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Investigation of External QE of P3DDT Photocathode for use in Gaseous UV Photon Detectors

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Abstract: The quantum efficiency results of a new air stable organic semiconductor UV photocathode P3DDT are presented in this paper.Measurement of QE was carried out as a function of wavelength in spectral region 190-250nm. It shows cut off near 230nm. However, QE is too low to be of interest as compared to CsI but being air stabile and easyto prepare photocathodeswith large area it can find applications in barium flouride scintilation based calorimetry and plasma diagnositic where photon flux is very high.

Keywords: (UV gaseous Photon detectors, Solid Photocathodes, MWPC (Multiwire proportional chamber), GEM (Gas Electron Multiplier) and Thick GEM)

1. INTRODUCTION

Photocathode is an essential ingredient of large area, gas filled UV photon detectors. These Detectors are position sensitive, fast response and compatible with magnetic fields. The history of gaseous UV photon detectors begun with introduction of small amount of photosensitive Vapours along with fill gas in Multiwire Proportional Chambers (MWPC).Several photosensitive gaseous such as TMA (Biteman, *et al.*, 2001), EF (Peskov, 1981), TEA and TMAE (Sêguinot, 1989) were investigated for QE measurement in the last decade of 20[th] century, of which Tetrakis Dimethylamine (TMAE) showed quantum efficiency of about 10% at λ = 230 nm which rises up to 30-40% in the spectral region 160-190nm which is highest of all the tested photosensitive Vapours. (Holroyd., *et. al.*, 1987). It made the use of Quartz as entrance window for radiation into the detector volume which is comparably less fragile and cheaper than formerly used CaF_2 and MgF_2entrance windows for radiation. 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.*, 986). as well as SLD CRID (Va'Vra. and Collaboration, 1999). However, due to its low vapour pressure at room temperature, it requires few cm long gap for conversion of photons which results in bad time resolution, otherwise detector has to be operated at high temperatures(40º-50º) which results in severe damage to materials employed in detector construction. Moreover, its extreme chemical reactivity imposes severe restriction on the materials choice for detector and ions formed during multiplication process also causes wire ageing due to polymer formation on the surface of anode wires. Meanwhile, attempts were made to use solid photo converters instead of photosensitive Vapours. In order to increase the QEon the other hand, solid phase reflective photocathodes showed better time resolution as electrons are emitted from a well-defined solid surface. CsI was found to have highest QE among all the investigated solid photo converters. It was employed in combination with MWPCs in many experiments (Dalla, 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. Although it can be handled in air for short time but it was found to be hygroscopic and degraded when exposed to humid air (Anderson, *et. al.*, 1992) (Dangendorf, *et. al.*, 1990). (Dutta, and Singh, 2012). (Heroux, *et. al.*, 1966). (Simons, *et. al.*, 1985). (Simons, *et. al.*, 1987). A detailed ageing studies of CsI were also carried out (Hoedlmoser, *et. al.*, 2007). and collection of few mC/cm^2 charge at photocathode surface caused severe decrease in QE. There were two reasons for ageing. Firstly, due to high flux of incident photons and secondly due to ion back flow (IBF) towards the photocathode, the ions that are created during avalanche process migrate towards photocathode and get deposited above its surface. The gas electron multipliers(GEM) was invented by Sauli in 1996 and used to prevent photocathode surface from positive ion bombardment. First version of GEM based detectors consists of semi transparent photo cathodes (Buzulutskov, et. *al.*, 2000). Since, reflective photocathodes are more efficient than semitransparent (Charpak. *et al.*, 1991) therefore, multi GEM structure with CsI coated on the top of first GEM was developed and successfully used in PHENIX-HBD (Anderson, *et. al.*, 2011). Such UV photon detectors

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were fast response devices with time resolution < 2ns (Mörmann, *et. al.,* 2003). In this way CsI photocathode was protected from positive ion bombardment and the ageing effects were reduced. Multi-GEM structures with semi-transparent (Bondar, *et. al.,* 2003). or reflective (Mörmann, *et. al.,* 2004). (Tessarotto,2018) reduced IBF from 2% to 10% respectively. IBF less than 1% was obtained at the cost of low value of electric field, without modifying the total gain, (Breskin, *et. al.,* 2002) the condition, not suitable for reflective photocathodes because investigations have showed that at CsI surface photoelectron extraction efficiency is too low at low values of electric field (Dalla, 2011). Modified GEM structures, the micro hole and strip plate (MHSP) improved multiplication or suppressed 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). COBRA is specially designed micro hole strip plates (MHSP), (Lyashenko, *et. al.,* 2007). was used to achieve extremely low IBF (less than 10^{-3}. A gain of 10^5achieved in laboratory conditions with multi GEM structures cannot be sustained below or around 10^4 in large tracking experiments. 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. Similar triple THGEMs have been used to achieve 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) in laboratory. A study of IBF with typical triple THGEM shows that it reduces to 30% (Alexeev, *et. al.,* 2013). It is clear from above mentioned facts that use of GEM and other GEM- based technologies for protection of CsI photocathode from IBF is departure from simple parallel plate geometry to sophisticated technology.

Consequently, it is departure from the main goal i.e., cost-effective, large area, air stable UV photon detectors with room condition operation. Therefore, there is still need to seek for new air stable Solid photosensitive materials for the possible replacement of CsI. In this context, a systemic study of quantum efficiency (QE) of P3DDT,aninnovative UV sensitive organic semiconductor is presented in this paper.

2. EXPERIMENTAL PROCEDURE

The experimental set up was same as described in (Laghari, *et. al.,* 2014). In order to prepare photocathode samples of P3DDT with different thickness 1mg of it was dissolved in 0.5,1. 1.5 and 2ml of chloroform. One photocathode sample was from solution of each concentration using following procedure: a piece of 2.3cm×2.9cm of PCB sheet was used as substrate. Decon 90 was used for cleaning the substrate. It was boiled in Decon 90,washed with double distilled water and dried in dust free environment. Solution was filled in pipette and applied on the surface of clean substrate starting from center and allowed to evaporate leaving a 2.3cm×3mm for electrical contact. A few µm thick layer of P3DDT appeared on the surface of substrate. One by one prepared PCs were loaded in a small prototype test detector. The test detector was then transported and installed in modified sample compartment of SHIMADZU UV-Visible spectrophotometer. The test detector was operated in DC current mode. The current resulting from test detector and a 10×10 mm^2 reverse-biased silicon photodiode (Hamamatsu S 1723-05) was measured with Keithley electrometers (model 6517 A). In order to reduce leakage current, a guard ring arrangement was used in test detector electrical assembly. Subtracting measurements taken with and without the incident beam were used to remove photodiode reverse leakage currents. Measurements in vacuum were made at a bias of 25 V. However, in argon and CH_4 the maximum safe electrometer offset voltage was 250V, corresponding to an electric field of about 100 V cm^{-1} at the photocathode surface. Still a slight increase in photocurrent was noticed in these gasesat this field Therefore, slightly higher QEs may be obtained if larger extraction fields are employed. The maximum effective QE observed in CH_4 was 80% of that of vacuum value.

3. RESULTS AND DISCUSSION

1) General properties of P3DDT

Poly (3-dodecylthiophene-2,5-diyl) P3DDT, 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 5.3 eV and melting point 31℃(Online catalogue Sigma Aldrich GmBH).

It was purchased from Sigma Aldrich GmBH and used as it is without further purification. The chemical structure of the substance is shown in **(Fig.1).**

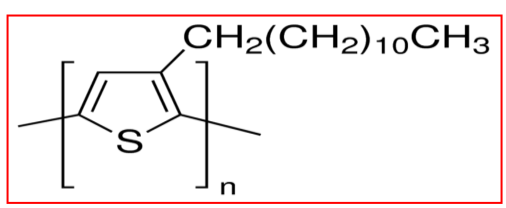

Fig.1. Ch

2) QE of P3DDT Photocathopde

(Fig. 2). shows QE result of P3DDT photocathode prepared using dissolving in solvent technique. Four different samples were prepared and tested. APC developed from a solution of 1mg P3DDT in 2.0ml chloroform showed maximum QE. The QE was measured as a function of incident photon wavelength in 190-240 nm range. The highest QE observed was only 0.69% at 190nm and shows cut off near 240nm.

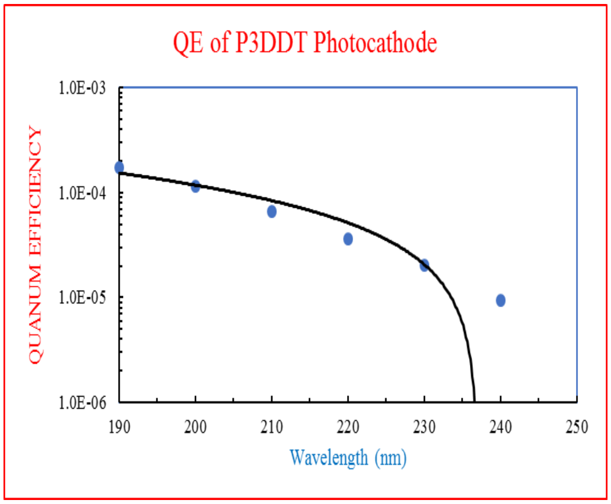

Fig. 2 QE of P3DDT using dissolving in solvent technique

A comparison of QE of P3DDT prepared using dissolving in solvent technique with QE of Vacuum evaporated bare copper cathode was carried out in order to observe layer effects the results obtained are shown in **(Fig. 3).**

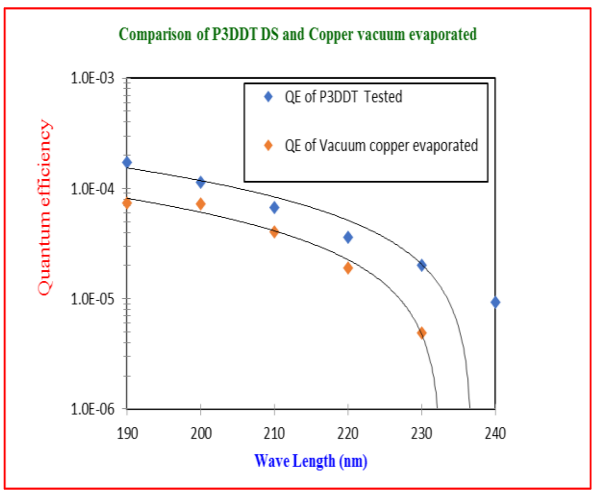

Fig.3 Comparison of QE of P3HT photocathode (DS) with copper vacuum evaporated

The layer effect is obvious from **(Fig.3)**. When photocathode of such materials are prepared using vacuum evaporation technique, generally a shift in QE was observed. As the surface of photocathode prepared using vacuum evaporation technique is highly smooth and surface scattering effects for both the incident photon and photoelectron are minimum therefore, the QE of photocathode greatly increased. On the other hand, monitoring of the thickness of the photocathode layer also becomes easy. Due to technical problem with Auto 306 coating system of our lab use of this technique for development of photocathode was not possible. Therefore, on the basis of trend in earlier work with similar materials by our group (Laghari, *et. al.*, 2014), an estimated shift in QE of the photocathodes was calculated. The QE shift of P3DDT photocathode, if it could have been prepared using vacuum evaporation technique is presented in **(Fig. 4).**

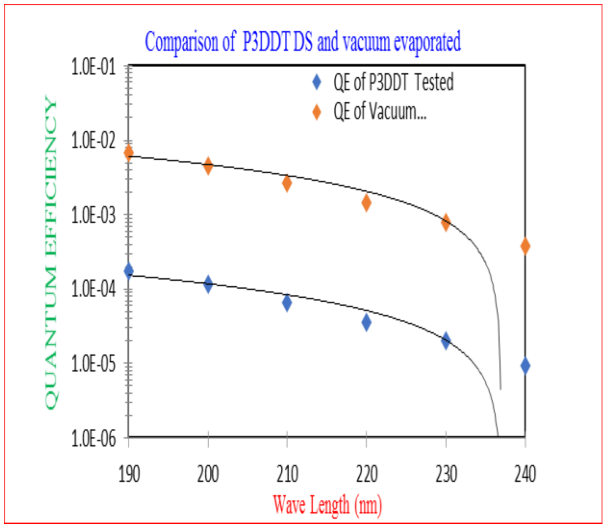

Fig 4 QE of P3DDT DS and shift in QE due to vacuum evaporation technique

4. CONCLUSION

QE ofP3DDT was measured using dissolving in solvent in spectral range 190 – 250nm and a possible shift in QE for vacuum evaporation technique was also estimated. The measurements show that application of the layer of this material enhances the sensitivity of metal surface but absolute value is too low to be of interest, apart from possible use in high energy barium fluoride-based calorimetry and plasma diagnostic where photon flux is expected to be very high. Moreover, it is not reactive to oxygen and thermally stable; Large surface area photocathodes can be prepared easily. On the other hand, this photocathode gives a noticeable QE at 230nm which is larger than that of CsI which has cutoff at 220nm.There is need to confirm the expected shift in QE due vacuum evaporation technique. It is also expected that application of a protective layer of this material on CsI surface may enhance QE of CsI and cause an increase in its spectral sensitivity.

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