# Precision GEM Production in Korea

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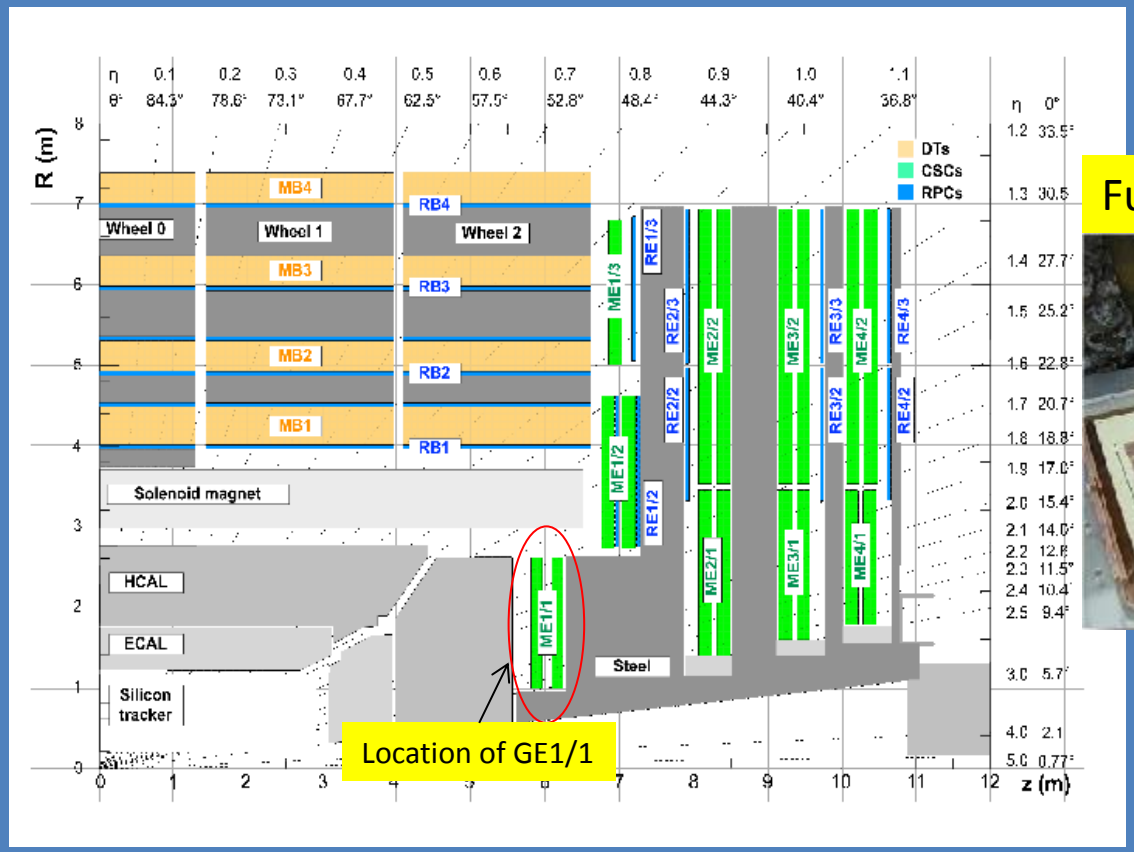
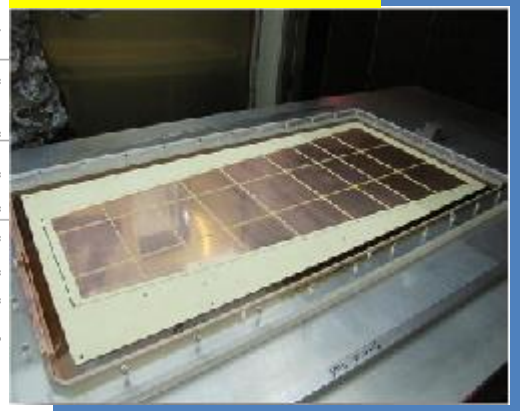
**Work presented here has been done before the signing of technology transfer agreement with CERN on GEM production.**

# GEM Detector for CMS Upgrade

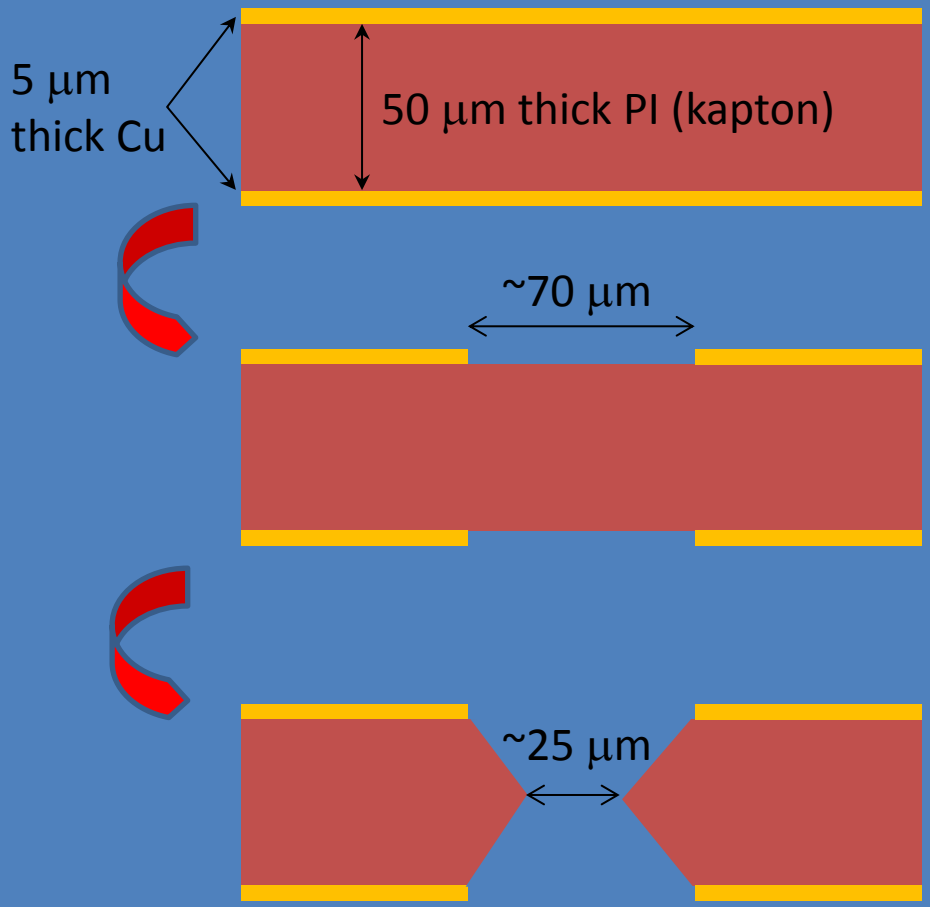



Full size GEM foil



- Triple GEM foil detectors for CMS detector upgrade in LS2
- for GE1/1 project, we need total 250~290 $m^2$ of GEM foils.

# GEM Fabrication




**FCCL**

**Cu hole etching**

- **Double mask**
- **Photolithography**
- **Chemical etching**

**PI etching**

- **Chemical etching**

# Players

- Academic Institutions
  - Univ. of Seoul and Chonbuk National Univ.
    - 3~4 more Universities to join.
  - R&D on PI (kapton) etching with Mecharonics.
- Saehan Micro Tech Co., Ltd.
  - Copper hole etching
- Mecharonics
  - PI hole etching
- And … CERN
  - provided GEM patterns
  - technical assistance (in the future)

# Mecharonics (www.mecharonics.com)

Semiconductor parts manufacturer in Korea.
Products: Heater block, Chemical Precursor, etc.


- Head Quarter & Production Facility
- Clean room : 1000 $m^2$

- R&D and Production Facility
- Clean room : 1300 $m^2$
- R&D for GEM foil fabrication done here


# Copper Etching

- Saehan Micro Tech Co., Ltd. is solely responsible for copper hole etching
  - Outsourcing is cheaper in the R&D phase
  - Mecharonics will take over in the full scale GEM foil production

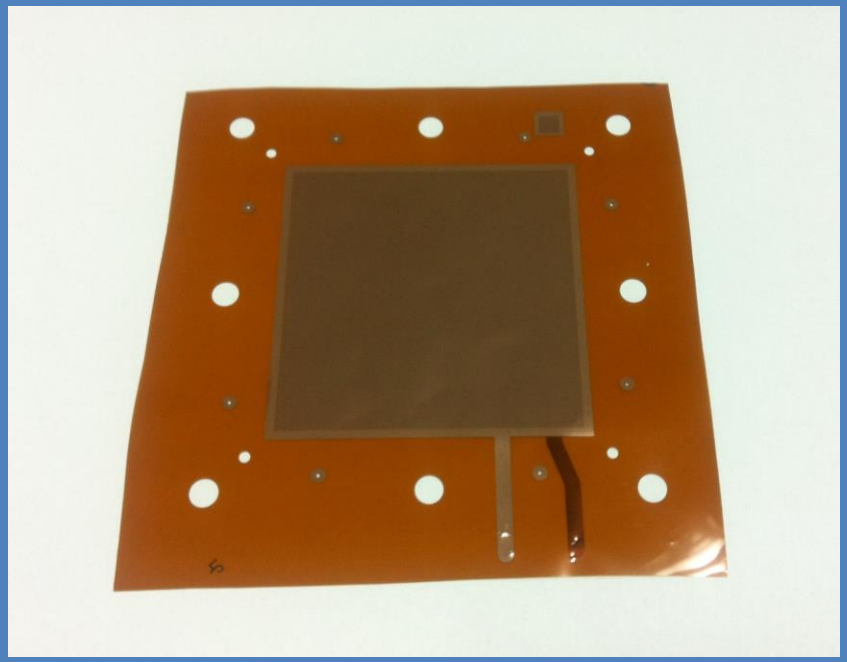
- Double Masking
- Full sized holes (ø~70 μm) are etched
- Hole size can be controlled at ~2 μm level

# What We Have Done for PI Etching

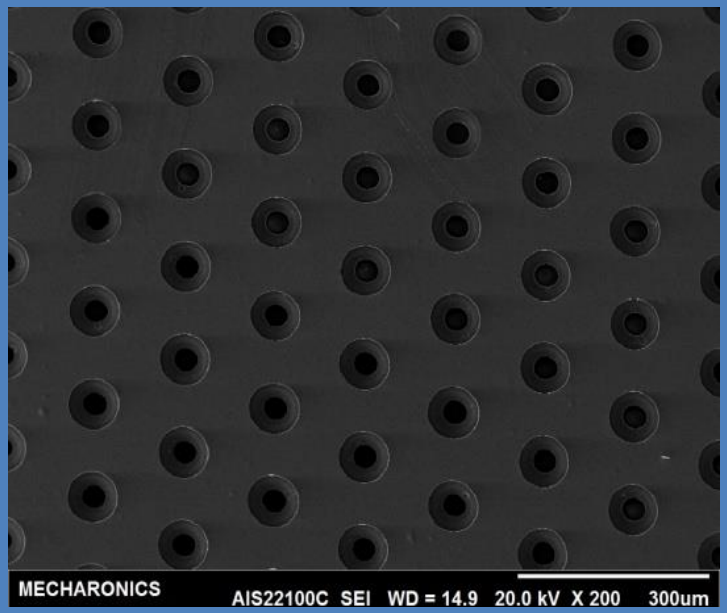
- Tried a couple of home brew etchant admixtures.
- Varied etchant temperature, etching time, and tried nitrogen bubbling to study for various effects.
- Mainly worked on 10 x 10 $cm^2$ GEM foils cut from a 3M produced FCCL roll.
  - We are trying other brand FCCLs.

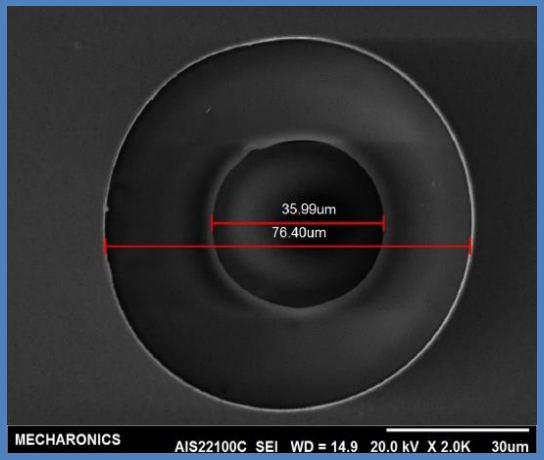
# 10 x 10 $cm^2$ GEM Foils

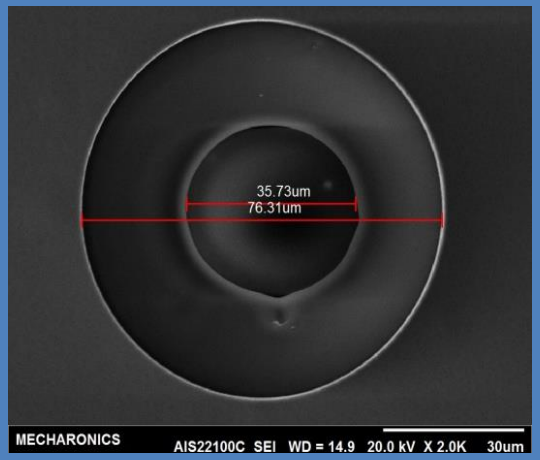
Produced six 10 x 10 $cm^2$ foils from a “cheap” 3M FCCL sample.



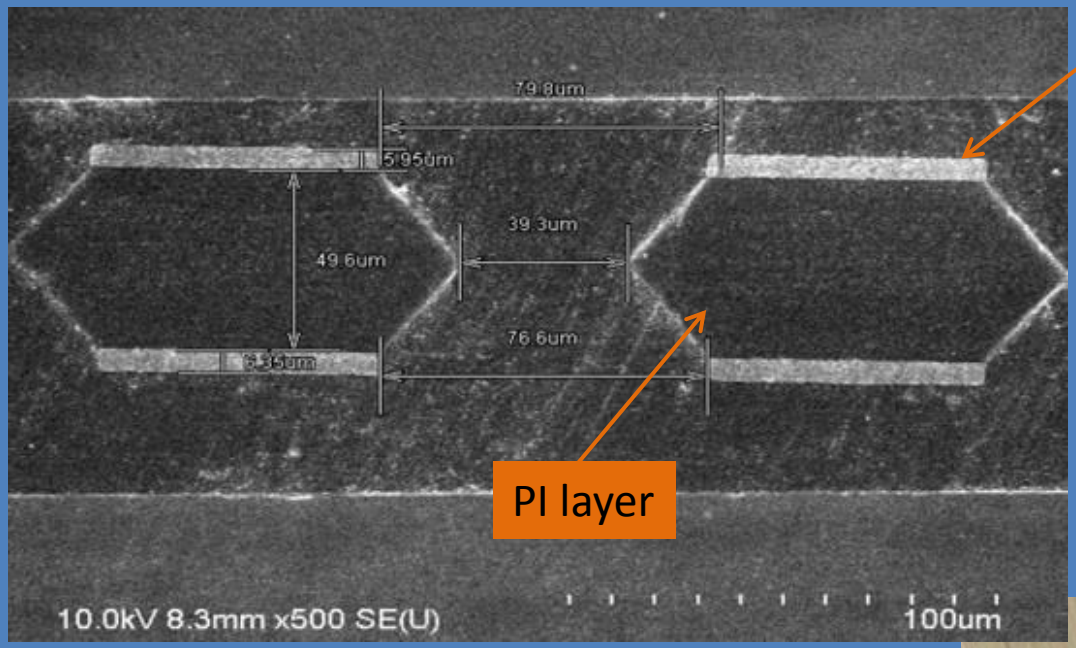
# Top View (SEM Images)



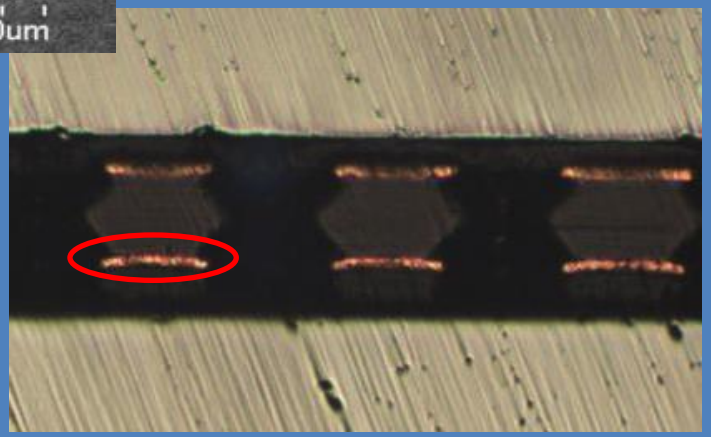
# Cross Section View




Cu layer

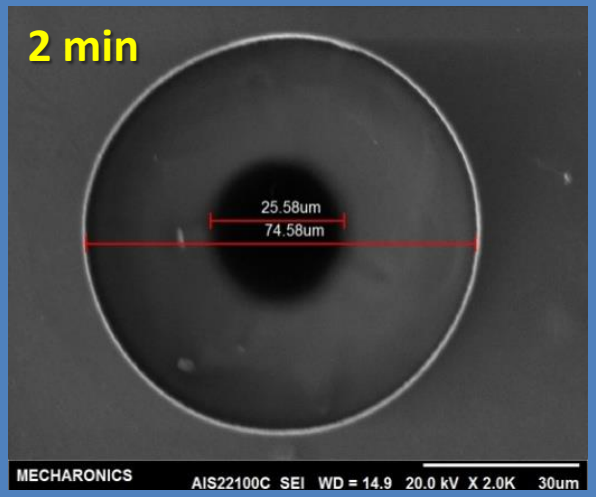
What we can do now

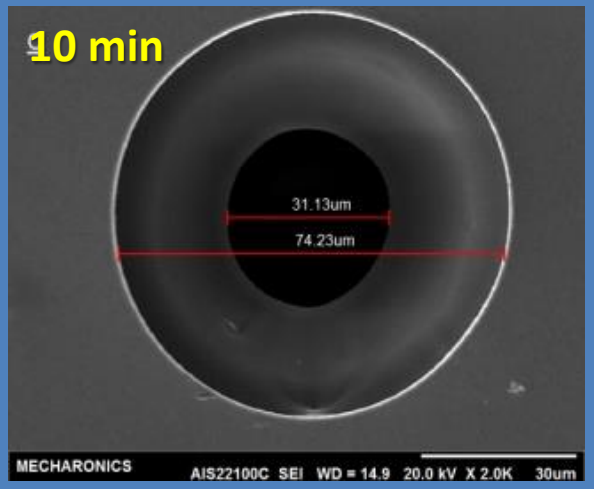
What we had earlier this year
with a different etchant

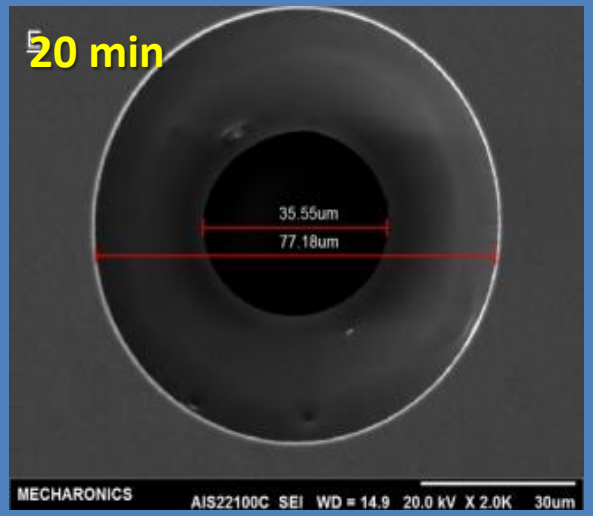


# PI Hole Size Control

Size of PI hole depends on the etching time.



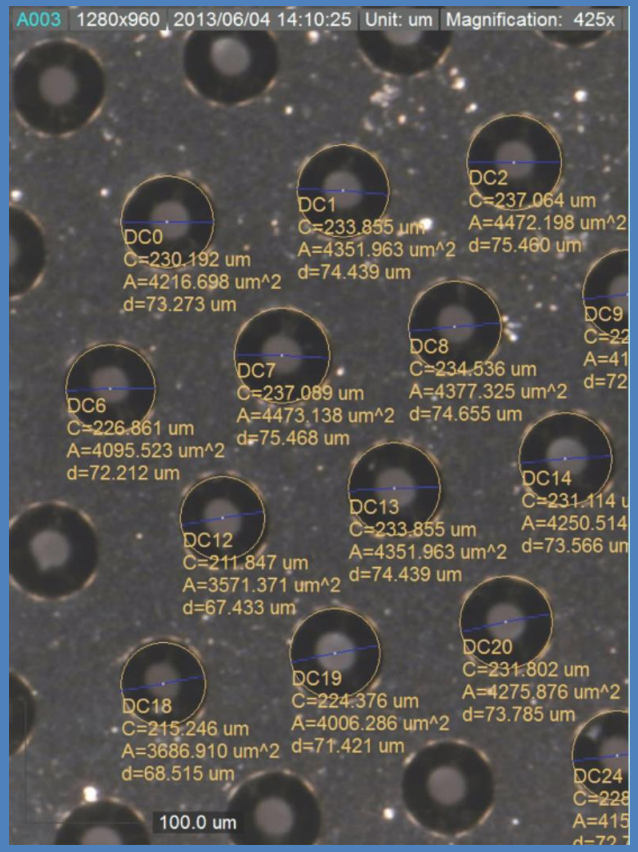



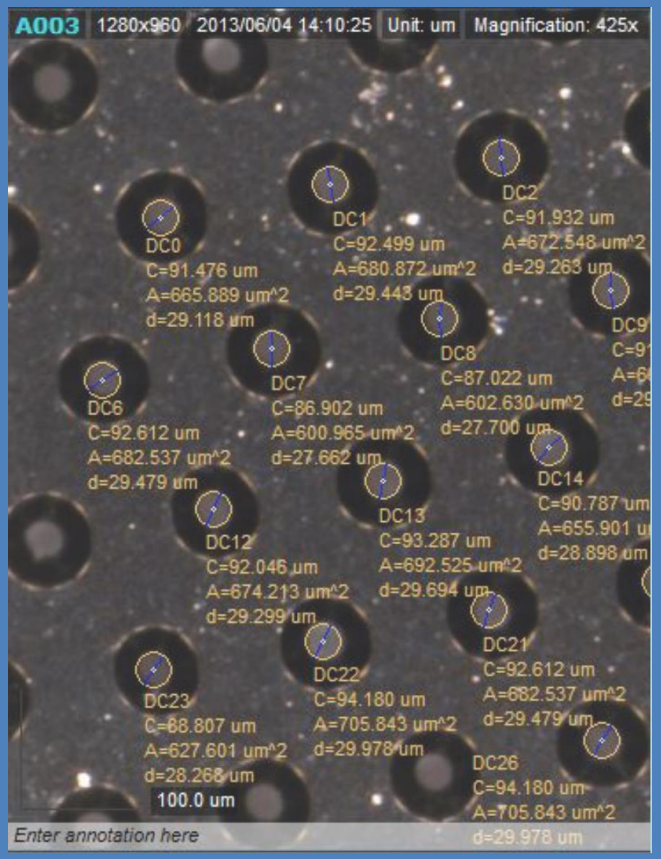




We do not have enough data yet to get the size of the hole as a function of etching time.

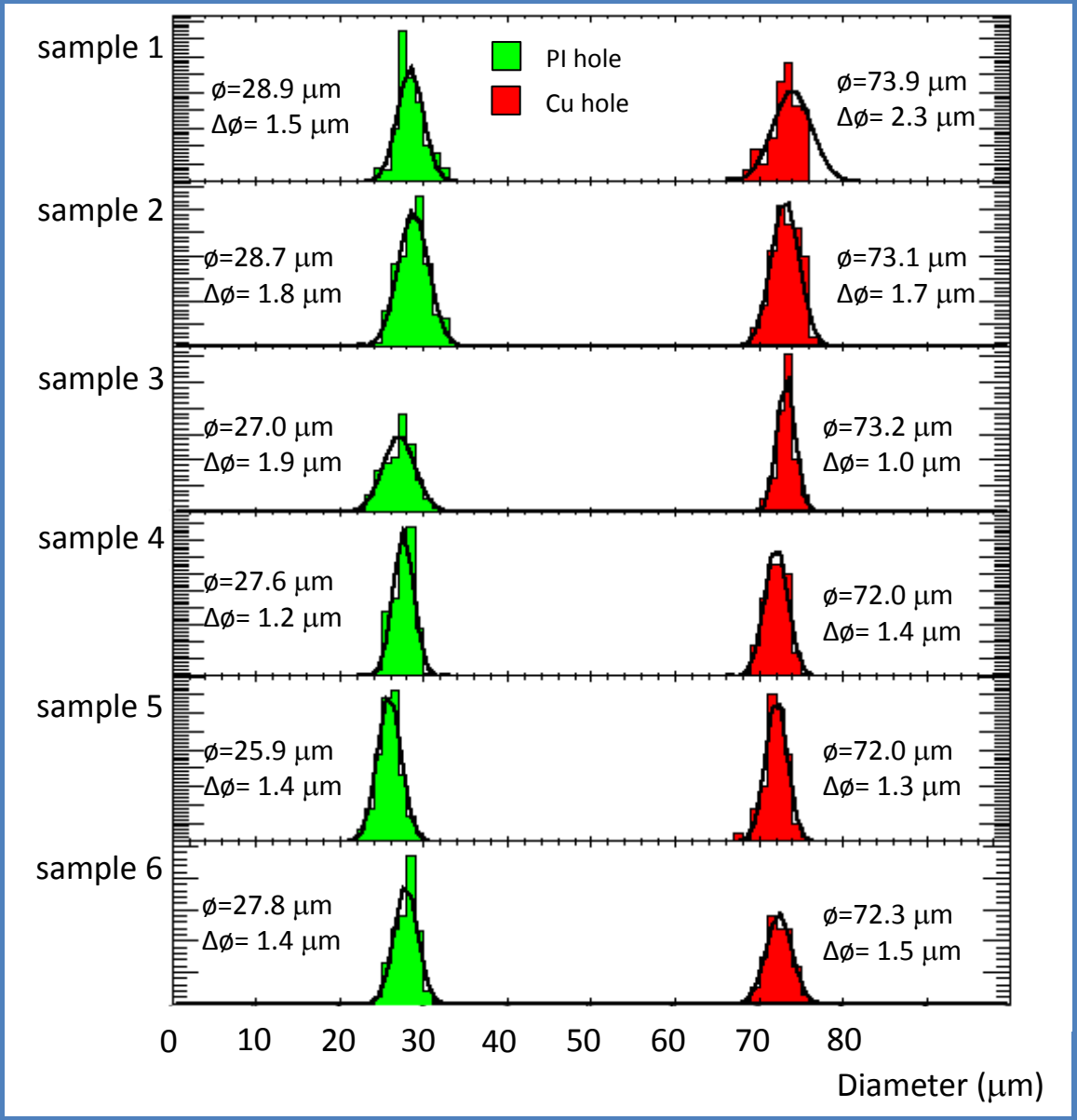
# Hole Sizes

Preliminary hole size measurements:
using an optical microscope (eyeballing).



# Hole Size Measurement




Six 10x10 $cm^2$ samples prepared under the same condition.

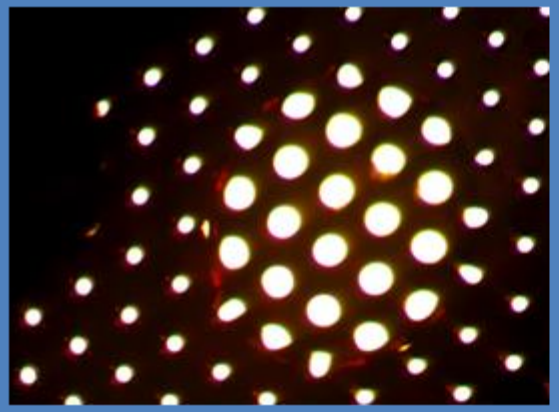
Random sampling of 100~150 points in each sample.

This includes systematic variance by eyeballing…

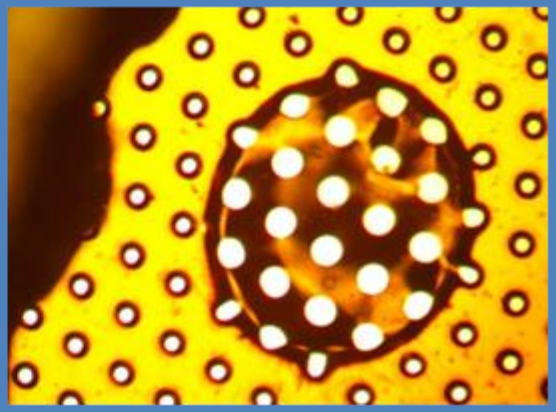
We are looking for better ways to do this.

# Defects Observed

Samples from a “cheap” 3M FCCL roll showed spots missing kapton layer between Cu layers. Identified as a white spot under a back light by naked eyes.



back lighting



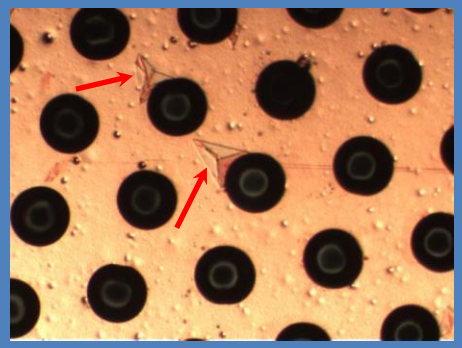
front+back lighting

Thought to be due to pre-existing defects in FCCL.

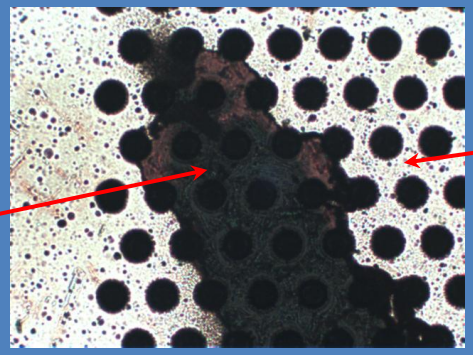
➡ We need to use better quality FCCLs.

# Post-PI Etching Cleaning

- We observed a film like residue after PI etching (Ni-Cr seed layer)



- We have tried ultra-sonic cleaning in Deionized Water.
  - De-lamination of copper layers occurred.

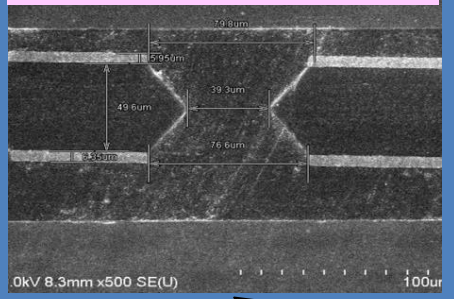



- Chemical cleaning as per CERN will used in the future, instead.
  - Chromic acid treatment

# History

double mask

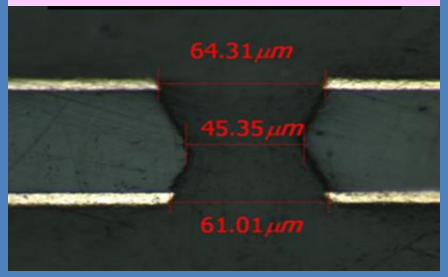
Mecharonics




Tech transfer from CERN

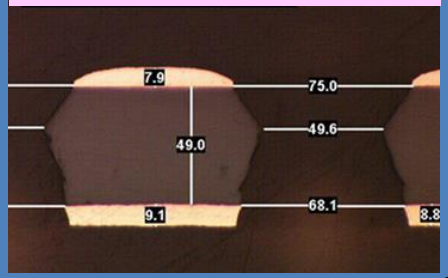
single mask

New Flex




single mask

CERN




2011

2013

# Numbers I do not have yet

- Production Capacity
  - how much do we invest in the production facility?
- Production costs
  - size of orders.
  - yields
  - quality of FCCL required.

# Plans

| no | action items | '13. 1Q | | 2Q | | | 3Q | | | 4Q | | | '14.1Q | | | 2Q | | | 3Q | | | 4Q | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1 | **License Agreement** | → | | | | signed | | | | | | | | | | | | | | | | | | |
| 2 | **100 x 100 Fabrication and QC Validation** | | | | | | | | | | | | | | | | | | | | | | | |
| | - Rebuild equipments/utility for GEM Foil | | | → | | | | | | | | | | | | | | | | | | | | |
| | - Prepare raw materials(FCCL, mixed chemical) | | | → | | | | | | | | | | | | | | | | | | | | |
| | - develop the **prototype** | | | | | → | | | | | | | | | | | | | | | | | | |
| | - QC validate the prototype @KOREA | | | | | | → | | | | | | | | | | | | | | | | | |
| | - QC validate the prototype @CERN | | | | | | | → | | | | | | | | | | | | | | | | |
| 3 | **100 x 100 Routine and standard production , 300 x 300 R&D** | | | | | | | | | | | | | | | | | | | | | | | |
| | - **100 x 100 routine** & standard production | | | | | | | | | Production start: Oct. 2013 → | | | | | | | | | | | | | | |
| | - develop the **prototype of 300 x 300** | | | | | | | | | | → | | | | | | | | | | | | | |
| | - QC validate the prototype @KOREA/CERN | | | | | | | | | | | → | | | | | | | | | | | | |
| 4 | **300 x 300 Routine and standard production , 500 x 500 R&D** | | | | | | | | | | | | | | | | | | | | | | | |
| | - **300 x 300 routine** & standard production | | | | | | | | | | | | | | → | Production start: March. 2014 → | | | | | | | | |
| | - develop the **prototype of 500 x 500** | | | | | | | | | | | | | | | | → | | | | | | | |
| | - QC validate the prototype @KOREA/CERN | | | | | | | | | | | | | | | | | → | | | | | | |

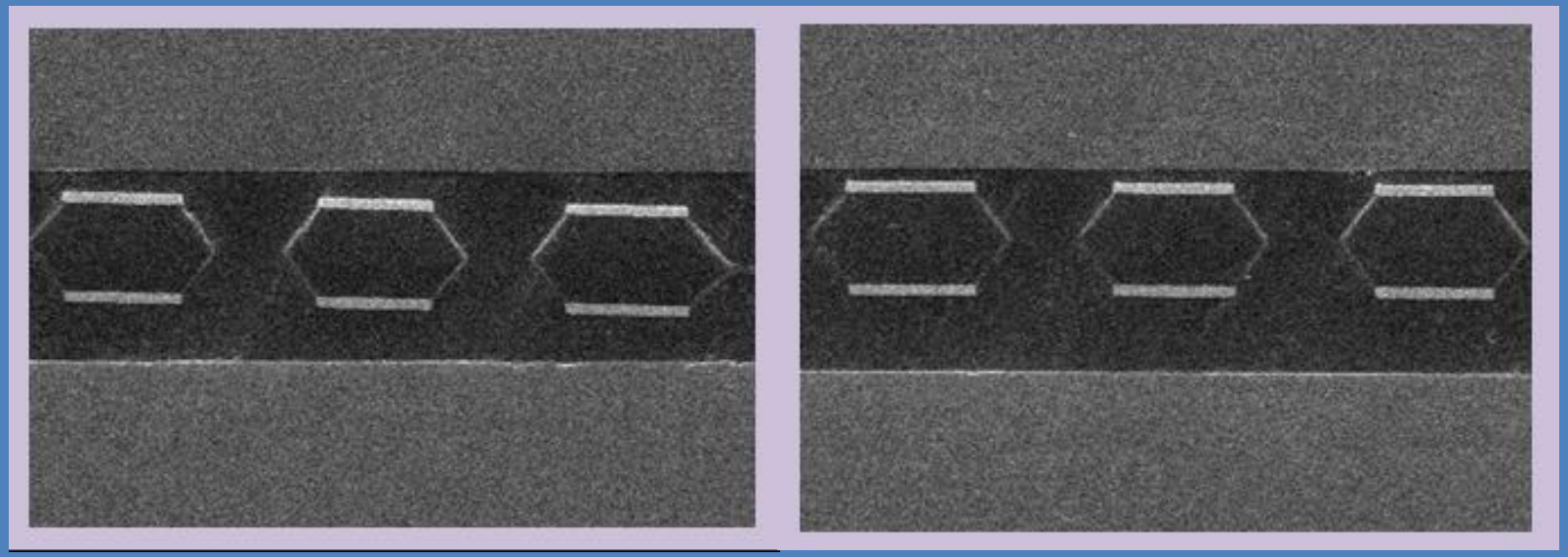
current test/
optical inspection

# Summary

- We are in R&D stage
  - tweaking PI etching conditions and cleaning options.
  - searching for optimal FCCL
- We have produced 10x10 $cm^2$ GEM foils with well defined shaped holes without technology transfer from CERN
- With the tech transfer, we expect improvements in GEM foil qualities and manufacturing procedures.

# Backup Slides

# Cross Section View (3M FCCL)



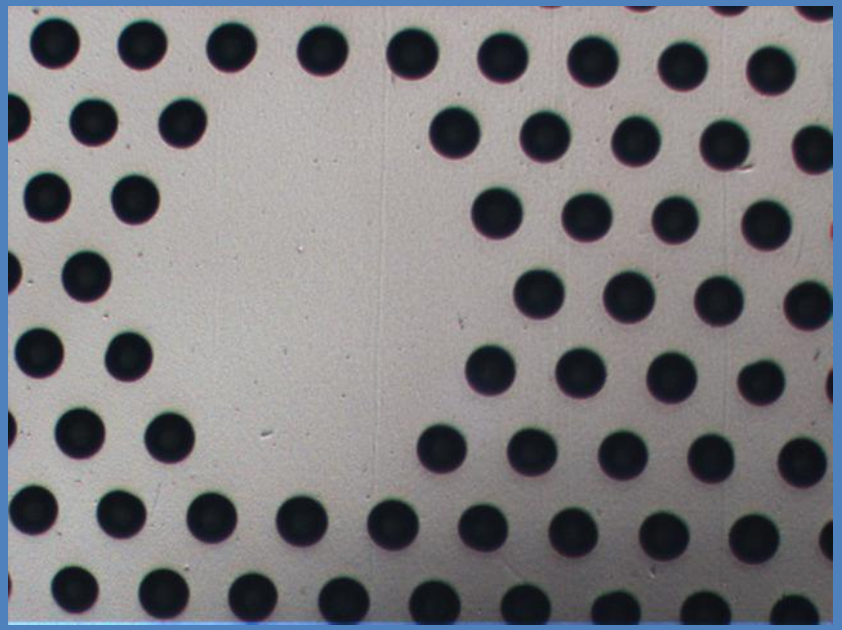
# Hole sizes

| Sample | PI Hole | | Cu Hole | |
|---|---|---|---|---|
| | Diameter (μm) | Width (μm) | Diameter (μm) | Width (μm) |
| 1 | 28.9 | 1.5 | 73.9 | 2.3 |
| 2 | 28.7 | 1.8 | 73.1 | 1.7 |
| 3 | 27.0 | 1.9 | 73.2 | 1.0 |
| 4 | 27.6 | 1.2 | 72.0 | 1.4 |
| 5 | 25.9 | 1.4 | 72.0 | 1.3 |
| 6 | 27.8 | 1.4 | 72.3 | 1.5 |
| all | 27.5 | 1.8 | 72.6 | 1.5 |

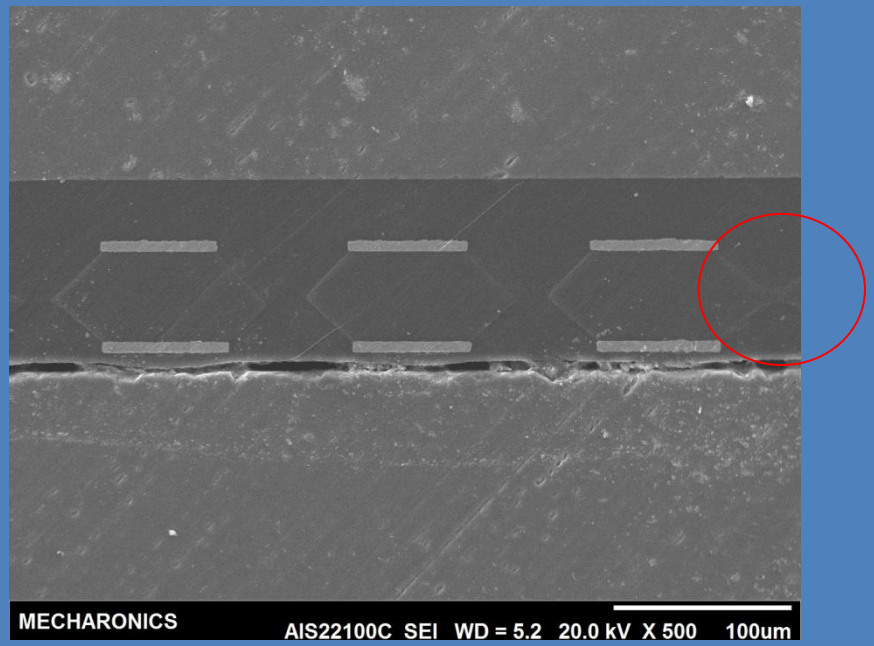
# Failure in Etching

Observed failure in etching on FCCL produced by GP Tech (PI by Ube)

Copper Etching



PI Etching




We are investigating the possible causes.