Studies of electroluminescence yield in THGEM UV detectors

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Introduction

Photon detectors based on MPGD (Micro-Pattern Gas Detector) [1] used in high energy physics, particle physics, medical instrumentation and many other fields stimulated the study of principle and engineering aspect of these detectors [2,3]. THGEM [4], one of the successful developments from the broad family of MPGD, coupled with CsI photoconvertor [5] are currently being used for detection of single UV photon in Ring Imaging Cherenkov (RICH) detectors [6]. THGEM holes, arranged in a hexagonal pattern are produced by mechanical drilling process. Each hole acts as an individual proportional counter by applying suitable potential difference between two electrodes of THGEM. The avalanche confinement in the holes results good intrinsic multi-track resolution. Most of the imaging applications are relying on electronic readout [7] that depends on secondary charge avalanche process. This approach provides excellent spatial resolution. However, it involves more channel numbers, complex data acquisition and readout geometry. These limitations of electronic readout method strongly motivate the development of optical readout which uses electroluminescence (EL), produced by electron impact [8]. Investigation of excitation and de-excitation of electrons produced during avalanche is important to understand scintillation capabilities while developing such promising large area detectors. The amount of light produced by a single primary electron depends on many factors such as gas mixture, its pressure and the intensity of electric field which acts on it and also on detector geometry. In this work, we have studied the EL yield of UV photon detectors based on THGEM in pure argon and neon gases using Garfield++ [9], a simulation toolkit, which allows estimating scintillation produced during avalanche.

Methodology

Modelling of a THGEM unit cell is done using ANSYS [10], a software tool based on finite element method. Geometrical parameters of THGEM chosen in this study are; insulator thickness 250 µm, hole diameter 200 µm and pitch 450 µm. Drift and induction gaps are kept at 3 mm and 2 mm respectively. Electric field maps are calculated using ANSYS. For further simulations, these files are imported to Garfield++, which has direct interface with ANSYS.

In Garfield++, primary photoelectrons are released at the photocathode plane with a given energy of 0.1eV. Initial coordinates of a photoelectron are chosen randomly within a specified area to simulate realistic situation. Each photoelectron is drifted towards THGEM under the influence of electric field applied between photocathode plane and top electrode of THGEM and then takes part in avalanche after reaching into the THGEM hole. Total number of electrons produced during avalanche is considered as absolute gain. The number of excited atoms and ionization, generated per photoelectron are considered to estimate excitation rate and ionization rate. Temperature and pressure are kept at 300K and 760 torr respectively unless otherwise specified.

Each excited atom is considered to give rise to a photon [11]. The total number of photons produced per primary electron is known as electroluminescence (EL) yield. Simulation was carried out for different multiplication voltages of THGEM and different gas pressures, which affect the EL yield.

Results and discussions

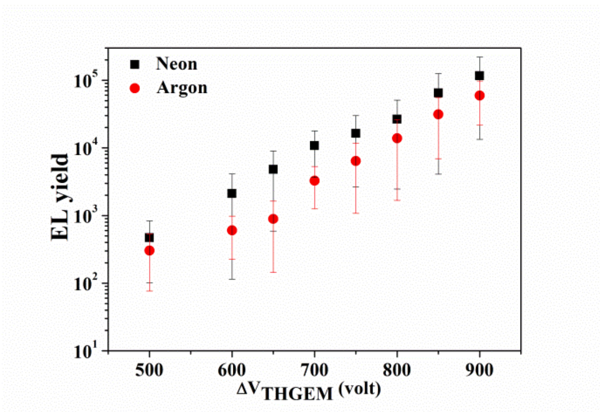

Fig.1 EL yield, as a function of multiplication voltage for argon and neon

The EL yield, as a function of multiplication voltage for argon and neon gases is presented in Fig.1. Gain, estimated from total number of electrons produced during avalanche is shown in Fig.2. The statistical fluctuations, associated with EL yield is due to fluctuations in secondary charge gain which increases with gain. In order to reach the suitable statistics, fluctuations can be minimized by increasing the number of simulated primary electrons. Gain and EL yield for neon gas shows higher value at comparatively low operating voltages because of Townsend coefficient [12].

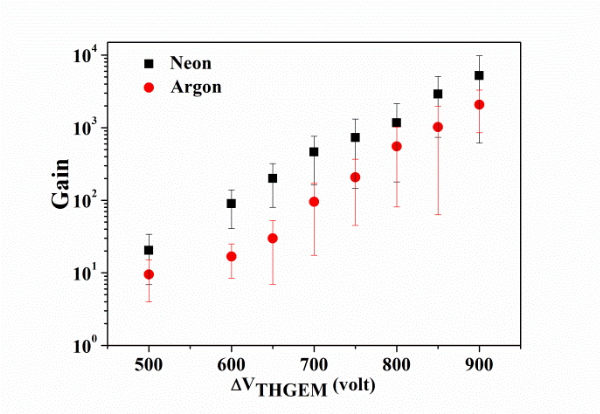

Fig.2 Gain, as a function of multiplication voltage for argon and neon

Fig.3 represents the ratio of number of excitations (R_{Exc}/R_I) to ionizations produced during avalanche as a function of reduced field (E/P) argon and neon gases. It is observed that, the ratio decreases with E/P for both and the value of this factor is higher in case of argon though gain is less compared to neon. As pressure increases, maximum energy acquired by electrons between collisions decreases due to lower mean free path. In addition, minimum energy required for ionization is higher than for excitation which results higher excitation to ionisation ratio as pressure increases [11]. Also it is observed that, the ratio is less for neon compared to argon. Higher value of first Townsend coefficient, the fractional increase in the number of electrons per unit length could be the reason for lower value of R_{Exc}/R_I in case of neon.

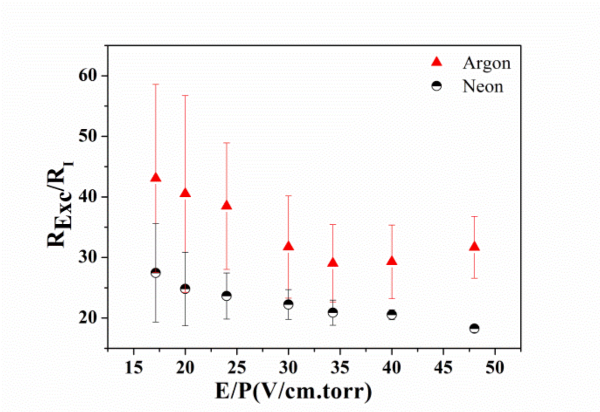

Fig.3 Ratio of excitation rate to ionisation rate as a function of reduced field for argon and neon gas

Conclusion

The electroluminescence yield, defined as the ratio of number of photons produced during avalanche to the number of primary electrons, is estimated for THGEM based UV photon detectors in pure noble gases. In this work, total number of excited atoms produced per primary electron was considered as EL yield. It was shown that EL yield increases with multiplication voltage applied between top and bottom electrodes of THGEM. The EL yield for neon gas is higher than argon gas. Also, the ratio of the number of excitations to ionizations strongly depends on reduced field. Due to higher value of first Townsend coefficient of neon, the ratio between the numbers of excitations to ionizations shows lower value than argon. These studies are important to understand the scintillation capabilities and hence development of large area UV photon detectors with enhanced EL yield, thereby increasing the detection efficiency.

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