



Quantum Efficiency of P3HT a new Air-Stable Photocathode for use in Gaseous UV Photon Detectors

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Abstract: We present the QE results of a new air stable organic semiconductor UV photocathode P3HT. QE was measured as a function of wavelength in spectral range 190-250nm. It shows nonnegligible QE near 230nm. Though QE is low as compared to CsI but due to ease of preparation of large area photocathodes and air stability it may replace CsI in some experiments where photon flux is high.

Keywords: (Photon detectors, Photocathodes, GEM (Gas Electron Multiplier) and Thick GEM)

1. INTRODUCTION

Gas filled large area UV photon detectors coupled with air stable solid photocathodes, operating under room conditions, have wide range of applications e.g., in high energy physics, detection of fast component of BaF₂ or liquid xenon calorimetry, and also in medical imaging (DiMauro, *et al.*, 1999). (Ketzer, *et al.*, 2001). (Breskin, *et al.*, 2000). (Del Guerra, *et al.*, 2003). These Detectors have several advantages such as they are position sensitive, fast response and compatible with magnetic fields. First generation of these detectors comprised of Multi wire Proportional Chambers (MWPC) combined with photosensitive Vapours. A large number of photosensitive gaseous were investigated for QE measurement long time ago, among which Tetrakis Dimethylamine (TMAE), a low photo-ionization threshold vapour, is known for its high QE. It allowed the use of Quartz window. It has quantum efficiency of about 30 to 40% in spectral range 160-190 nm and minimum about 10% at 210nm (Sêguinot, *et al.*, 1990). TMAE is used in a number of experiments such as the largest ever built RICH Detectors: (OMEGA RICH (Siebert, *et al.*, 1994), DELPHI RICH (Müller, *et al.*, 1996). TPC RICH (Apsimon, *et al.*, 1986). as well as SLD CRID (Va'Vra.J., and Collaboration, 1999). Since TMAE has low vapour pressure at room temperature so, it requires few cm long gap for conversion of photons. On the other hand, detector has to be operated at elevated temperature (40°-50°) which can cause severe damage to materials used in detector construction. Furthermore, it is air sensitive and extremely chemically reactive. Therefore, imposes

severe restriction on the choice of materials for detector and tolerance of gas impurities. The second generation, photosensitive Vapours were replaced by solid photoconverters. Solid phase reflective photocathodes provide better time resolution because electrons are emitted from a well-defined solid surface. CsI has highest QE among all the solid photo converters investigated for QE measurement in the past. It is used in combination with MWPCs in a number of experiments (Dalla Torre, 2011). and still being used in several experiments COMPASS (Tessarotto, *et al.*, 2014). at CERN, HADES (Braem, *et al.*, 2003). at GSI, STAR (Zeitelhack, *et al.*, 1999). at HALL-A, NA 44 (Fabjan, *et al.*, 1995). at CERN and etc. however it is hygroscopic and gets degraded when exposed to humid air for short time (Anderson, *et al.*, 1992). (Dangendorf, *et al.*, 1990). (Dutta, and Singh, 2012). (Heroux, *et al.*, 1966). (Simons, *et al.*, 1985). (Simons, *et al.*, 1987). CsI also has been investigated for detailed ageing studies (Hoedlmoser, *et al.*, 2007). and it is reported that after collection of few mC/cm² charge, there is a severe decrease in QE. Ageing is due to two reasons. Firstly, due to high photo flux and secondly due to ion back flow (IBF) towards the photocathode, the ions that are created during avalanche process. The third generation begun with invention of gas electron multipliers (GEM) by Sauli in 1996. Semitransparent photocathode was used in first version (Buzulutskov, *et al.*, 2000). afterwards, multi GEM structure with CsI coated on the top of first GEM was developed and is successfully used in PHENIX-HBD (Anderson, *et al.*, 2011). GEM based photon detectors have fast response

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with time resolution $<2\text{ns}$ (Mörmann, *et. al.*, 2003). GEM can protect CsI photocathode from positive ion bombardment and improve the ageing. Multi-GEM structures with semi-transparent (Bondar, *et. al.*, 2003). or reflective (Mörmann, *et. al.*, 2004). (Tessarotto, 2018). can reduce IBF from 2% to 10% respectively. Without modifying the total gain, IBF less than 1% is obtained at the cost of low value of electric field (Breskin, *et. al.*, 2002). this condition is not suitable for reflective photocathodes because at CsI surface photoelectron extraction efficiency is too low at low values of electric field. A novel GEM structure, the micro hole and strip plate (MHSP) were used to improve multiplication or to suppress IBF to 3×10^{-4} at gain of 10^5 in Ar/CH_4 with multiple MHSPs in reverse biased mode (Lyashenko, *et. al.*, 2007). Specially designed MHSP called COBRA (Lyashenko, *et. al.*, 2007). have been used to achieve extremely low IBF (less than 10^{-3}). Although, a gain of 10^5 is achievable in laboratory conditions with multi GEM structures reduces below or around 10^4 in large tracking experiments. The fourth generation comprised of Thick-GEMs (THGEMs) derived from GEM design. Material budget for THGEMs is large as compared to typical GEM. Furthermore, space resolution is also modest about 1mm (Cortesi, *et. al.*, 2007). However, achievable gains are large and electron transport and collection are effective. The THCOBRA and the Blind-THGEM also called WELL, are the analog of the GEM COBRA. Typical multilayer THGEM with CsI coated on the upper surface of the first THGEM (Alexeev, *et. al.*, 2013) have been constructed and operated using Ar-based and Ne- based gas mixtures. An effective gas gain of the order of 10^5 - 10^6 (Alexeev, *et. al.*, 2010). and a time resolution of 10ns (Alexeev, *et. al.*, 2012) have been achieved with similar triple THGEMs in laboratory. A study of IBF with typical triple THGEM reaches 30% (Alexeev, *et. al.*, 2013). It can be concluded from above facts that use of GEM and other GEM-based technologies to protect CsI from IBF is departure from simple parallel plate geometry to sophisticated technology. It is departure from the main goal of cost-effective large area, air stable UV photon detectors with room condition operation. Therefore, there is still need to search for new air stable UV sensitive Solid materials that may possibly replace CsI. In this context, we present systemic study of QE of P3HT, a novel UV sensitive organic semiconductor.

2. EXPERIMENTAL PROCEDURE

Photocathodes were prepared from the solutions of P3HT in chloroform with different concentration using dissolving in solvent technique. For preparation of photosensitive films of different thickness, P3HT was dissolved in 2, 1.5 1 and 0.5ml of chloroform respectively. The solution was put on the center of the substrate strip prepared from a piece of PCB, drop by

drop and allowed to spread on entire surface and evaporate leaving a $2.3\text{cm} \times 3\text{mm}$ for electrical contact. After evaporation of solvent a layer of about few μm thickness appeared on the surface of the substrate. In order to clean, substrates were boiled in Decon 90, washed with double distilled water and dried in dust free environment. The prepared PCs were loaded in a small prototype test detector that was operated in DC current mode. The experimental set up was same as described in (Laghari, *et. al.*, 2014). Keithley electrometers (model 6517 A) were used to measure current resulting from test detector and a $10 \times 10 \text{ mm}^2$ reverse-biased silicon photodiode (Hamamatsu S 1723-05). A guard ring arrangement was used to reduce the leakage current. Subtraction of measurements with and without the incident beam were used to eliminate photodiode reverse leakage currents. For measurements in vacuum a bias of 25 V was sufficient. However, in CH_4 the maximum safe electrometer offset voltage of 250V was used, corresponding to an electric field of about 100 V cm^{-1} at the photocathode surface. Still a slight increase in photocurrent was noticed in CH_4 at this field. Therefore, slightly higher QEs may be obtained if larger extraction fields are employed. The maximum reflective QE observed in CH_4 was 80% of that of vacuum value.

3. RESULTS AND DISCUSSION

1) General properties of P3HT

It is a polymer category organic p-type semiconductor. It is air stable and thermally stable, chloroform soluble crystalline solid photosensitive material with ionization potential value 4.7 eV and melting point 238°C (Online catalogueSigma Aldrich GmbH).

It was purchased from Sigma Aldrich GmbH and used as it is. The chemical structure of the substance is shown in (Fig.1).

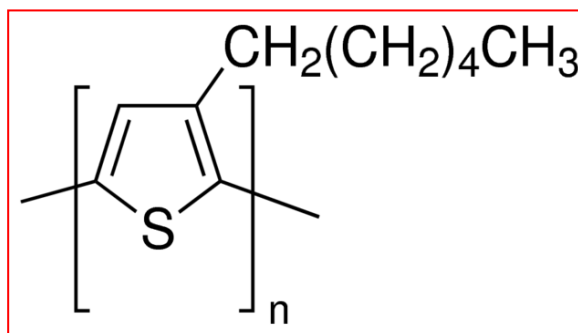


Fig.1 Chemical Structure of P3HT

2) QE of P3HT Photocathode

(Fig. 2). shows QE result of P3HT photocathode prepared using dissolving in solvent technique. Four different samples were prepared and tested. Maximum QE was achieved with PC developed from a solution of

1mg P3HT in 1.5ml chloroform. The QE was measured as a function of incident photon wavelength. The highest QE observed was only 0.1% at 190nm and shows cut off near 240nm.

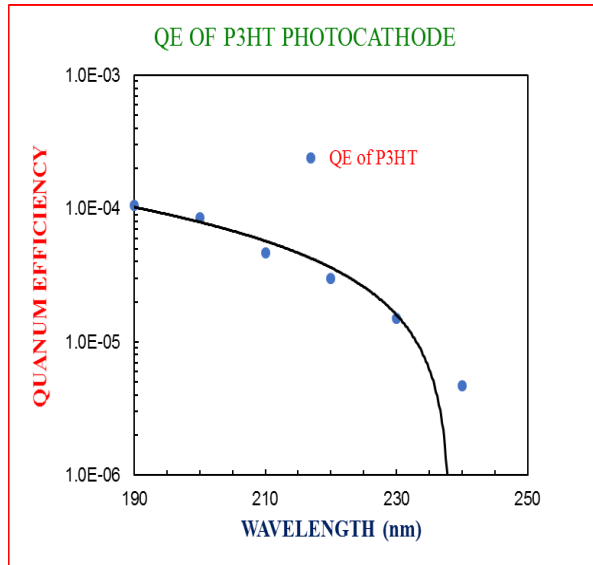


Fig.2 QE of P3HT using dissolving in solvent technique

The QE of P3HT prepared using dissolving in solvent technique was then compared with QE of Vacuum evaporated bare copper cathode in order to observe layer effects the results are shown in (Fig. 3).

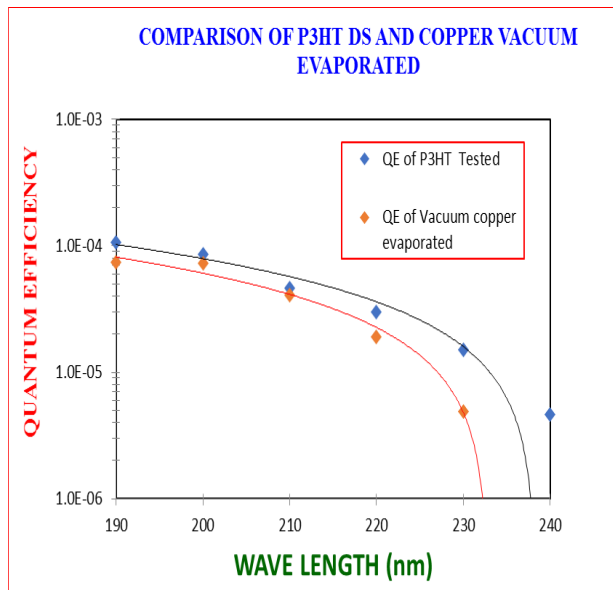


Fig.3 Comparison of QE of P3HT photocathode (DS) with copper vacuum evaporated

The layer effect is clearly visible. It was noticed that when photocathode from such materials are prepared using vacuum evaporation technique, in

general a shift in QE was observed. The reason for such behavior is that surface of photocathode is highly smooth and surface scattering effect is extremely low which greatly enhances the QE of photocathode. Moreover, the thickness of the photocathode layer can be monitored. Since Auto 306 coating system of our lab was not functioning well. Therefore, development of photocathode using this technique was not possible. Thus, an estimated shift in QE of the photocathodes was calculated. The shift in QE of P3HT photocathode, if it could have been prepared using vacuum evaporation technique is presented in (Fig. 4).

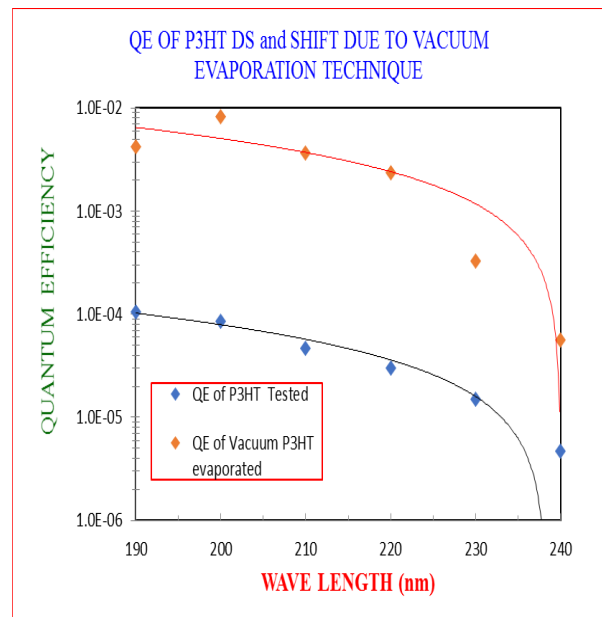


Fig 4 QE of P3HT DS and shift in QE due to vacuum evaporation technique

4. CONCLUSION

It is obvious from above discussion that maximum QE that was achieved with reflective UV photocathode P3HT at 190nm is lower as compared to that of CsI and reduces to a value equal to that of bare copper at 240nm. The advantage of using this photocathode is that it gives a noticeable QE at 230nm which is larger than that of CsI which has cutoff at 220nm. Moreover, Ease of the preparation of photocathodes with large surface area, air and thermal stability make it an attractive potential photocathode candidate for use in gaseous UV photodetectors in experiments where photon flux is high.

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