PRELIMINAR STUDIES ON GEM FOIL DEGRADATION IN HARSH RADIATION ENVIRONMENTS

Tiago F. Silva, Marco Bregant, Geovane Grossi, Cristiane Jahnke, Marcelo G. Munhoz*

Physics Institute of the University of São Paulo – IFUSP
* tfsilva@if.usp.br

INTRODUCTION

Several High Energy Physics experiments are adopting Gaseous Electron Multipliers (GEMs) in substitution for the Multi-Wire Proportional Counters (MWPC) either in upgrade plans or in the design stage.

The ALICE experiment, for instance, is passing through upgrades that, among other goals, aim the replacement of the MWPC at the readout planes of its Time Projection Chamber (TPC) by a stack of four GEMs. By this replacement, achieving a higher count rate capability and no need for the gate mode of operation are definitely the ultimate goals. The count rate enhancement of the TPC together with the Inner Tracking System (ITS) upgrade shall increase the ALICE efficiency for particle identification drastically [1].

Another example is the upgrade of the CMS experiment where GEM are replacing the MWPC at the Muon chamber end caps. Improvements in the maximum limit of count rate and in the Higher Level Trigger are expected by adopting a stack of three GEM-foils [2].

Because of all this interest on GEMs for high count rates measurements, it is important to evaluate the degradation of its constituent materials under such circumstances.

This work aims to bring insights from material science to that matter. For this, we studied two possible effects that may play some role in the degradation process of the GEM foils in a harsh radiation environment: One of them is the Kapton degradation due to energy deposition by ionization, which is an effect expected to be triggered by highly energetic particles. The second process considered in this study is the degradation of the Copper clad. Opposite to the Kapton degradation, the Copper clad degradation may be induced by low energy ions associated to a sputtering process of the Copper or a material deposition on its surface, i.e. organic deposition, either from CO2 reduction or eroded Kapton.

DEGRADATION MODEL

Aiming the determination of the most important parameters that have influence in the detector lifetime, we established a model for the degradation of a GEM foil under a harsh radiation environment. The model consists of two separate processes: one for the degradation of the Kapton substrate, and another for the Copper clad.

In our model, the Kapton degradation it is expected to occur involving high energy particles, which induces ionization followed by the polymer molecular breakup.

Moreover, the degradation of the Copper clad is expected to occur involving low energy ions produced in the avalanche process, which can trigger a sputtering process of the Copper, or start a process for material deposition on its surface.

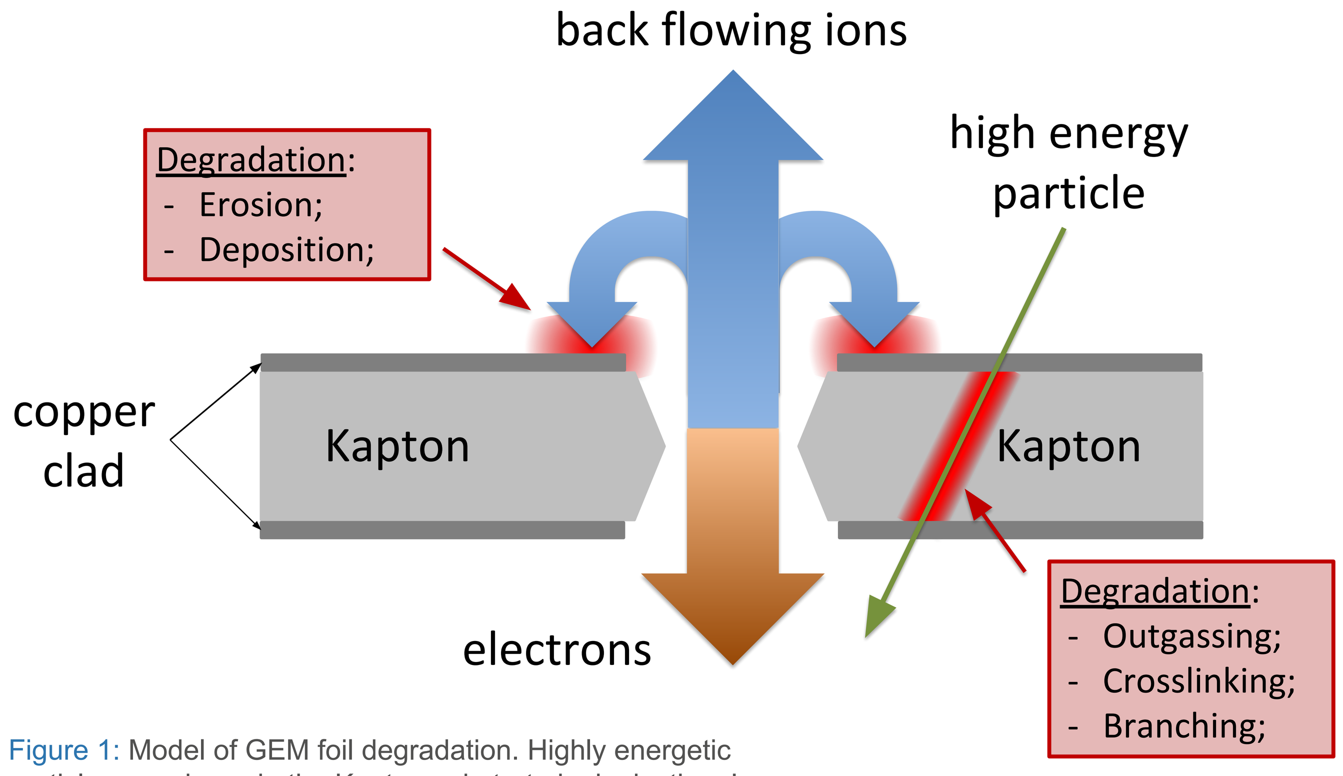
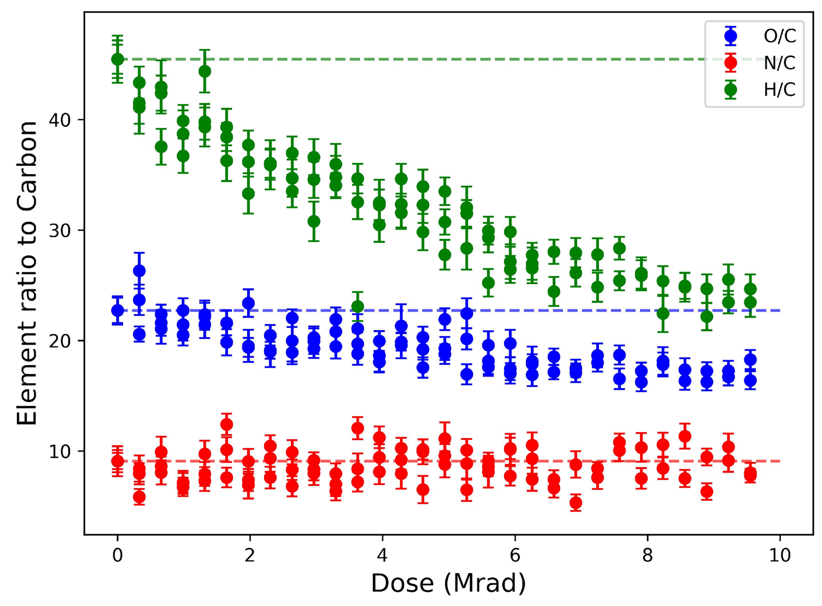


Figure 1: Model of GEM foil degradation. Highly energetic particles can degrade the Kapton substrate by ionization. Low energy ions produced in the cascade can degrade the Copper clad by erosion or deposition of organic materials.

KAPTON DEGRADATION

We degraded a Kapton foil using 2.2 MeV He^+ ions. At this energy, the electronic stopping dominates the interaction processes, thus depositing energy by sequences of ionization. The Kapton composition was assessed by real-time nuclear scattering spectrometry, revealing the Hydrogen losses as the major effect (see Fig. 2). It is expected that the mechanism of Hydrogen loss involves the outgassing of H_2 molecules [3]. Oxygen loss is expected in the form of outgassing of either CO or CO_2 molecules.



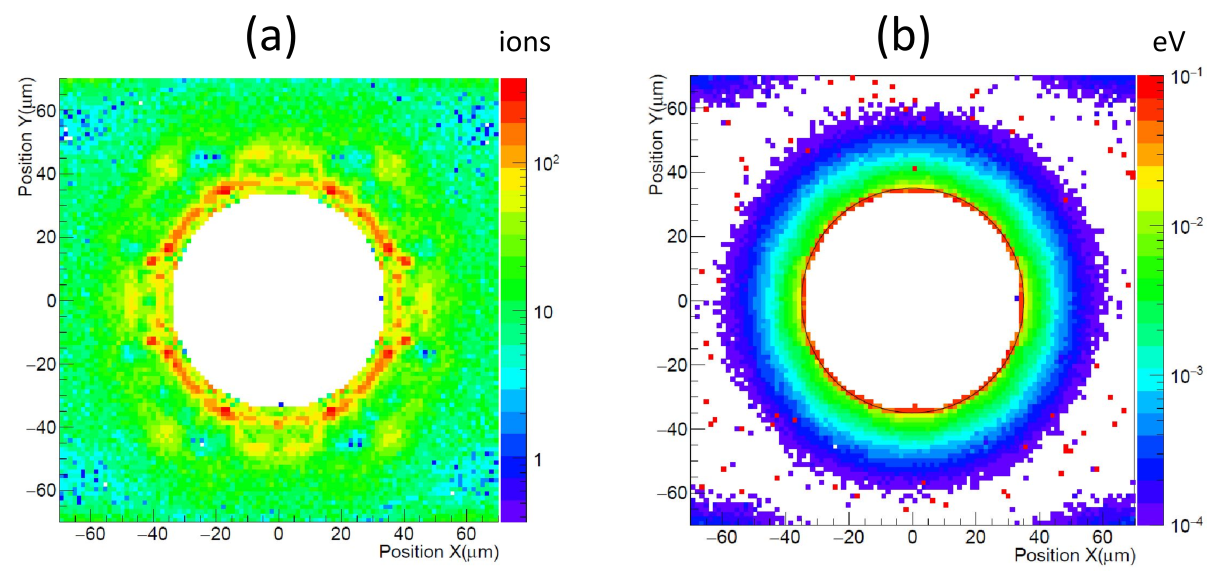
Thanks for the real-time scattering spectrometry to the Laboratory of Material Analysis by Ion Beams (LAMFI-USP)

Figure 2: Oxygen, Nitrogen and Hydrogen ratio do Carbon amounts as a function of absorbed dose. The dashed lines represent the ratios for the pristine Kapton ($C_{22}O_5N_2H_{12}$).

COPPER CLAD DEGRADATION

Part of the low energy ions generated during the avalanche process is expected to hit the upper surface of the GEM foil (see schematic in Fig. 1). This effect was simulated using the Garfield++ framework [4]. Fig. 3 (a) shows a map of hits distribution of Argon ions; Fig. 3 (b) shows the mean kinetic energy of the Argon ions right before hitting the GEM foil surface.

Figure 3: Argon ions hits at the upper surface of a GEM foil as simulated using Garfield++ framework. (a) Map of hits distribution; (b) Mean kinetic energy of Argon ions right before hitting the surface.



CONCLUSION AND PERSPECTIVES

In this preliminary study of the degradation process of GEM foils when submitted to a harsh radiation environment, we established a model considering the Kapton substrate and the Copper clad degradation separately.

The Kapton degradation was emulated by a 2.2 MeV Helium ion. A high rate of Hydrogen loss was observed. The Copper clad degradation by low energy ions was explored through simulations. The maximum observed energy of Argon ions that hits the upper surface of the foil was ~0.1 eV, not enough to trigger an erosion process of the clad (sputtering threshold energy of ~27 eV [5]).

As a perspective of this work, we intend to approach the organic material deposition at the GEM surface.

References

[1] Technical Design Report for the Upgrade of the ALICE Time Projection Chamber” (DOI: 10.13140/RG.2.1.1761.7681).

[2] A. Colaleo, CERN-LHCC-2015-012, 2015.

[3] M.E. Adel et. Al, Journal of Applied Physics 66, 3248 (1989).

[4] H. Schindler, Garfield++, http://garfieldpp.web.cern.ch/garfieldpp/ (May, 2019).

[5] W. Eckstein, Sputtering Data, IPP REPORT 8/82, 1993.

Financial Support

CNPq Conselho Nacional de Desenvolvimento Científico e Tecnológico
FAPESP FUNDAÇÃO DE AMPARO À PESQUISA DO ESTADO DE SÃO PAULO