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Advanced European Infrastructures for Detectors at Accelerators

Milestone Report

Qualification of the new candidate materials for THGEM substrate

Dalla Torre, Silvia (INFN)

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MILESTONE REPORT

QUALIFICATION OF THE NEW CANDIDATE MATERIALS FOR THGEM SUBSTRATE

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Abstract:

THGEMs by Permaglas have been built and fully characterized: the results qualify this material as a new one fully adequate for the production of high-quality THGEMs. The characterization procedure and the results are reported in detail.

AIDA-2020 Consortium, 2017
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	Name	**Partner**	**Date**
Authored by	S. Dalla Torre	INFN	01/06/2017
Edited by	S. Dalla Torre	INFN	01/06/2017
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Executive summary

THGEMs by Permaglas have been built and fully characterized. The characterization studies include measurements of the geometrical parameters of the row material plates, electrical stability tests, measurements of the gain uniformity of the electron multiplier, measurement of the energy resolution and the gain variation versus the applied voltage; the gain evolution versus time has also been determined. The results of this extended investigation qualify Permaglas as a fully adequate substrate for the production of high-quality THGEMs.

1. INTRODUCTION

THick GEMs (THGEM), also called LEM in literature, introduced in parallel by several groups [1], are electron multipliers derived from the GEM design, scaling the geometrical parameters and changing the production technology. The Cu-coated polyimide foil of the GEM multipliers is replaced by standard Printed Circuit Boards (PCB) and the holes are produced by drilling. The conical shape of the GEM holes formed by uncoated polyimide rings around the holes themselves is replaced by a clearance ring, the rim, surrounding the hole and obtained by Cu etching (Fig.1). The hole arrangement is similar to the one adopted for the GEMs; the circular hole centres are distributed according to a repetitive pattern: the basic cell is an equilateral triangle. In the following, the distance between the centres of adjacent hole centres is referred to as pitch. THGEMs exhibit large gains; they have an intrinsic mechanical stiffness, and they are robust against damages produced by electrical discharges. They can be industrially produced in large series and large size, in spite of the relevant number of holes: some millions per square meter. Due to the technology used, the material budget of THGEM-based detectors is not particularly reduced and, because of the enlarged geometrical parameters, they cannot offer space resolution as fine as GEM-based detectors. Thanks to the reduced gaps between the multiplication stages, THGEM-based detectors can be easily operated in magnetic field. These features, shortly mentioned above, match very well the requirements of specific applications in fundamental research, where the large gain, the robustness, the production technique and the mechanical characteristics are advantages, while the material budget and the space resolution aspects do not represent a limitation. THGEMs are considered for the single photon detection in Cherenkov imaging applications [2], as active elements in hadron sampling calorimetry [3], for muon tracking [4] and for the read-out of noble liquid detectors [5].

So far, there have been two large production series of THGEMs: for the novel single photon detectors of COMPASS RICH-1 [2] and for the sensors of the LBNO-DEMO, a cryogenic two-phase Ar detector [6]. These large size THGEMs make use of fiberglass as dielectric material separating and supporting the two metallic faces, namely the two electrodes. Fiberglass is an economic material well mastered by PCB producers. In spite of the success of these first productions, some critical aspects of the THGEMs by fiberglass have been identified. Water can be trapped in the fiberglass, and later slowly released over long time periods affecting the atmosphere inside the detector and, therefore, favouring discharges. The woven texture of the fibres makes rough the internal surface of the THGEM holes, as can be seen in metallographic sections: this aspect is also a potential source of electrical instabilities. The presence of a glass-based component is the source of a long-term time evolution of the electric field of a biased multiplier, resulting in an important time-evolution of its gain [7]. These considerations suggest the identification of different materials suitable for the production of high quality THGEMs.

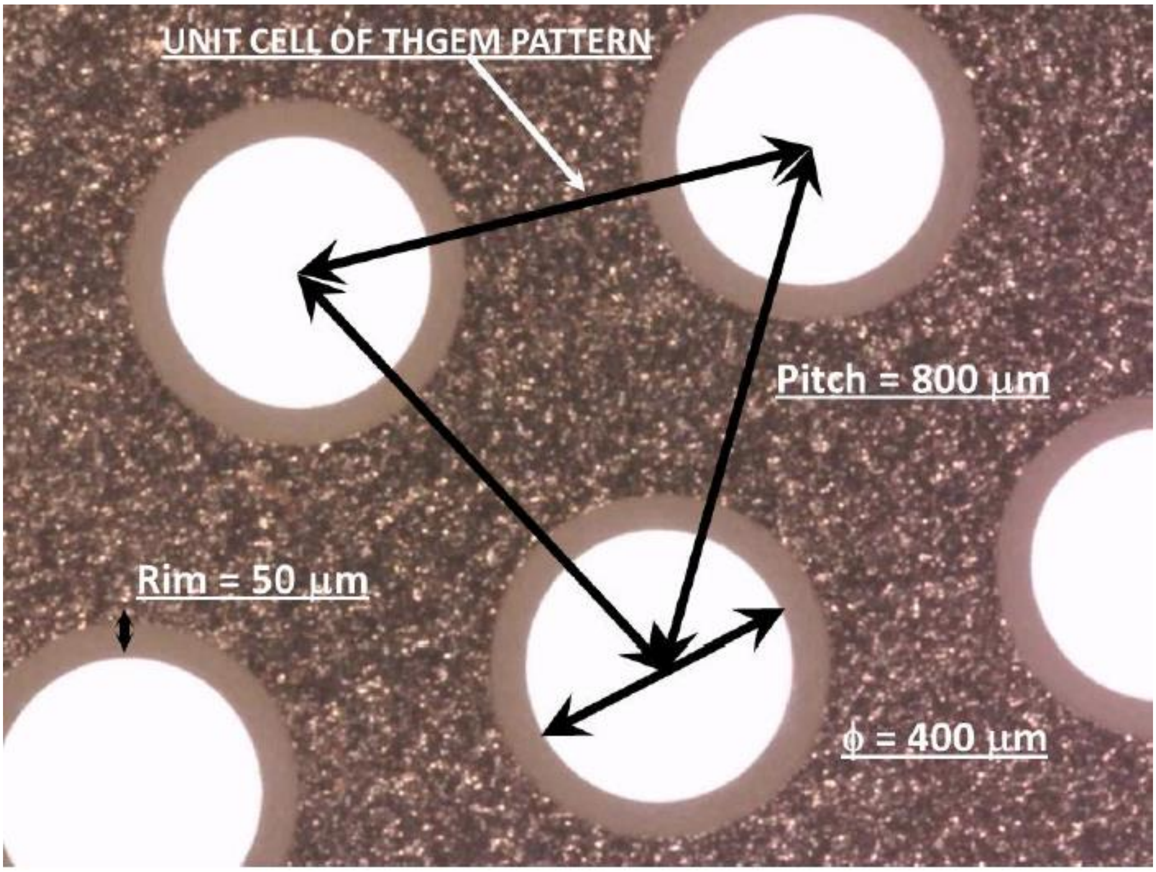

Fig. 1: Detail of a THGEM PCB (picture).

2. PERMAGLAS AS THGEM SUBSTRATE

Permaglas ME730 by RESARM Engineering Plastics SA (RESARM Engineering Plastics SA, rue Près-champs 21, 4671, Barchon, Belgium) is an epoxy glass fibre material, amorphous (no fibre weaving) and, therefore, easily machinable. The material components are the same as for fiberglass, nevertheless the material structure is substantially different and it is expected that the smoother internal surface of the holes contributes to good characteristics in term of the electrical stability of THGEMs by Permaglas. The planarity of a Permaglas plate is obtained by machining.

We have purchased samples of Permaglas plates, 50 x 50 cm^2, of two different nominal thicknesses: 0.70 mm (nominal tolerance: -0, +0.05 mm) and 1.00 mm (nominal tolerance: -0.04 mm, +0.04 mm). The thickness uniformity is a key requirement for THGEM performance: in fact, the gain uniformity of a THGEM is strongly related to the thickness one. It is expected that the plates with nominal thickness of 1.00 mm are more uniform, because this is the standard production thickness, while thinner plates are obtained by machining. The thickness of the Permaglas plates has been measured in a grid of nine points uniformly distributed on the plate surface. The peak to peak thickness variation is 4% and the r.m.s. is 2% for the nominal thickness of 0.7 mm, while these parameters are, respectively, 2% and 1% for the 1.00 mm plates. These figures are very promising.

THGEMs have been produced with the following geometrical parameters: hole diameter of 0.4 mm, hole pitch of 0.8 mm, no rim. GEMs of both thicknesses have been produced. The size of the active area is 30 x 30 cm^2, segmented in 6 strips electrically independent. In the following, we report in detail about the characterization of THGEMs with nominal thickness of 1.00 mm.

3. THE CHARACTERIZATION OF THGEMS BY PERMAGLAS

3.1. ELECTRICAL STABILITY STUDIES

The electrical stability of the THGEMs is studied by the Paschen test, namely comparing the maximum voltage that can be applied between the two THGEM faces with the phenomenological Paschen limit [8] that provides the maximum voltage that can be applied between two electrodes in a given atmosphere composition, at given pressure and temperature. A good THGEM has to reach at least the 90% of the Paschen limit.

Increasing voltage is applied to each of the six individual segment strips of a THGEM under controlled atmosphere, pressure and temperature; typically, not all the segments immediately reach the maximum voltage: in fact, the voltage application also acts as a commissioning procedure. The final voltage reaches or overcomes 90% of the Paschen limit for all the segments of the studied Permaglas THGEMs, as shown in the example presented in Fig. 2. Therefore, one can conclude that the THGEMS by Permaglas exhibit good properties of electrical stability.

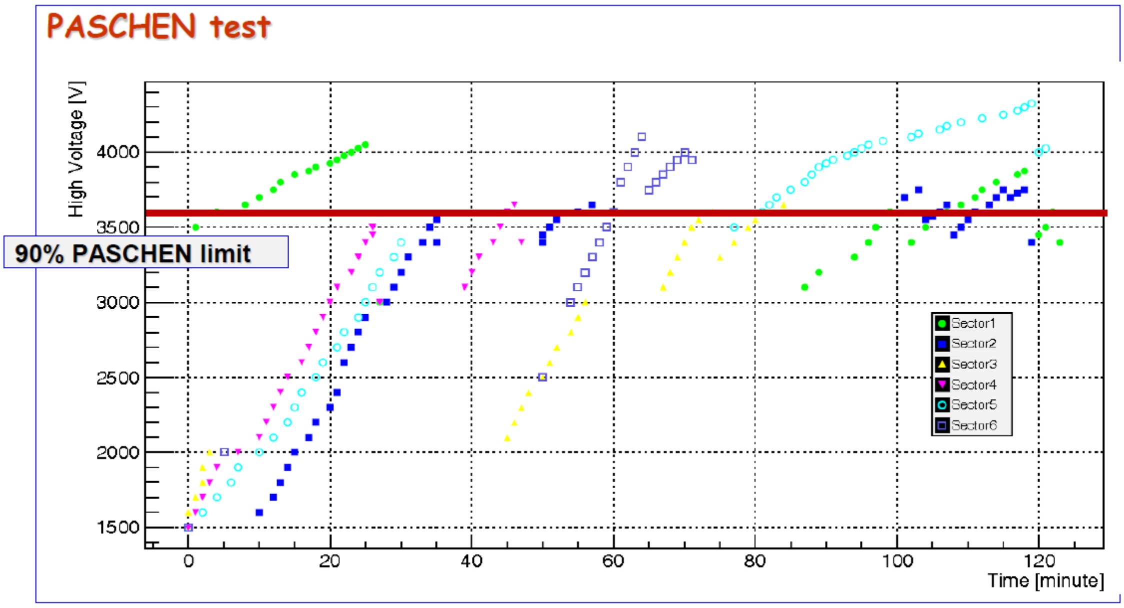

Fig. 2: The results of the Pashen test for the six segments of a 1.00 thick THGEM: the applied voltage versus the time is shown.

3.2. GAIN AND RESOLUTION ASPECTS

The characterization studies have been performed with the Permaglas THGEMs in single layer arrangement (Fig. 3) using a gas mixture Ar:CO$_2$=70:30 and an ^{55}Fe source.

Figure 4 presents a typical amplitude spectrum; the resulting resolution is r.m.s. 20%. The gain uniformity has been measured collecting spectra in a grid of 18 points (Fig. 5): the r.m.s. of the distribution of the 18 gain measurements is 13%. The gain evolution versus the applied voltage is shown in Fig. 6: the expected exponential behaviour is verified and the detector is electrically stable up to relevant gain values, larger than 500.

The gain studies show typical THGEM resolution in amplitude measurement, remarkably good gain uniformity and high gain potentialities.

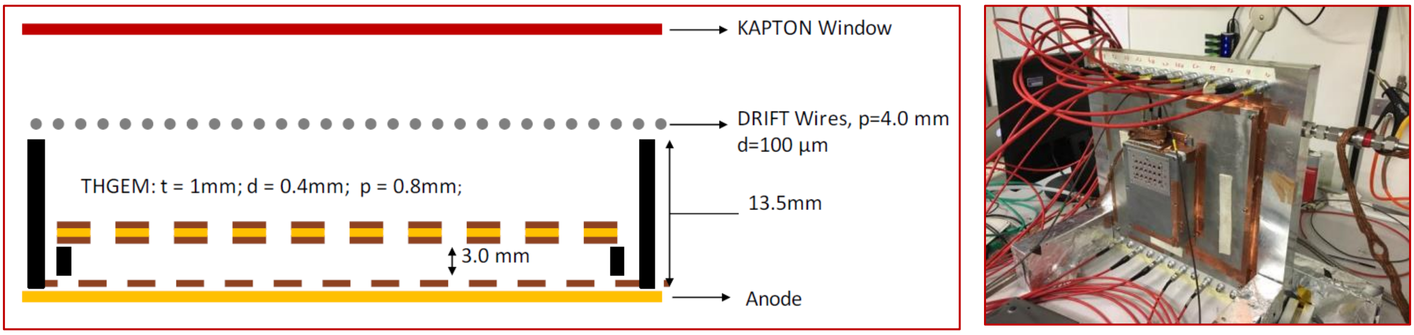

Fig. 3: (Left) Schema of the single layer Permaglas THGEM detector used for the characterization studies; (Right) detector picture.

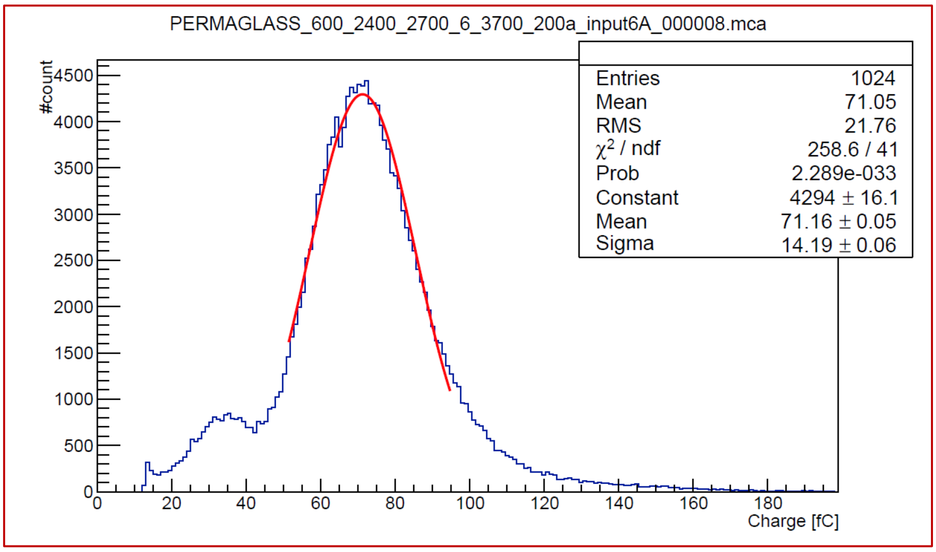

Fig. 4: Amplitude spectrum obtained illuminating a Permaglas THGEM in single layer configuration with an ^{55}Fe source.

Effective gain	**1**	**2**	**3**	**4**	**5**	**6**
A	150	139	139	134	120	121
B	121	108	101	103	116	116
C	142	105	121	121	116	90

Fig. 5: The gain uniformity measurement: the values of the main amplitude spectrum obtained illuminating with an ^{55}Fe source are reported.

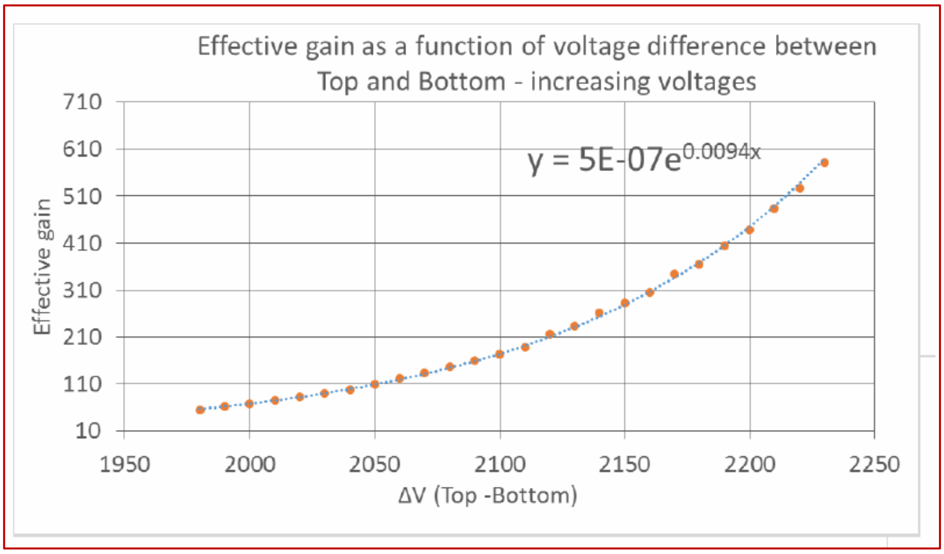

Fig. 6: Effective gain of the single layer Permaglas THGEM versus the THGEM biasing voltage.

3.3. GAIN DEPENDANCE VERSUS TIME

The gain evolution versus time of a THGEM has two components [7]: (i) one, faster, due to the charging up of the open dielectric surfaces and a (ii) second one, slower, related to the motion of ions in biased dielectric material. Both effects have been studied.

i. The gain evolution due to charging up is shown in Fig. 7: it is described by an exponential function with a time constant of about 23 minutes and maximum gain excursion of the order of 30-40%. Both the time constant and the gain excursion depend on the illumination rate. The behaviour observed is typical for THGEM multipliers.
ii. The gain evolution due to the motion of ions is illustrated in Fig. 8: it is described by an exponential function with time constant of about 333 minutes and maximum gain excursion of the order of 20%. The relatively short time constant and the modest gain excursion qualify Permaglas as a very good material for THGEM production. In fact, in THGEMs by fiberglass, gain excursions up to 500% and time constants of the order of 1 day have been reported [7].

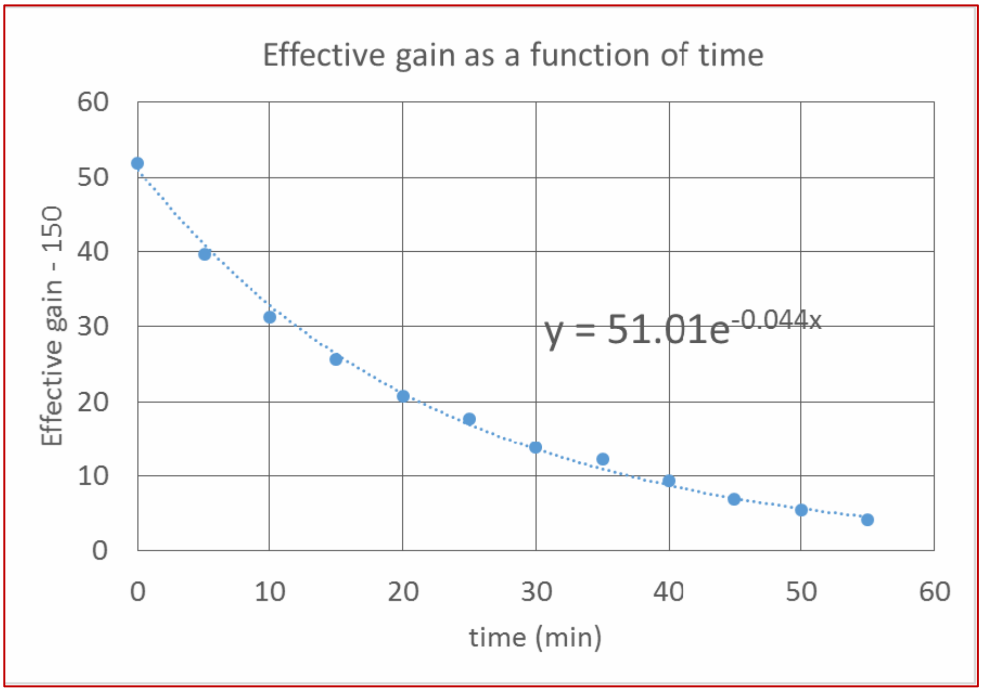

Fig. 7: Gain evolution of a detector including a single layer Permaglas THGEM versus time: charging up effect.

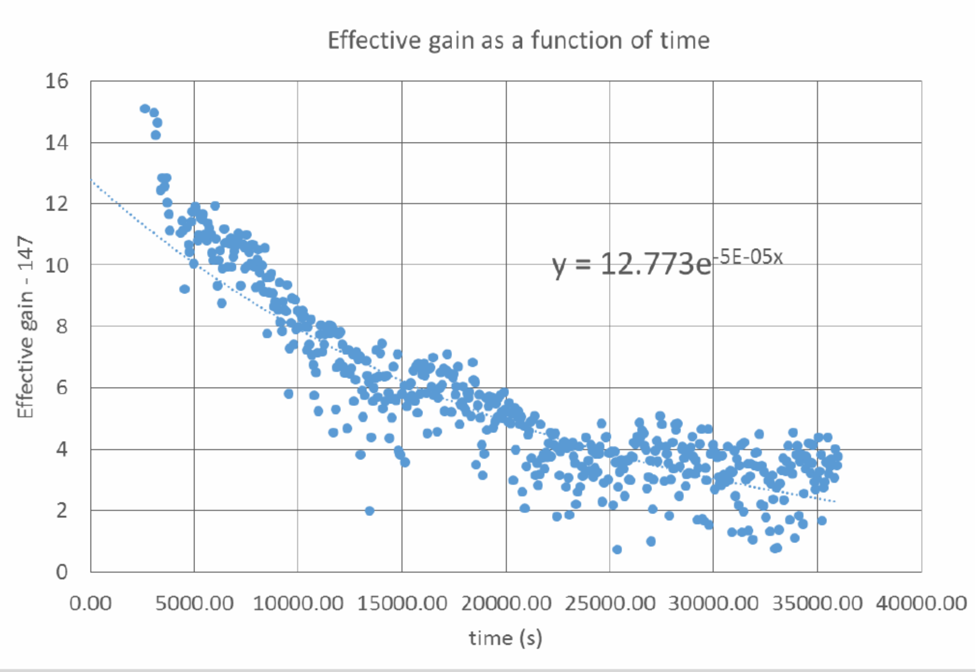

Fig. 8: Gain evolution of a detector including a single layer Permaglas THGEM versus time: ion motion effect.

4. CONCLUSIONS

The characterization studies qualify Permaglas as a suitable material for the production of high quality THGEMs; in particular, the gain uniformity, the high gain achievable preserving electrical stability and the modest gain evolution versus time due to the internal ion motion in the biased material exhibit remarkable good features suggesting the use of Permaglas in applications for fundamental science.

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ANNEX: GLOSSARY

Acronym	**Definition**
THGEM	THick Gaseous Electron Multiplier
PCB	Printed Circuit Board