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Production and Characterization of GEM Foils in India

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Abstract

The Gas Electron Multipliers (GEM) foils have been successfully produced for the first time in India in collaboration with Indian Industry. We will present the first results on a comprehensive quality control (QC) and characterisation of these GEM foils involving optical (geometrical) and electrical properties. We will present the results on the inner and outer hole diameter studies as well as size uniformity and leakage current measurements. The measured mean diameter and uniformity of the holes and pitch are found to be consistent with the desired parameters. The electrical measurement results are well within the thresholds and in agreement with the double mask foils produced elsewhere.

Motivation

- Performance of RPCs limited due to space charge effect and the problem of aging
- Experiments such as CMS at the LHC to face high rate during high luminosity phase (HL-LHC)
- CMS Muon detector requirements
  - Detector should be able to cope up with high rate
  - Good timing resolution for fast triggering
  - Better spatial resolution so as to use it as a tracking detector
  - Should be radiation hard
- Micropattern gas detector such as Gas Electron Multiplier (GEM) [1] seems a suitable option
- Various other High Energy Experiments such as ALICE[2], TOTEM[3], LHCb[4] etc. are currently using GEM technology successfully.
- CERN being only the sole distributor of the GEM foils
- Production of large area GEM foils to ease the commercialization

Introduction

GEM

- Thin double-sided metal-coated polymer foil chemically pierced by a high by a high density a high densityof holes [1]
- Typicaal parameters:
  - Kapton meteal coated ~50µm
  - Pitch ~140µm
  - Cu thickness ~5µm
  - Hole density ~50 to 100mm^{-2}

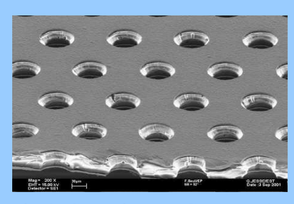


Fig 3. SEM image GEM Hole distribution

Performance

- Rate Capability ~10^5 Hz/cm^2
- Spatial Resolution ~100µm
- Temporal Resolution ~5ns
- Detection Efficiency ~98%

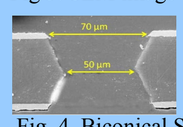


Fig. 4. Biconical Single hole of a typical double-mask GEM foil

Foil production in India

- Micropack Pvt. Ltd. [5] in Collaboration with other research institutions of India including University of Delhi signed a Transfer of Technology (TOT) agreement in 2013 with CERN for the development of GEM foils in India
- Micropack has been successful in realizing 10 cm x 10 cm double-mask GEM foils as shown in Fig. 1.
- Foils are produced in similar fashion as produced at the CERN PCB workshop [6]
- Fig. 3. shows cross-sectional view of the foil showing the double cone structure of the engraved holes

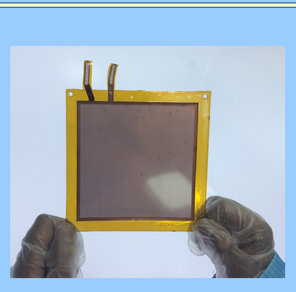


Fig. 1: Newly produced 10 cm x 10 cm GEM foil

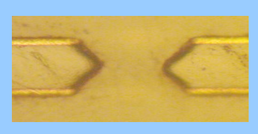


Fig. 2: Perfect Bi-Conocal Single Hole Structure

Measurement Setups

Optical Setup

- A Soft Box (1 m × 1 m) light source to provide uniform illumination to the GEM foils
- Foils scanned using Micro lensing technique with an AF-S Micro Nikon 40 mm 1:2.8G lens where multiple images of micrometer resolution per pixel were captured

Electrical Setup

- The measurement setup consists of a bare GEM foil connected to Keithley 6517B picoammeter interfaced with a computer via a GPIB interface and the Labview program used to record the measurements

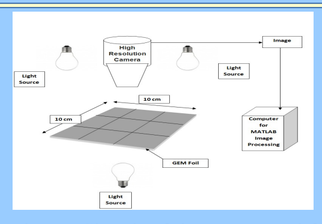


Fig. 5.: Sketch of the setup used for the optical measurements.

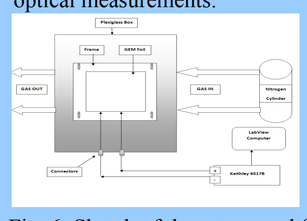
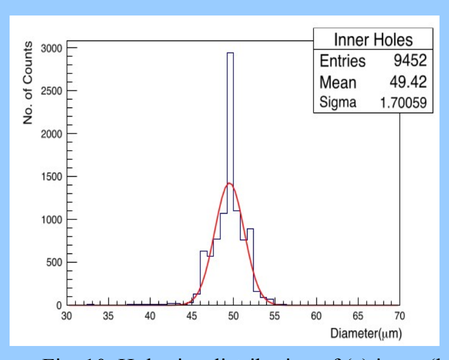


Fig. 6: Sketch of the setup used for the measurement of leakage current.

Optical Study

- Inner and outer hole diameters have been measured optically
- To assess the entire area of the foil, each of the foils were divided into several sub-sectors



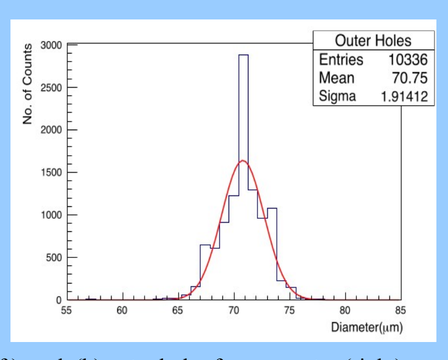
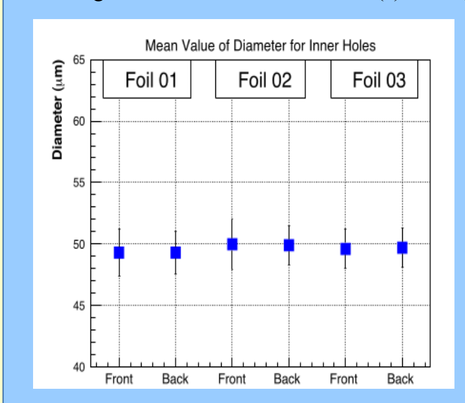


Fig. 10. Hole size distribution of (a) inner (left) and (b) outer holes for one sector (right).



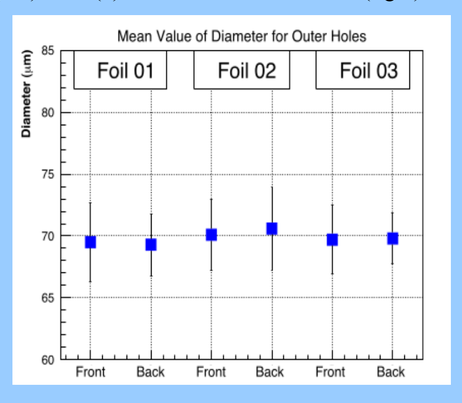
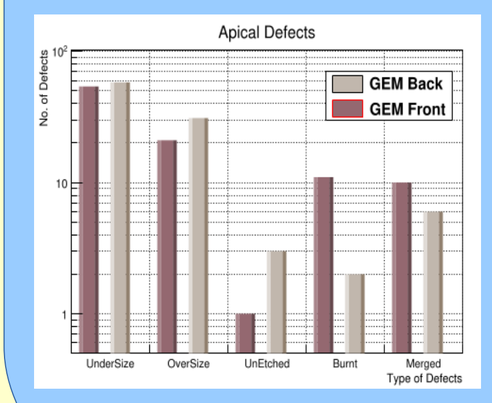


Fig. 11. Mean diameter for (a) inner (left) and (b) outer holes for each side of GEM foils (right).



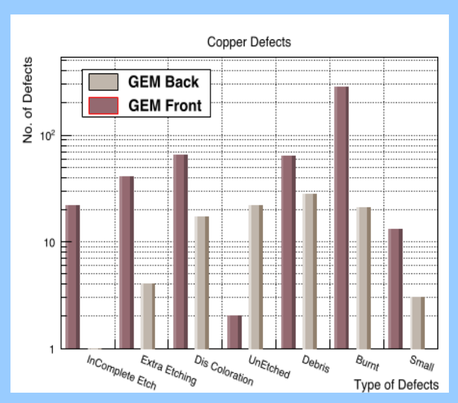


Fig. 12. Number of defects seen in (a) insulator (left) (Apical Type NP) and (b) Copper, for one of the 10 cm × 10 cm foil (right).

Surface Morphology

- Various imperfections have been observed and are shown in Fig. 7 and Fig. 8.
- Scan with the front light ON and the back light OFF has been performed as to make the scan sensitive to the outer holes.
- For the inner holes of the foil, the scan has been performed with the front light OFF and back light ON

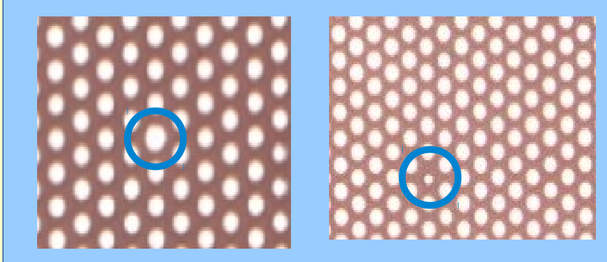


Fig. 7. Observed imperfections in the foils: (a) over-size hole (left) (b) undesize hole (right).

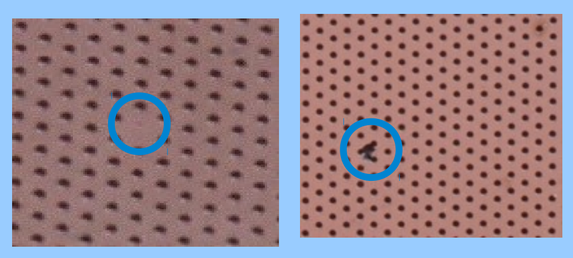


Fig. 8. Observed imperfections in the foils: (a) missing hole (left) (b) excess etching (right).

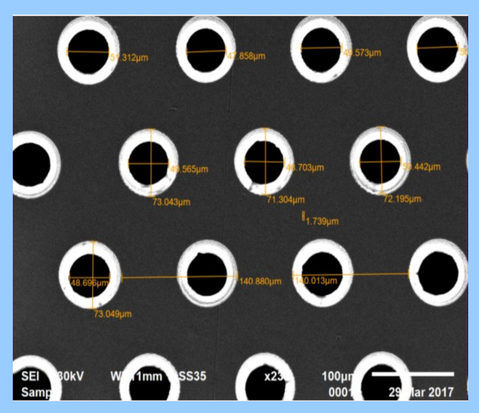
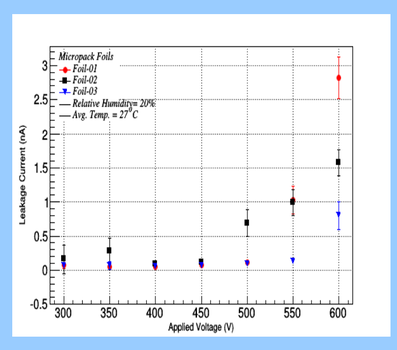


Fig. 9: SEM image showing the overall uniformity, pitch, inner and outer hole diameter's

Electrical Study

- Quality control short and quality control long (QC long) as per the CERN standards of quality control classification
- QC fast gives the preliminary idea of leakage current
- QC long provides the informationtion regarding the actual leakage current and the number of discharges



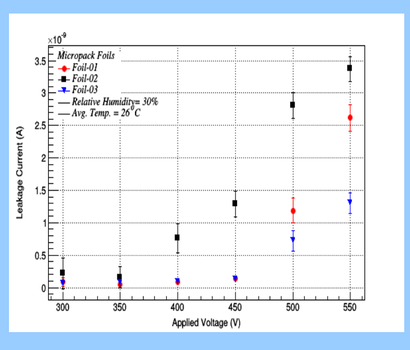
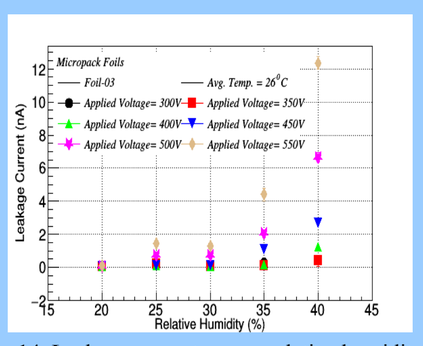


Fig. 13. Leakage current of micropack Foils at relative humidity of 20% (left) and 30% (right) and at a constant temperature. Leakage currently is strongly affected by humidity variations.



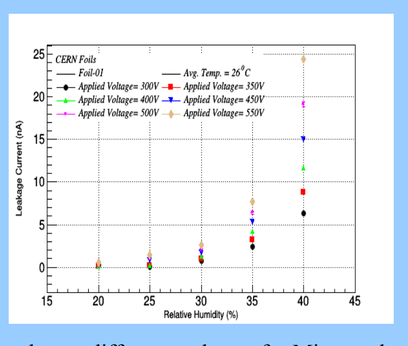
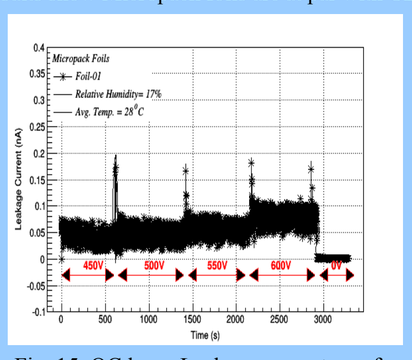


Fig. 14. Leakage current versus relative humidity taken at different voltages for Micropack foils (left). For comparison same measurements have been perfoemed CERN foils (right). Results show Micropack foils are at par with CERN foils.



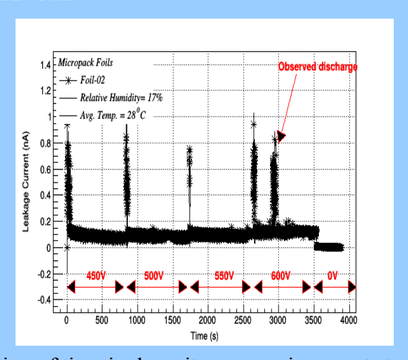


Fig. 15. QC long: Leakage current as a function of time in dry nitrogen environment at different voltage steps with an average ambiant temperature of T = 28 ^{0}C and relative humidity equal to 17%. Either no or maxmum one discharge has been observed at 600V

Summary and Outlook

- GEM foils were produced for the first time in India under the TOT agreement between Micropack Pvt. Ltd. and CERN
- Optical tests reveal that the holes are quite uniform with inner and outer diameters of 49.9±1.6 µm and 70.01 ±2.02 µm respectively
- Current of less than 1nA has been observed in dry nitrogen environment from electrical measurements and were in agreement with CERN foils
- The measured optical and electrical properties of Micropack foils were found to reflect the desired parameters and are at par with the double mask foils produced at CERN
- Tripple GEM Detector has been assembled and its performance tests are ongoing

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