Employment of nanodiamond photocathodes on MPGDbased HEP detector at the future EIC

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Outline

- Motivation
- Coating unit & QE Setup in Bari
- QE measurement in Bari
- ASSET @ CERN
- Preliminary measurement with ASSET
- Employment of ND on THGEMs
- Conclusion

Motivation of this specific R & D

- Demand of a compact RICH for the future EIC ► short radiator length (Limited number of Photons)
- As standard quartz window is opaque below 165 nm ► windowless RICH is a possible approach ► Gaseous detectors
- CsI most used, however ageing due to humidity and ion bombardment ► quest for novel PC with sensitivity in the far UV region
- **H-ND** powder as possible **more robust** alternative photocathode of CsI
- Our R & D; H-ND coupled to THGEM
- We report here some preliminary results on the initial phase of these studies

Why and which Nano Diamond

	6	Comparison Csl to Nano Diamond		Comparative QE: CsI: ND/HND
		H – ND	Csl	
	•	Low electron affinity ► 0.35 – 0.5 eV	 Low electron affinity ► 0.1 eV 	
		Wide band gap ► 5.5 eV	• Wide band gap ► 6.2 eV	
		Preliminary measured QE ► 30 – 40% @ 140 nm for Hydrogenated samples. (We mes 7.7% after one year H – ND	 Typical Quantum Efficiency ► 35 – 50% @ 140 nm 	
		in H ₂ O).	CsI has hygroscopic nature	
	•	Chemically inert	 Aging ► Ion Accumulation 	
		Radiation hard	Degradation in QE of PC	
	· Seteration	Good thermal conductivity		0.01
,	Microwave Plasma Enhance	ed Chemical Vapour Deposited (MW	/PECVD) diamond films are used for	0.001
	thermionic current generation Csl.	on and for UV photocathodes, becau	ise they exhibit a better stability than	110 160 210 260 Wavelength [nm]
•	Production of diamond films by MWPECVD technique at 800°C. Peculiarity: hydrogenated surface!!			• CsI [NIM-A-438 (1999) 94]
	Moves down Negative Electron Affinity (N.E.A.) to -1.27 eV. A crucial parameter for electron photo			• ND [APL-108 (2016) 083503]
	and thermo emission. Maxin	num Q.E. achieved for the MWPECVI	D based diamond is 12% at 140 nm	• HND [APL-108 (2016) 083503]



Photocathode coating & photocurrent measurement @ Bari

Pulsed spray thin film coating setup: No of Shots determine the coating thickness



Figure : The pulsed spray technique for thin film coating, equipped with an ultrasonic atomizer and with a heater at INFN Bari, Italy

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Pictorial view of photoemission measurement setup:



Figure : McPherson VUV monochromator for the photocurrent measurement at INFN Bari, Italy

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Quantum Efficiency Formula Bari



Coating Details

Coated Substrate/THGEMs	Type of ND	#Shots
тв іх	ND	300
TB VIII	H-ND	140
TB III	H-ND	43
TBVII	H-ND	55
TB XIX	H-ND	59
тв хі	H-ND	250
PCB9	H-ND	25
PCB7	H-ND	50
PCB10	H-ND	100
PCB11	H-ND	200
PCB8	H-ND	400
PCB1	ND	100
PCB2	ND	100
PCB3	ND	200
PCB4	ND	200
PCB5	ND	50
PCB6	H-ND	50





THGEM (AA) : 30 mm X 30 mm

PCB Coin : 25 mm diameter

Coated THGEMs and PCB Coins:

ND & H-ND coted on 14 PCB coins
 Non-hydrogenated ND full THGEMs (One)
 Hydrogenated ND full THGEMs (Five)

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Figure details: (A) Au_PCB of 01 inch diameter substrate used for the QE measurement. (B) Uncoated THGEM of active area 30 mm x 30 mm. (C) Half uncoated and half coated THGEM with ND powder, mounted into the test chamber and zoomed view of the both coated (D) and uncoated (E) parts are shown. (E) Test chamber with readout pad where the THGEMs are tested. (G) The test chamber after installation of a THGEM, with gas flow and and a work to the test of the both coated (INFN Trieste & INFN Bari collaboration) 10

Noise, Reproducibility and Electric field scan @INFN Bari

Noise and Reproducibility





Photocurrent Results

QE vs λ for various H-ND shots on PCB Coin



Quantum Efficiency of ND and H-ND



Photocurrent measurement @ CERN

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Schematic & Pictorial view of photoemission measurement setup: ASSET



Quantum Efficiency Formula CERN



Comparison of Bari and CERN results



ASSET is in building up state, comparative analyses are useful

Comparison with literature

- Deposited by Miranda and Thomas in CERN.
- Substrate used: Au PCB coin
- Measured in ASSET @ GDD lab.
- QE: ~ 23.6% @ CERN &
 ~34.8 in literature
 for λ = 160 nm



Reproducibility @ CERN



Aging study with X-Ray irradiation of H-ND PC



NOTE: This is the first preliminary irradiation ageing study of H-ND photocathodes ever performed.

THGEM Characterization



- THGEMs are standard Printed Circuit Boards (PCBs) with holes produced by mechanical drilling.
- Like in GEMs, in the presence of a correct electrical bias and in a proper gas mixture, each hole acts as an electron multiplier.
- The signal generated by the gas multiplication is collected at the anode.
- The geometrical parameters of our THGEMs are: hole diameter (d) = 0.4 mm; hole pitch (p) = 0.8 mm; thickness of the fiberglass (t) = 0.4 mm; and rim around holes < 5 um.

- For measurements the gas mixture used is: Ar:CH₄ 50:50
- CAEN N1471H HV PS has been used.
- CREMAT CR-110 Preamplifier with CREMAT CR-150 r5 evaluation board has been used to read the signal from the detector.
- Ortec 672 Spectroscopy amplifier with AMPTEK MCA 8000A has been used for processing the signal and for saving the data.

A typical ⁵⁵Fe X-ray spectrum obtained in Ar:CH₄ = 50:50 gas mixture for uncoated and H-ND coated THGEM VIII



Uncoated and **H-ND** coated THGEM VIII in Ar:CH₄ = 50:50 gas mixture

THGEM effective gain vs. bias voltage



Conclusion

- A systematic R&D has been started to explore the characteristics and possibilities of ND photocathode.
- H-ND is having comparable QE to CsI @ 140 nm.
- Preliminary measurements have been performed and found promising results.
- Aging studies have been started & preliminary results of QE shows that, H-ND photocathodes are quite stable in comparison with CsI
- H-ND has been applied on THGEMs and a R&D towards a detector of single photon based on hybrid (THGEM + MM) MPGD technology with H – ND photocathode has been started.
- Coated THGEMs show a decrease in electrical stability, in particular, for the H-ND case, however an improvement is observed after heat treatment in electric oven.
- Hydrogenated Nano Diamond is a potential candidate as CsI substitute after overcoming the observed challenges.





Backup slides

Quantum Efficiency Formula CERN





Position scanning



- We scanned two of our samples with 2 mm @ 0 nm wavelength to see the profile.
- A clear difference between CsI and H – ND can be seen.
- The reduced photocurrent is due to lower QE (?).