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Photoelectron Extraction Efficiency of N,N′-Bis(3-methylphenyl)-N,N′-diphenylbenzidine (TPD) in CH_4 and Ar+ CH_4 Mixtures

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Abstract: Photoelectron extraction efficiency of N,N′-Bis(3-methylphenyl)-N,N′-diphenylbenzidine (TPD) was measured in pure Methane (CH_4) and in mixtures of Methane (CH_4) & Argon (Ar) with different ratios at 200 Torr pressure as a function of applied reduced electric field. In pure methane the quantum efficiency (QE) reaches to maximum value of ~97% of vacuum value in charge collection mode approximately at reduced field of 4 $Vcm.^{-1}Torr$. In Ar+CH_4, the QE reaches to ~95%, 94% and 95% with 50:50, 80:20 and 90:10 ratios respectively, in charge multiplication mode at lower reduced electric field values i.e. 3.5 $Vcm^{-1}.Torr$, 2.5 $Vcm^{-1}.Torr$ and 2 $Vcm^{-1}.Torr$ respectively at 190 nm.

Keywords: Photoelectron extraction efficiency, photocathodes, quantum efficiency, applied reduced electric field, charge collection mode, charge multiplication mode.

1. INTRODUCTION

Solid photocathode coupled with gaseous detector where photocathode surface comes in contact with the gas atmosphere undergoes backscattering of photoelectrons coming out from photocathode during photoionization. This backscattering of photoelectrons is as a result of elastic collisions of photoelectrons with the gas molecules (Loeb, 1955) Studies reveal that the photoelectron extraction efficiency in different gases depends on nature of gas, photon energy and electric field intensity at the photocathode surface (Breskin, 1995). (Di Mauro, 1996). (Buzulutskov, 1999). (Buzulutskov, 1999). (Phelps and Petrovic 1999). (Buzulutskov, 2000). (Breskin, 2002). (Dias, 2004).

Significant reduction in quantum efficiency is observed while detectors were filled with noble gases because of the backscattering of photoelectrons by the filled gas atoms (Buzulutskov, 1999). (Buzulutskov, 1999). (Phelps and Petrovic 1999). (Buzulutskov, 2000). However, it is important to fill gaseous detector with noble gas because of large scintillation, it is easy to handle, it is purified and solid photocathode coupled in noble gas filled gaseous detector is already implemented (Phelps and Petrovic 1999). (Buzulutskov, 2000). (Breskin, 2002). (Dias, 2004). (Meinschad, 2005).

Photoelectron extraction efficiency of CsI photocathode have been studied in Ar, He, Ne, Kr, Xe and CH_4. Ar exhibits maximum photoelectron extraction efficiency amongst all studied noble gases (i.e. ~60% with charge collection mode operation as compared to He and Xe exhibiting ~30% and for Ne and Kr exhibiting values ~50%) but this value is lower as compared to CH_4 (Coelho, 2007). At low photoelectron energies, inelastic collisions are most probable in CH_4 and CH_4 – based gas mixtures,; the photoelectron extraction efficiency is independent of the field and reaches to the vacuum values at low reduced electric field values i.e. E/p. and at atmospheric pressure. Therefore, CH_4 based gas mixtures seems to be the best candidates for operation of UV sensitive gaseous detectors having photoelectron extraction efficiency with almost free from backscattering, but safety regulations impose reduction of the amount of flammable gas in large systems (Buzulutskov, 1999).. On the other hand, the Ar – hydrocarbon mixtures show similar behavior to that of hydrocarbons. Therefore, there is need of further investigation, to determine thye type and accurate amount of quenchers that should be added to decrease background initiated by the Ar scintillation (Buzulutskov, 1999).

In this work photoelectron extraction efficiency of TPD in CH_4 and Ar+CH_4 mixture at different rations has been investigated. The photoelectron extraction efficiency is defined as a function of applied reduced electric field E/p, where p is the pressure of gas inside the detector or it is the ratio of QE achieved in gas to the QE achieved in vacuum (i.e. EQ_g/QE_v) or it can also be given as the ration of gas current to the vacuum current (I_{cg}/I_{cv}). (Di Mauro, 1996). (Buzulutskov, 1999). (Coelho, 2007).

2. EXPERIMENTAL SETUP

Experimental setup for measurement of QE is same as in (Laghari, *et al.*, 2014) However, for measurement of photoelectron extraction efficiency as a function of reduced electric field at photon energy of 190 nm wavelength, the photocurrent of the test chamber was measured under vacuum of 1×10^{-4} Torr for monochromatic photons of 190 nm wavelength and at different applied voltages. Procedure was then repeated for measurement of photocurrent in gas medium. For which, the test chamber was first filled with pure CH_4 at 200 Torr and exposed to the monochromatic beam of 190 wavelength. At different applied voltages the photocurrent was measured. Similarly, after filling the test chamber with $Ar+CH_4$ gas mixtures at ratios 90:10, 80:20 and 50:50 at 200 Torr, exposed to monochromatic beam of wavelength 190nm and measured photocurrent at different applied voltages respectively.

3. RESULTS AND DISCUSSION

The photoelectron extraction efficiency is defined as photocurrent produced in gas environment per photocurrent produced under vacuum.

Therefore,

$$Photoelectron\ Extraction\ Efficiency = \frac{Photocurrent\ Under\ Gas\ Media}{Photocurrent\ \ Under\ Vacuum}$$

$$=> \qquad Ec = \frac{I_{pg}}{I_{pv}}$$

Where, Ec is the photoelectron extraction efficiency, I_{pg} is photocurrent under gas media and I_{pv} is the photocurrent under vacuum.

QE of TPD photocathode as a function of applied electric field at different gas pressure was measured for investigation of photoelectron extraction efficiency. Gas mixtures under which photoelectron extraction efficiency of TPD photocathode was measured are pure CH_4, $Ar+CH_4$ gas mixtures at 50:50, 80:20 and 90:10 ratios filled at variable pressure. Results are presented in (**Fig. 1, 2, 3 and 4)** respectively.

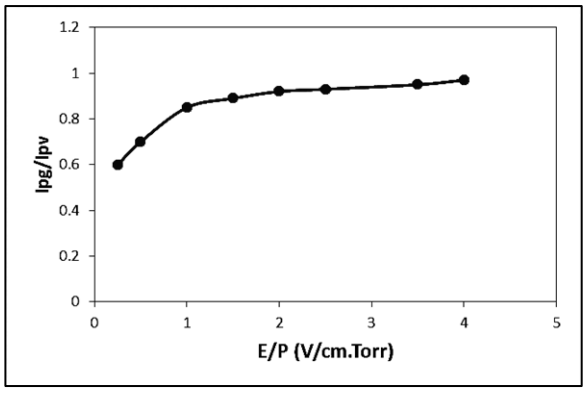

Fig. 1. Photoelectron extraction efficiency of TPD in CH_4.

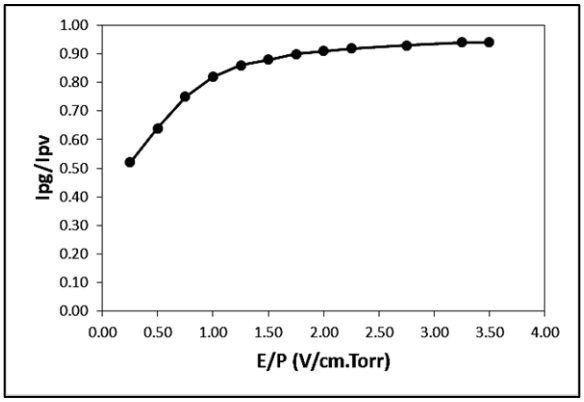

Fig. 2. Photoelectron extraction efficiency TPD in Ar+ CH_4 with 50:50 ratio.

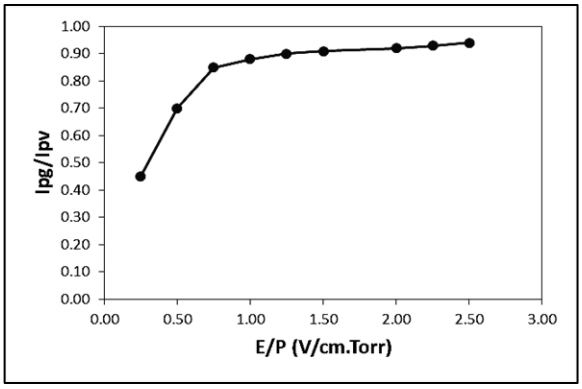

Fig. 3. Photoelectron extraction efficiency of TPD in Ar+CH_4 with 80:20 ratio.

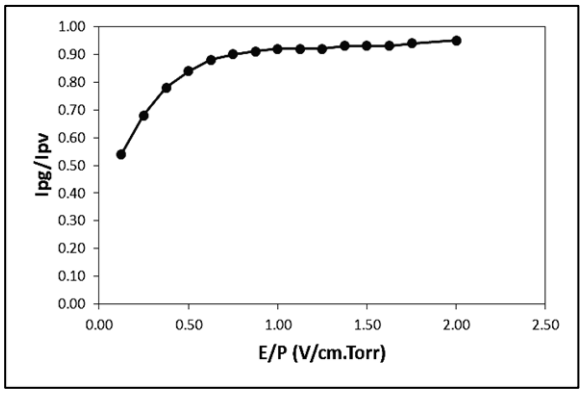

Fig. 4. Photoelectron extraction efficiency of TPD in Ar+CH_4 with 90:10 ratio.

Results show that when, the counting plateau is achieved in charge collection mode , the QE becomes independent of the field, in comparison to vacuum, it is lower The maximum QE depends upon gas or gas mixtures. When detector is operated in charge collection mode, in pure methane, approximately at E 4 Vcm^{-1}.Torr QE approaches to the maximum value of ~97% of vacuum value.

For Ar+CH_4 with 50:50, 80:20 and 90:10 ratios the QE reaches to ~95%, 94% and 95% in charge multiplication mode at lower reduced electric field values i.e. 3.5 Vcm^{-1}.Torr, 2.5 Vcm^{-1}.Torr and 2 Vcm^{-1}.Torr respectively at 190 nm.

The photoelectrons extraction probability, which is dependent on elastic backscattering probability from different gas molecules, for TPD photocathode can be used to describe these results. At high reduced electric field, inelastic collisions dominate the elastic backscattering, the resulting QE value is equal to the vacuum value and is independent from the gas or gas mixture. Ar based gas mixtures are relatively better, specially Ar–CH_4 with 90:10 ratio where elastic backscattering overcame at lower reduces electric fields.

4. CONCLUSION

In this work the relative QE of the TPD photocathode surface as a function of reduced electric field, for photons of energy 190 nm wavelength has been measured in pure CH_4 and in Ar+CH_4 gases mixtures at 50:50,80:20 and 90:10 rations. When the detector operating in charge collection mode, approaches the counting plateau, the QE becomes independent of the field and is lower than the QE in vacuum. The QE in gas media depends upon gas or gas mixtures. In pure methane, in charge collection mode, approximately at 4 Vcm^{-1}Torr the QE reaches to the maximum value of ~97% of vacuum value has been received whereas for Ar+CH_4 with 50:50, 80:20 and 90:10 ratios the QE reaches to ~95%, 94% and 95% in charge multiplication mode at lower reduced electric field values i.e., 3.5 Vcm^{-1}Torr,2.5Vcm^{-1} Torr and 2 Vcm^{-1}Torr respectively at 190 nm.

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REFERENCES:

Breskin, A., (1995). "Field-dependent photoelectron extraction from CsI in different gases."Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 367 (1): 342-346.

Buzulutskov, A. (1999). "GEM operation in pure noble gases and the avalanche confinement."Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 433 (1): 471-475.

Buzulutskov, A. (2000). "The GEM photomultiplier operated with noble gas mixtures."Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment**443**(1): 164-180.

Breskin, A. (2002). "GEM photomultiplier operation in CF 4."Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 483(3): 670-675.

DiMauro, A. (1996). "Photoelectron backscattering effects in photoemission from CsI into gas media."Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 371(1): 137-142.

Coelho, L., (2007). "Measurement of the photoelectron-collection efficiency in noble gases and methane."Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 581(1): 190-193.

Dias, T., (2004). "The transmission of photoelectrons emitted from CsI photocathodes into Xe, Ar, Ne and their mixtures: a Monte Carlo study of the dependence on E/N and incident VUV photon energy."Journal of Physics D: Applied Physics 37(4): 540.

Loeb, L. B. (1955) Basis processes of gaseous electronics (University of California Press, Berkeley,.

Laghari, B. A., I. A Ismaili, J. V. Grazeulvacious, Fredrick. K. A. Khalique R. I.. Ahmed, I. A. Halepoto (2014). "Organic semiconductor UV Photocathodes for Photosensitive Gaseous detectors."IOSR Journal of Applied Physics (IOSR-JAP) 6(6): 8Pp.

Meinschad, T., (2005). "Detection of primary and field-enhanced scintillation in xenon with a CsI-coated GEM detector."Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 547(2): 342-345.

Phelps, A. and Z. L. Petrovic (1999). "Cold-cathode discharges and breakdown in argon: surface and gas phase production of secondary electrons."Plasma Sources Science and Technology 8(3): R21.