R&D of Commercially Manufactured Large GEM Foils

College of Science and Technology
TEMPLE UNIVERSITY®

Matt Posik[1] and Bernd Surrow[2]

[1]posik@temple.edu [2]surrow@temple.edu

Temple University, College of Science and Technology, Philadelphia, PA

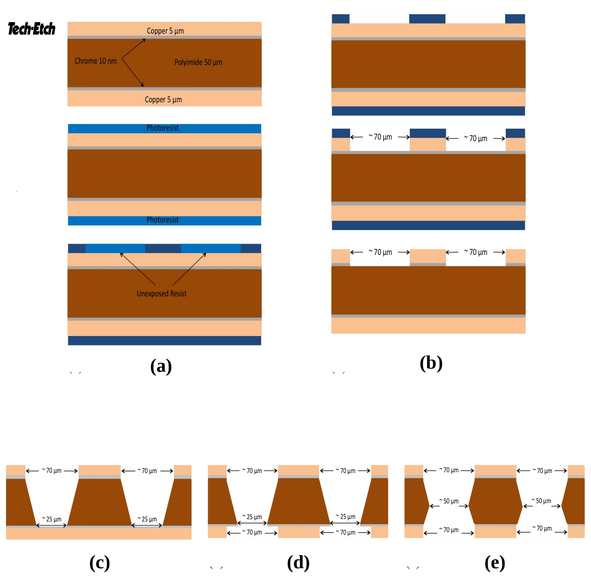
www.tech-etch.com

CIPAP d'Elba, Italy, May 24-30, 2015

Motivation

- Currently CERN is the only main distributor of GEM foils.
- Many physics experiments are either already using or are developing detectors that incorporate GEM technology. This has created a large demand in the particle and nuclear physics communities for GEM foils.
- To help alleviate this demand, Tech-Etch has succeeded in the commercialization of GEM foils via the single-mask and double-mask processes.
- The single-mask process is critical for the production of large area (~ 1 m long) GEM foils.

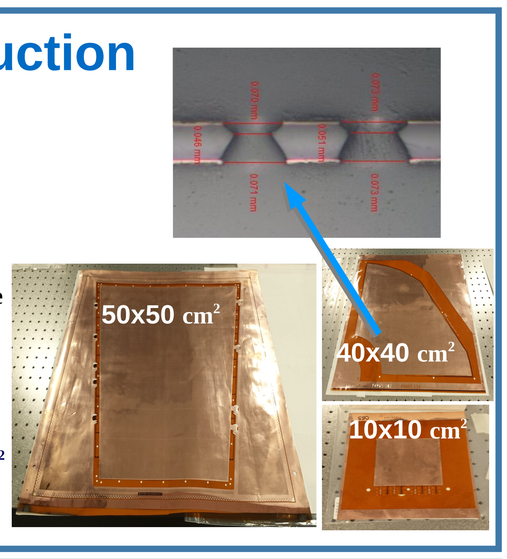
Single-Mask Process



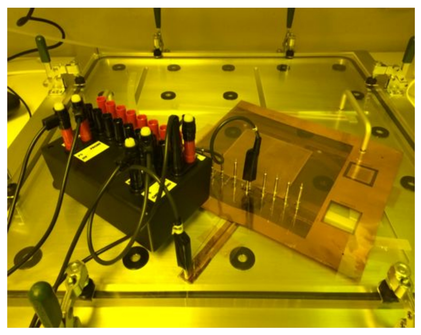
- (a): Coating of bare foil (~ 5 µm copper and ~ 50 µm polyimide layers) with photoresist and use of laser direct imaging to apply single-mask micro pattern.
- (b): The removal of unexposed photoresist, etching of front side copper layer, and removal of the chrome adhesive.
- (c): EDA chemistry is used to etch the front side of the polyimide layer.
- (d):The back side copper layer is etched via electrolytic etching.
- (e): The etching of the back side polyimide is done using EDA chemistry.

Tech-Etch GEM Production

- Three foil sizes have been produced by Tech-Etch: 10x10, 40x40 and just recently 50x50 cm^2.
- There were three 10x10 cm^2 manufacturing lots produced for Temple University consisting of 6/12/6 foils respectively.
- There was one 40x40 cm^2 manufacturing lot produced for Temple University consisting of 3 foils.
- The electrical and geometrical properties of all 10x10 and 40x40 cm^2 single-mask GEM foils have been analyzed.
- Tech-Etch is in the process of fine tuning foils of about 50x50 cm^2



Measurement Techniques

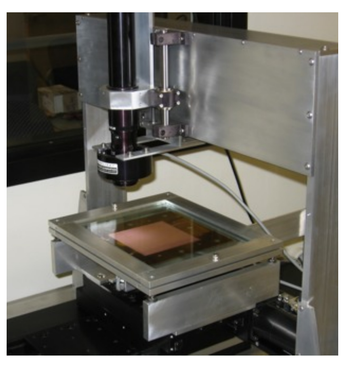


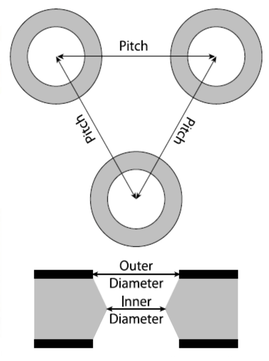
Electrical Analysis

- The electrical quality of a GEM foil is determined by its leakage current.
- Leakage current measurements are performed in a class 1,000 clean room.
- The foil is placed in an air tight enclosure which is flushed with nitrogen.
- Leakage current results measured at Temple University were taken after about an hour of nitrogen flushing time.

Optical Analysis

- Geometrical properties such as pitch, inner (polyimide layer) and outer (copper layer) hole diameters are determined using an automated 2D CCD scanner.
- This CCD scanner is unique in the micro-patten community as it allows the scanning of the entire active area of the GEM foil.
- By changing the lighting options of the CCD scanner, one is sensitive to either the inner (back lighting) or outer (front lighting) hole diameters.

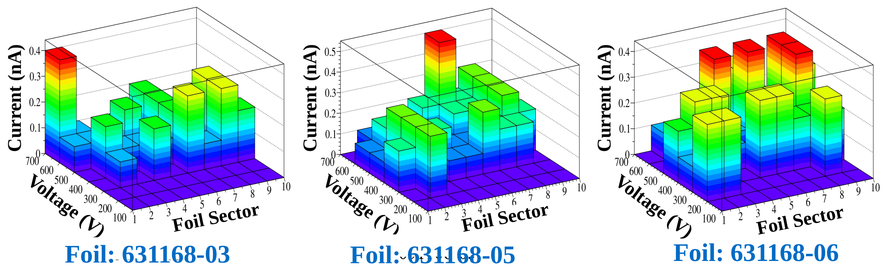




Electrical Performance

- Single-mask GEM foils switched polyimide material from Kapton to Apical resulting in a leakage current that is about 10 times smaller.
- Single-mask foil leakage currents were typically measured to be less than 1 nA for up to 600 V for all foils.
- Leakage current measurements agree with those measured independently by Tech-Etch prior to shipping foils.
- Tech-Etch single-mask foils showed same electrical performance as CERN single-mask foils.

40x40 cm^2 Leakage Current Measurements

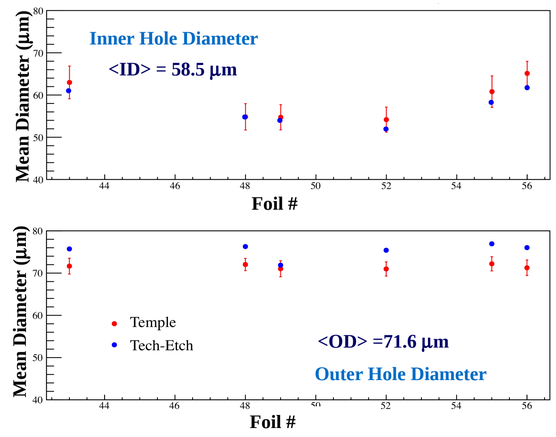


Foil: 631168-03 Foil: 631168-05 Foil: 631168-06

Geometrical Properties

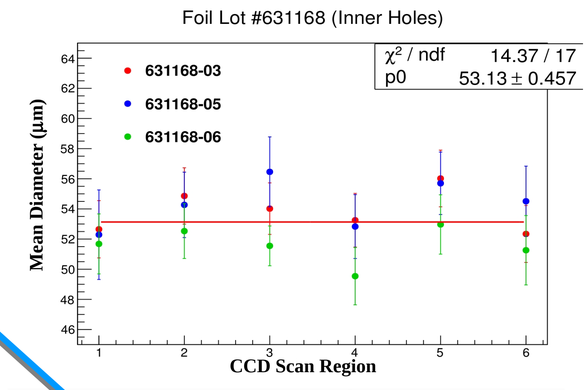
10x10 cm^2 Single-Mask GEM Foils

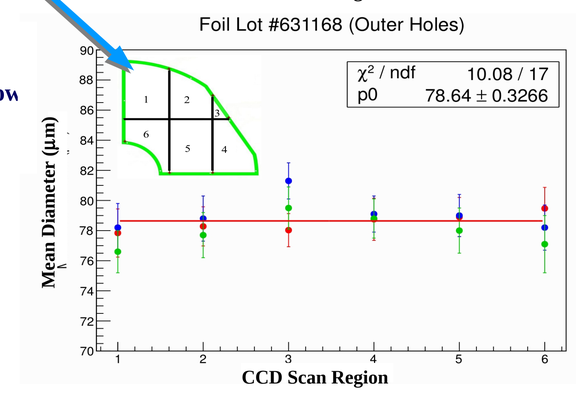
- The mean pitch = 138 µm and inner (outer) hole diameters = 58.5 (71.6) µm across all foils are consistent with previous GEM foils produced via the double-mask process: pitch = 139 µm, inner (outer) diameters = 56.7 (78.4) µm.
- These foils have excellent hole uniformity. The inner and outer hole deviations from the mean were found to be about +/- 6 µm, with the inner hole diameters having the largest deviation.
- Simple calculations were done which show such a deviation in hole uniformity would not have a significant affect on the reconstructed hit position or resolution of a potential tracking detector.
- Tech-Etch inner and outer hole diameter measurements (includes only 9 holes) agree with those measured at Temple University (includes all holes).



40x40 cm^2 Single-Mask GEM Foils

- Due to travel limitations of the CCD scanner, larger foils needed to be divided into 6 scan regions.
- The mean geometrical properties across all foils were found to be similar to those of the 10x10 cm^2 foils: pitch = 138 µm, inner (outer) hole diameters = 53.1 (78.6) µm.
- Inner and outer hole deviations were all found to be below +/- 10 µm, with the inner (outer) hole deviations widths ranging from σ = 1.7 to 3 (1.1 to 1.8) µm.

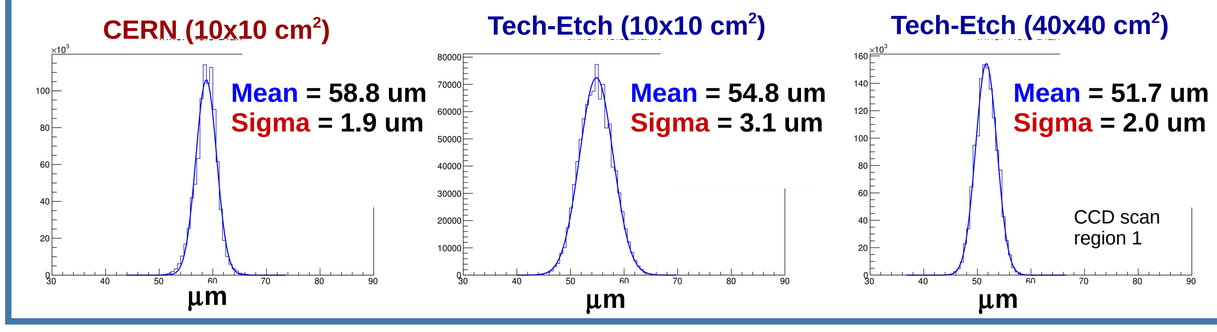




CERN Single-Mask GEM Foil Comparisons

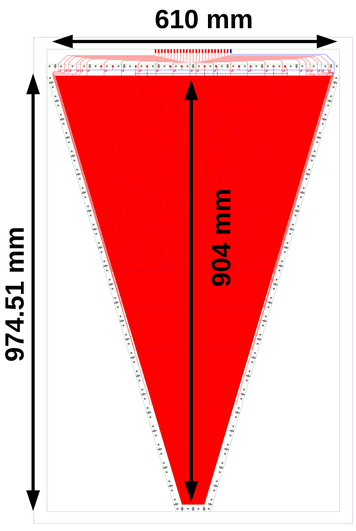
- 3 10x10 single-mask CERN foils were compared to 10x10 and 40x40 single-mask Tech-Etch foils.
- The CERN mean inner hole diameters, widths, and pitches are consistent with those found in Tech-Etch foils.

Inner Hole Diameter Distributions



EIC Foil Design

- A common EIC GEM foil design has been established between Florida Tech, Temple University, and Uva
- Common foil design to be manufactured at Tech-Etch and used in three different prototype EIC tracing detectors.
- Each foil segment has an opening angle of 30.1 degrees, and has a maximum height and width of 974.51 and 610 mm.
- The foil has a total of 24 HV segments, each with an area of about 107 cm^2.
- There are 8 azimuthal and 16 radial HV segments.
- The unique design simultaneously satisfies all three institutions GEM stretching and assembling techniques. Including building chambers via screws or glue.



Summary

- Commercialization of single-mask (and double-mask) GEM foils has been established at Tech-Etch.
- With the switch from Kapton to Apical material, all foils were found to have exceptional electrical properties, with the leakage current being reduced by about an order of magnitude (typically below 1 nA).
- The geometrical properties of the Tech-Etch single-mask 10x10 and 40x40 cm^2 GEM foils were found to be consistent with each other and previously produced double-mask foils and single-mask CERN foils.
- The single-mask foils also showed very good inner and outer hole diameter uniformity across the entire active area.
- Production of 50x50 cm^2 single-mask foils is well underway at Tech-Etch, and they are now fine tuning their manufacturing parameters for commercial foils.
- Tech-Etch is actively into upgrading their manufacturing facilities to accommodate foils on the order of 1 m long.