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Photoelectron Collection Efficiency Measurement of Vp81 Photocathode

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Abstract: We present experimental measurement of photoelectron collection efficiency of a new organic semiconductor photocathode Vp81in pure methane and argon methane mixtures in different ratios as a function of applied reduced electric field at a gas pressure of 200 torr. It is confirmed that collection efficiency increases in charge collection mode and reaches near the vacuum value at high gas gain. The general universal behavior was also confirmed as predicted by some authors.

Keywords: Photocathodes, Gaseous Photon detectors, Quantum efficiency (QE), Photoelectron Collection efficiency

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 BaF_2 or liquid xenon calorimetry, and also in medical imaging (Ketzer, *et al.*, 2001) (Di-Mauro, *et al.*, 1999) (Breskin, *et al.*, 2000) (Joram, 1999) (Del Guerra, *et al.*, 2003) For this purpose, Vp81 Photocathode preparation and quantum efficiency (QE) measurement in vacuum have already been presented (Laghari, *et al.*, 2014). Since, photocathode is to be used in gaseous atmosphere and hence subject to photoelectron back scattering and ion back flow (IBF) that results in reduced effective QE.

CsI is known for best QE for all the investigated solid UV photocathodes and is used in gaseous photon detectors employed in a large number of high energy experiments. Several investigation groups have performed, simulation or experimental studies, to determine the photoelectron collection efficiency in various gases/gas mixtures in comparison to vacuum for photoconverters coupled with CsI photocathode (Breskin, *et al.*, 1994). Photoelectron collection efficiency depends on nature and pressure of gas, the incident photon energy and field intensity on photocathode surface. For CsI, measurements have been made in charge collection mode as well as multiplication mode. It was found that the QE of CsI in charge collection mode, as a function of the field is rather constant, and has a gas nature dependent value. It was demonstrated that in all studied gases, QE reaches its vacuum value, at high gas gain. In the charge collection mode, in CH_4, the QE was found rather constant and reached 97% of the vacuum value at low fields. A decrease in the elastic backscattering due to dominant process inelastic (ionization and excitation), in the multiplication region can explain this behavior. The direction of motion of electron is only slightly perturbed in the inelastic collisions, on the other hand, in case of elastic collision, velocity vectors are random. Therefore, it was predicted that such a universal behavior should be obeyed by any gas, including noble gas mixtures.

In this work, photoelectron collection efficiency of Vp81 photocathode is investigated as function of the reduced applied electric field E/P, where p is the gas pressure. The measurements are carried out in pure CH_4, Ar 90%+10%CH_4, Ar80%+$CH_4$20% and Ar50% +$CH_4$50% mixtures at a pressure of 200 Torr and fixed photon energy at 195nm.

2. EXPERIMENTAL SET UP AND PROCEDURE

The systematic investigation of the dependence of photoelectron collection efficiency of the Vp81 photocathode on the electric field at photocathode surface and nature of gas was carried out in the laboratory, with a DC current measurement technique. CH_4, and Ar-CH_4 mixtures, were studied at a pressure of 200 Torr.

Details of design, construction and calibration of experimental set up used for this work are given elsewhere. The set up consists of a test chamber installed in compartment of UV-visible spectrophotometer (UV-1601) Shimadzu made in Japan which was used as calibrated UV light source, two electrometers (Kethley model 6517 A) for the measurement current from test chamber and Hamamatsu photodiode (S1723-05). The gap between photocathode surface and anode wire plane was 9mm. The test chamber was connected to turbo molecular pump system and gas supply through a four-way hub so that it can be evacuated or filled with a gas or a gas mixture in desired ratio. The measurement for photocurrent were made both in vacuum (in charge

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collection mode) and in CH_4 and in Ar-CH_4 mixtures in 50/50, 80/20 and 90/10 ratio (in charge collection mode as well as at a gas gain of about 100) using Keithley electrometers. In this work borosilicate glass substrate was used for photocathode preparation. For this a strip of size 2.3cm×2.9cm was cut from a microscope glass slide using diamond glass cutter, washed in DD to remove glass and dust particles the boiled in Decon 90 for about 10minutes in order to remove greasing and other contaminations then for 10minutes in DD. Finally, it was rinsed with DD and dried to be ready for deposition. Photocathode was prepared using vacuum deposition technique. For this, Borosilicate glass substrate was then placed on the hole cut into the substrate holder dome of Auto 306 coating system, for placing substrate. Pieces of pure copper wire were placed in the basket of tungsten heating element and some quantity of photosensitive compound Vp81 in a molybdenum boat in another source position then bell jar was closed vacuum pump was started when a vacuum of $\approx 10^{-6}$Torr was achieved, deposition of thin metallic layer was started after acquiring desired thickness of about 1000 nm, evaporation was stopped and shutter was closed to protect electrical contact, photosensitive material Vp81 source was then positioned for deposition after reaching the desired thickness of 500nm evaporation was again stopped. Prepared photocathode was then moved to test chamber for QE measurement, during this it was exposed to air for about 5min. After loading Vp81 photocathode, test chamber was pumped down to a vacuum of 2.4×10^{-4} Torr time required for this was not more than 10 minutes. Photocathode was then irradiated with a photon beam of width 1×10 mm^2 with fixed photon energy at λ=195nm.The photocurrent was measured for different values of electric field at the photocathode surface, then the test chamber was filled with pure methane gas at a pressure of 200Torr. The process was repeated for Ar-CH_4 mixtures in different ratio.

3. RESULTS AND DISCUSSION

Maximum QE was obtained for a 500nm thick Vp81 vacuum evaporated photocathode. Therefore, for the measurement photoelectron collection efficiency similar photocathode was prepared and its QE was measured in vacuum first at a fixed photon energy at 195nm for different values of electric field then TC was filled with 99.999% pure methane gas at a pressure of 200 Torr, and QE was measured at same fixed photon energy as for vacuum at similar values of electric field. Then vacuum to gas ratio of photocurrent was calculated in order to determine QE. **(Fig. 1)** shows vacuum to gas ratio of photocurrent for Vp81 photocathode in CH_4 at a pressure of 200 Torr as function of reduced electric field at the photocathode surface. The ratio increases at low values of field and reaches the plateau at 2.2V/cm Torr. Photoelectron collection efficiency reaches the maximum value of 97% at 4V/cm Torr without break down. This confirmed the universal behaviour predicted by some authors.

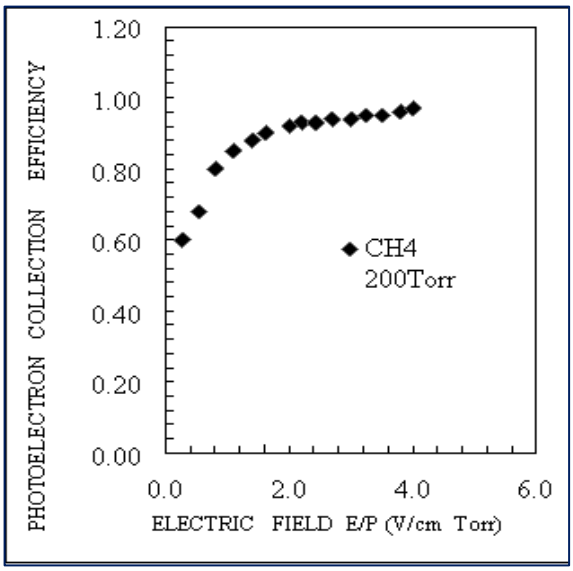

Fig. 1. Photoelectron collection efficiency of 500nm thick Vp81 photocathode in CH_4 at 200 Torr for fixed photon energy at λ=195nm as function of reduced electric field E/P (V/cm Torr).

Vacuum to gas ratio of QE at the surface of 500nm thick Vp81 photocathode for reduced values of electric field in argon methane mixture (50/50) ratio at a pressure of 200 Torr is shown in **(Fig. 2).** One can see from the figure that the ratio of photocurrents increases at low values of E/P and reaches the plateau at E/P =2V/cm Torr and reaches the maximum value of 98% for an electric field E/P = 3.75 V/cm Torr at the photocathode surface without spark to appear.

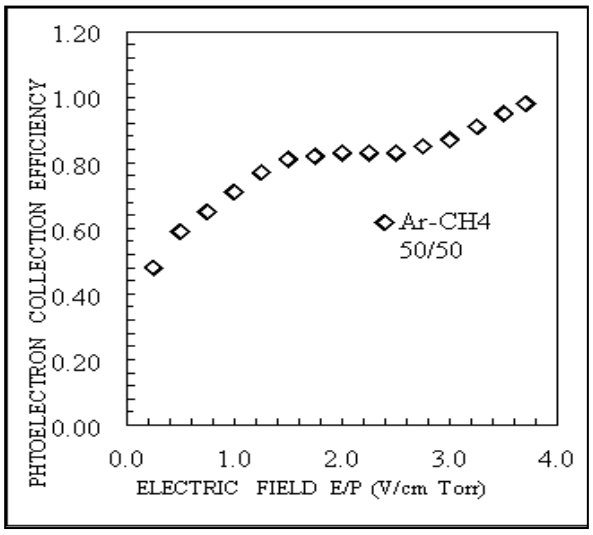

Fig. 2 Photoelectron collection efficiency of 500nm thick Vp81 photocathode in Ar-CH_4 (50/50) at 200 Torr for a fixed Photon energy at λ= 195 nm as function of reduced electric field E/P (V/cm Torr).

(Fig. 3) shows the photoelectron collection efficiency of 500nm thick photocathode in Ar-CH_4 (80/20) ratio at a pressure of 200 Torr and at fixed photon energy λ= 195nm

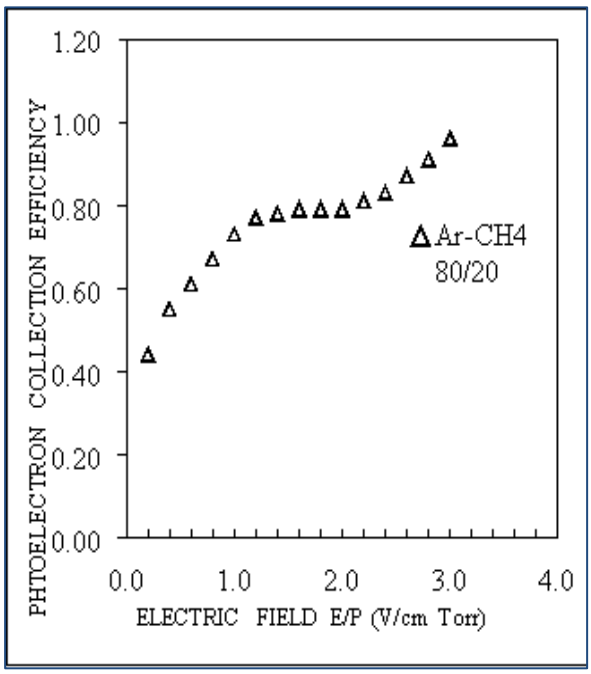

Fig. 3 Photoelectron collection efficiency of 500nm thick Vp81 photocathode in Ar-CH_4 (80/20) at 200 Torr for a fixed photon energy at λ= 195 nm as function of reduced electric field E/P (V/cm Torr).

Under reduced electric field E/P (v/cm Torr) at the photocathode surface. For low values of electric field, it increases slowly and reaches the plateau at E/P = 1.6 V/cm Torr. Photoelectron collection efficiency for Ar-CH_4 (80/20) reaches the maximum value 96% for E/P = 3.0 V/cm Torr.

The photoelectron collection efficiency for a 500nm thick Vp81 photocathode in Ar-CH_4 (90/10) ratio at a pressure of 200 Torr under reduced electric field at photocathode surface at a fixed photon energy λ= 195nm is depicted in **(Fig.4).** it increases for low values of reduced electric field E/P and reaches the plateau at 1.53V/cm Torr and to the maximum value 95% for an electric field of 2.5 V/cm Torr.

4. SUMMARY AND DISCUSSION

We have investigated the effects of reduced electric field on the photoelectron collection efficiency of Vp81 photocathode for a fixed photon energy of λ=195 nm in pure CH_4 and Ar -CH_4 mixtures (50/50), (80/20) and (90/10) ratios respectively at 200 Torr. Measurements were made using DC current measurement in vacuum ($\approx 10^{-4}$ Torr) for different values of electric field then in gas media at pressure of 200 Torr. Then vacuum to gas

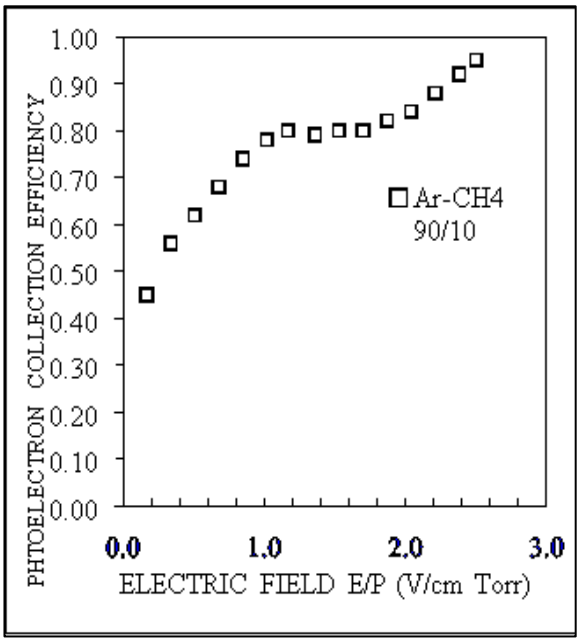

Fig. 4 Photoelectron collection efficiency of 500nm Thick Vp81 photocathode in Ar-CH_4 mixture (90/10) at 200 Torr for fixed photon energy at λ=195nm at reduced electric field E/P (V/cm Torr).

ratio of Dc current was plotted against reduced electric field E/P (V/cm Torr) to obtain photoelectron collection efficiency. QE is lower than the vacuum value in charge collection mode and does not depend on electric field. On the other Hand, it was observed that it increases with field in multiplication mode and reaches the vacuum value for higher gas gain. It was also observed that the photoelectron collection efficiency not only depends on electric field but also on the nature of gas. Photoelectron collection efficiency in pure methane reaches the maximum value for lower value of electric filed than in Ar-CH_4 mixtures because methane is a poly atomic molecule, therefore, due to presence of vibrational and rotational levels majority of collisions involve large energy losses above the ionization threshold so the inelastic collision is the dominant process and electrons produced in these ionizing collisions have very low energy and hence follow the accelerating electric field without backscattering. In mixtures with higher component of Ar, due to elastic collisions back scattering is dominant process because the mono atomic gases lack in vibrational and rotational levels. Therefore, maximum photoelectron collection efficiencies are achieved at little higher values of reduced electric field.

Similarity between Argon based mixtures and pure hydrocarbons have been noticed. Since there is a factor risk using pure hydrocarbon gases due to inflammable nature. Therefore, argon-based mixtures are most suitable for this application. The measurements

have shown that Ar-CH_4 90/10 is most suitable combination for this work.

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