum efficiency up to 230nm.*

Keywords: *Position sensitive gaseous detectors, Photon detection, Solid Scintillator Proportional Counter (SSPC), Reflective Photocathodes, Gas electron multiplier (GEM).*

I. Introduction

Position sensitive gaseous detectors with solid photocathodes are of great interest in the field of ultraviolet and visible photon detection [1]. These devices have been investigated with different geometries combined with solid photocathodes to achieve optimal results in terms of single photon detection, having large sensitive area, and compatible with high magnetic field. These designs include Multi Wire Proportional Counter (MWPC)[2], Solid Scintillator Proportional Counter (SSPC)[3], Gaseous Electron Multiplier[4] and its derivatives[5-8]. These modern devices are still under investigation for their potential use. In various fields, these devices have been utilized for study of scintillators, medical imaging, plasma diagnostic [9], astrophysics and particle physics [2].

A number of low ionization potential liquid and solid materials as photocathodes have been investigated for their quantum efficiency properties use in position sensitive gaseous detectors for detection of ultra violet and visible photons detection[1]. In vapor phase, successfully used photosensitive materials were EF (IP= 6.08eV)[3], TEA (IP= 7.8 eV) and TMAE (IP= 5.28 eV)[10]. Best quantum efficiency results were obtained for TMAE; therefore, it was employed in alarge number of experiments[11-14]. A major drawback of TMAE isdifficult to handle it because it was reactive to Oxygen and to other materials [3] used in detector fabrication and its read-out electronics [15]. Amongst solid phase UV photosensitive materials best known CsIreceived attention because it is solid at room temperature and can be handled for a short exposure time in air[16]. Although, its QE is lower than TMAE by a factor of 2[17], its QE decreases under exposure to humidity, intense photon flux and ion bombardment at photocathode surface[18,19] it hasbeen utilized in a variety of experiments[20]. The ageing properties of CsI [21] photocathodes allow us to continue our search for locating new low IP compounds having better ageing properties as compared to CsI.

In this context the properties of 1,3,5-Tris(2-(9-ethylcarbazyl-3)ethylene)benzene (TECEB) Poly(3,4-ethylendioxythiophene)-poly(styrenesulfonate) (PEDOT/PSS) allow us to investigate their QE.

II. Properties of Compounds

2.2 Properties of TECEB

TECEB [empirical formula:$C_{54}H_{44}N_3$] with work function 5.2 eV, is a Solid yellow powder. It was purchased from sigma-Aldrich chemical Incorporation LLC and used as it is. The structure of TECEB is illustrated in fig.1.Its molecular weight is 735.96 gm/mol soluble in organic solvents such as chloroform, tetrahydrofuran (THF) etc, morphologically and thermally stable up to 313°C [22].

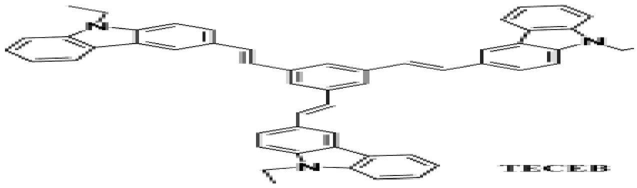

Fig.1 The structure of TECEB

2.2 Properties of PEDOT/PSS

PEDOT/PSS is a polymer blend with work function 5.20 eV [23], appears dark blue in color. It was also purchased from sigma Aldrich chemical corporation LLC and used as it is. The structure of PEDOT/PSS is shown in fig.2. Though it is hygroscopic and air sensitive but can be handled in air safely for few hours [24, 25].

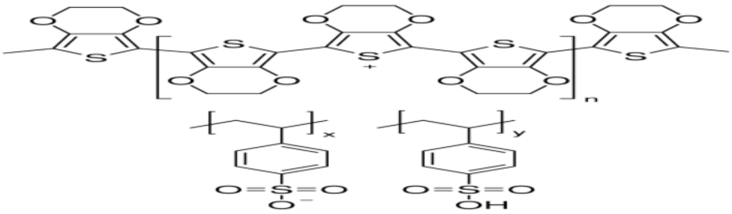

Fig.2. The structure of PEDOT/PSS

III. Experimental Techniques

In this work, we have used DC current measurement technique for QE studies of photocathodes under vacuum. Experimental setup comprised of a test detector, a double beam spectrophotometer as mono chromatic UV photon source having sample and reference beams (SHIMADZU UV 1601), a photodiode worked as reference detector (HAMAMATZU Photodiode No. S1723 – 05), vacuum system(BOC EDWARDS), for test detector evacuation up to 10^{-4} Torr,electrometers (KEITHLEY 6517A) and a vacuum evaporator (EDWARDS Auto 306)vacuum system and thickness monitor SIGMA SQM 160 for layer thickness measurement. Experimental setup is schematically shown in fig.3.

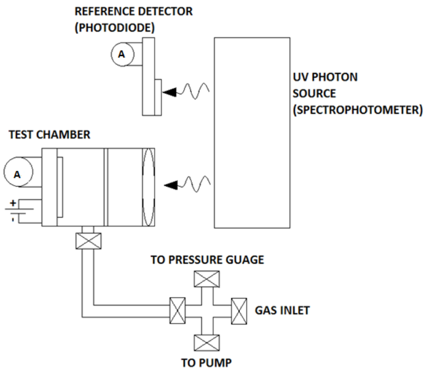

Fig.3. Schematic diagram of the experimental setup

Initially , the test detector was calibrated by measuring the QE of bare copper substrate and 545 nm thick vacuum evaporated CsI photocathode and found reproduce able results of both the substrates which are in great agreement with results available [26, 27](See fig.4 and fig.5).

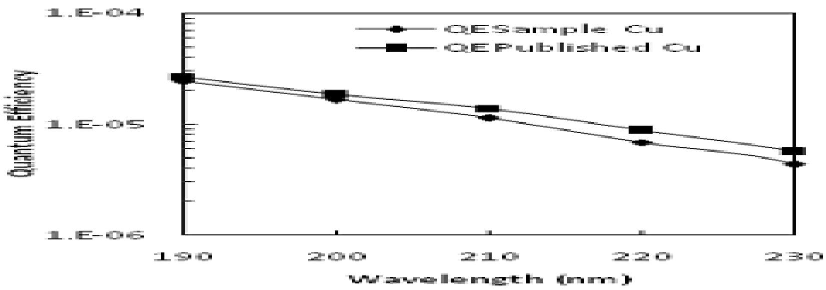

Fig.4. Comparison of QE of copper sample diamonds copper published [26]

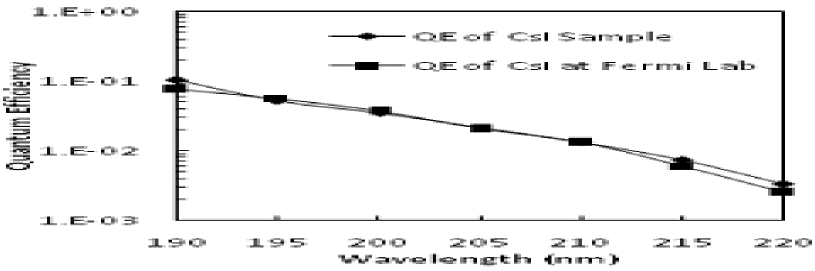

Fig.5. Comparison of QE of CsI sample diamonds and CsI FERMI Lab squares [27]

IV. Results and Discussion:

TECEB photocathodes were prepared using vacuum evaporation technique in Edwards Auto 306 coating system at about 10^{-6}Torr, while PEDOT/PSS photocathodes were prepared using joule heater. A time of about three minutes was required for transportation of the photocathode to the prototype test detector.The prepared photocathodes were scanned in spectral sensitivity region 190-250nm. Both the photocathodes TECEB and PEDOT/PSS exhibited non-negligible QE up to 230nm.QE results of TECEB and PEDOT/PSS photocathodes in comparison with Cu photocathode are illustrated in fig.6 and fig.7 respectively, photosensitive layer effect over metal is obvious in both cases. Photocathodes with different thickness were prepared but no notice able change in QE was observed; this showed that thickness of photocathode layer has no effect on the QE of the photosensitive materials under investigation.

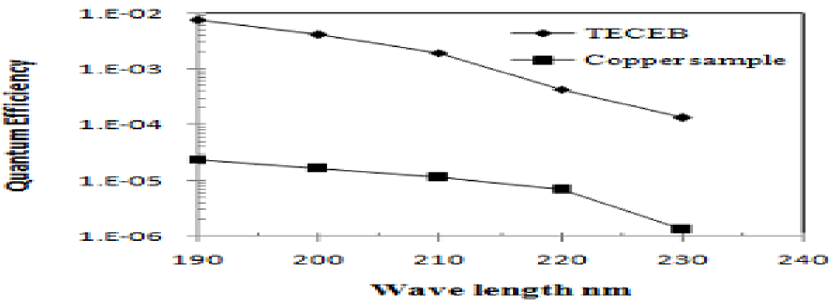

Fig.6 QE comparison of TECEB diamonds and copper sample squares.

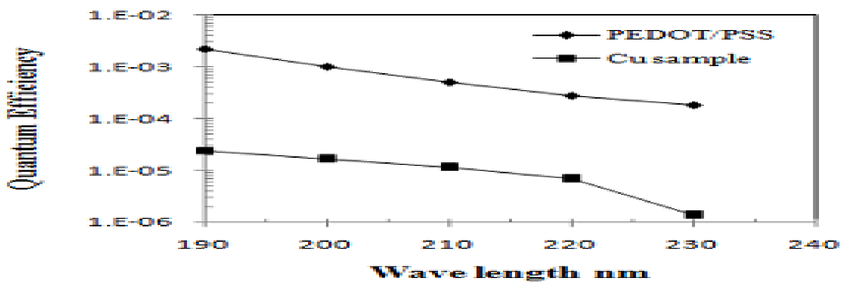

Fig.7 QE comparison of PEDOT/PSS diamonds with copper sample squares.

Results were also compared with CsI, the most popular solid photocathode used so far in gaseous detectors employed in high energy physics experiments, for detection of UV photons. Fig.8 and fig.9 show the QE comparison of TECEB and PEDOT/PSS with CsI sample respectively. Two photocathodes, TECEB and CsI were about 500nm thick, as their thickness was monitored using a standard thickness monitor of Sigma instruments (SQM-160) provided with Edwards Auto 306 coating system where as thickness of PEDOT/PSS is subject to exposure time.

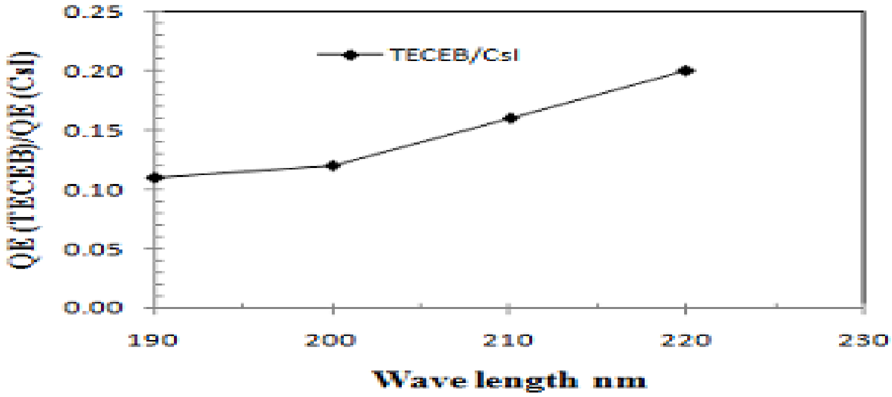

Fig. 8 Comparison of QE of TECEB with CsI sample for spectral region 190-220nm

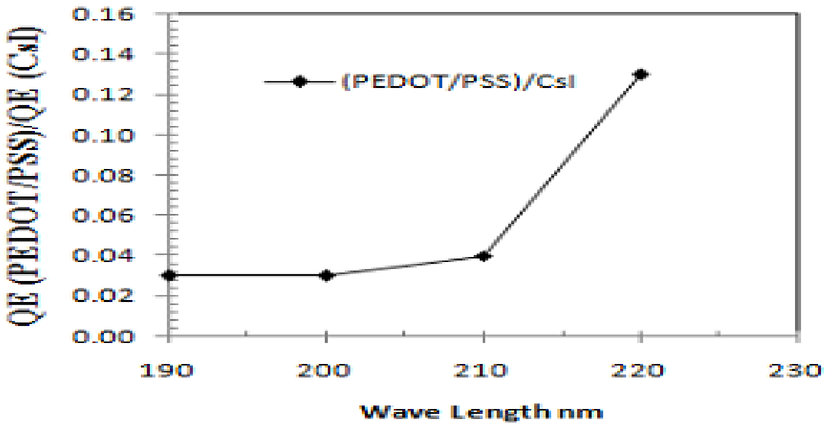

Fig. 9 Comparison of QE of PEDOT/PSS with CsI sample for spectral region 190-220nm

It is obvious from fig.8 and fig. 9 that the QE of TECEB and PEDOT/PSS relative CsI for wavelength 190nm are 11% and 3% respectively.

V. Conclusion

Preliminary QE measurement results are inspiring. TECEB have a QE in the range 11% to 20% of the CsI QE between 190 and 220nm, while PEDOT/PSS have a QE in the range 3% to 13% of the CsI QE in the same spectral range. Since TECEB is solid at room temperature, can suit to build large surface area photosensitive gaseous detectors as an alternative to CsI and should be studied in more details.

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