Photoelectron Collection Efficiency of PDT

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Abstract:
Photoelectron collection efficiency for 3-(2-Pyridyl)-5,6-diphenyl-1, 2, 4-triazine (PDT) photocathode in pure Methane and in Argon Methane gas mixtures at different rations i.e. 50:50, 80:20 and 90:10 against decreased electric field and photons of wavelength ranging from 190nm to 230nm has been presented. Maximum QE reaches to ~95%, ~94 and ~95 of vacuum QE respectively in charge multiplication mode. These values are achieved at approximately E/p = 3.5 V/cm.Torr, 2.5 V/cm.Torr and 2 V/cm.Torr at 190 nm respectively. Similar QE are achieved E/p = 4.1 V/cm.Torr, 2.7 V/cm.Torr and 2.2 V/cm.Torr respectively at 230 nm.

Keywords: Good quantum efficiency, Solid Photocathodes, Gas filled Photon detectors, Quantum efficiency (QE), Photoelectrons Collection efficiency.

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Introduction:
Detector coupled with solid photocathode when operated in gas media, the photoelectrons ejected from the photocathode surface on their way to the anode possibly may collide with gas molecules and result in the elastic backscattering and in turn reduces effective quantum efficiency. This phenomenon primarily occurs because of the elastic collisions between photoelectrons and atoms or molecules of filled gas. The backscattering probability is controlled by the rate of inelastic collision, so the back scattering is lower for higher rates of inelastic collision. Especially, it has been perceived that for monoatomic contribute largely in the backscattering, and can be small for molecular gases and noble gases. Factors like nature of gas, incident photon energy and intensity of the electric field at photocathode surface control the rate of inelastic collision between photoelectrons and fill gas particles.
Especially when photo detectors are filled with noble gases, photoelectrons are back scattered because of their collision with gas molecules, this reduces the charge collection at anode. In Argon which has been considered to be the best choice for filling in practical detectors the achieved value of photoelectron collection efficiency is 60% for CsI photocathode in charge collection mode. On the other hand, photo detectors combined with solid photocathodes, filled with molecular gases such as methane; 90% of the vacuum values of QE are achieved.

QE is commonly lower in gas in comparison to vacuum, when photodetector is operated in charge collection mode, this is universal behavior for any gas including noble gases. However, an increase in QE with field is observed in multiplication mode and approaches the vacuum values at high gains.

In this work, Impact of reduced electric field on photoelectron collection efficiency and the effect of photon energy on the collection efficiency is also investigated in pure CH₄ and Ar–based gas mixtures; so that the best gas or gas combination ratio can be achieved for use in the UV sensitive gaseous detector with the proposed photocathodes.

**Experimental Setup:**

Experimental setup is detailed in for QE measurements. For this study, firstly prototype detector was operated at 1×10⁻⁴ Torr, monochromatic photons were incident on photocathode, photocurrent was measured for different values of field and QE was calculated. The photocurrent measurement procedure for photon beams of different wavelengths ranging from 190 to 230 nm was repeated. The procedure was then repeated for measurement of the photocurrent current in presence of gases i.e Pure Methane, Argon+Methane with combinations 90:10, 80:20, 50:50 simultaneously at 200 Torr pressure.

**Results and Discussion:**

The efficiency of a detector for collection of photoelectrons can be defined as the ratio of photocurrent obtained in gaseous atmosphere to photocurrent obtained in vacuum.

Thus,

\[
\text{Photoelectron Collection Efficiency} = \frac{\text{Photocurrent in Gaseous Medium}}{\text{Vacuum based Photocurrent}}
\]
or \[ PEC = \frac{I_{pg}}{I_{pv}} \]

Where, PEC is the photoelectron collection efficiency, \( I_{pg} \) is photocurrent in gaseous medium and \( I_{pv} \) is vacuum based photocurrent.

Experimental results for collection efficiency of a detector in reduced electric field at photocathode surface for UV photons with energies ranging from 190 to 230 nm in pure \( \text{CH}_4 \) and in argon methane gas combinations of different ratios such as 50:50, 80:20 and 90:10 at fixed pressure 200 Torr are presented in figures 1, 2, 3 and 4 respectively.
Figure 1: Photoelectron collection efficiency of PDT in CH4 at 200 Torr at different photon energies.

Figure 2: Photoelectron collection efficiency PDT in Ar+CH4 with 50:50 ratio at 200 Torr at different photon energies.
Figure 3: Photoelectron collection efficiency of PDT in Ar+CH4 with 80:20 ratio at 200 Torr at different photon energies.

Figure 4: Photoelectron collection efficiency of PDT in Ar+CH4 with 90:10 ratio at 200 Torr at different photon energies.
Figure 1 shows the results in pure CH$_4$, the collection efficiency of detector approaches to ~97% of vacuum values at reduced field= 4 V/cm.Torr at 190 nm and at reduced field = 4.6 V/cm.Torr at 230 nm.

Figure 2 shows collection efficiency results in charge multiplication mode, in Ar+CH$_4$ gas mixtures ratio 50:50, it is observed the value approaches to ~95% of vacuum QE. Figure 3 and 4 show results under similar conditions for argon methane mixtures in ratios of 80:20 and 90:10, the maximum QE reaches, ~94 and ~95 of vacuum QE respectively in charge multiplication mode. These values are achieved at approximately E/p = 3.5 V/cm.Torr, 2.5 V/cm.Torr and 2 V/cm.Torr at 190 nm respectively. The same QE are achieved E/p = 4.1 V/cm.Torr, 2.7 V/cm.Torr and 2.2 V/cm.Torr respectively at 230 nm. Hence, lowering the photon energies the charge is collected at higher electric fields in gas media.

We made measurements of the collection efficiency for PDT photocathode in pure CH$_4$, and in Ar+CH$_4$ gas mixtures. The highest efficiency achieved in CH$_4$ but at much higher applied electric field. However, in Ar based gas mixtures, the maximum photoelectron collection efficiency achieved in Ar–CH$_4$ with 90:10 ratio. Therefore, it can be summarized that the best gas combination filled in gaseous detector having PDT photocathode will be Ar having 10% CH$_4$ filled in the detector.

**Conclusion:**
In this work, the collection efficiency for PDT photocathode in pure Methane and in Argon Methane gas mixtures at different ratios i.e. 50:50, 80:20 and 90:10 at reduced electric field for photons energies from 190nm to 230nm has been presented. Results reviled that highest efficiency is achieved in pure Methane but at much higher applied electric field. Since methane is a highly flammable gas so there is a greater chance of spark to take place at higher values of applied electric field. Whereas, in Argon based gas mixtures, the maximum collection efficiency is reached in Argon & Methane at 90:10 ratio. Hence, it can be concluded that the best gas combination for filled in gaseous detector having PDT photocathode will be Argon 10% combined with 10% of Methane.

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