

Status report

Large GEM production in Korea

Dec. 15, 2017

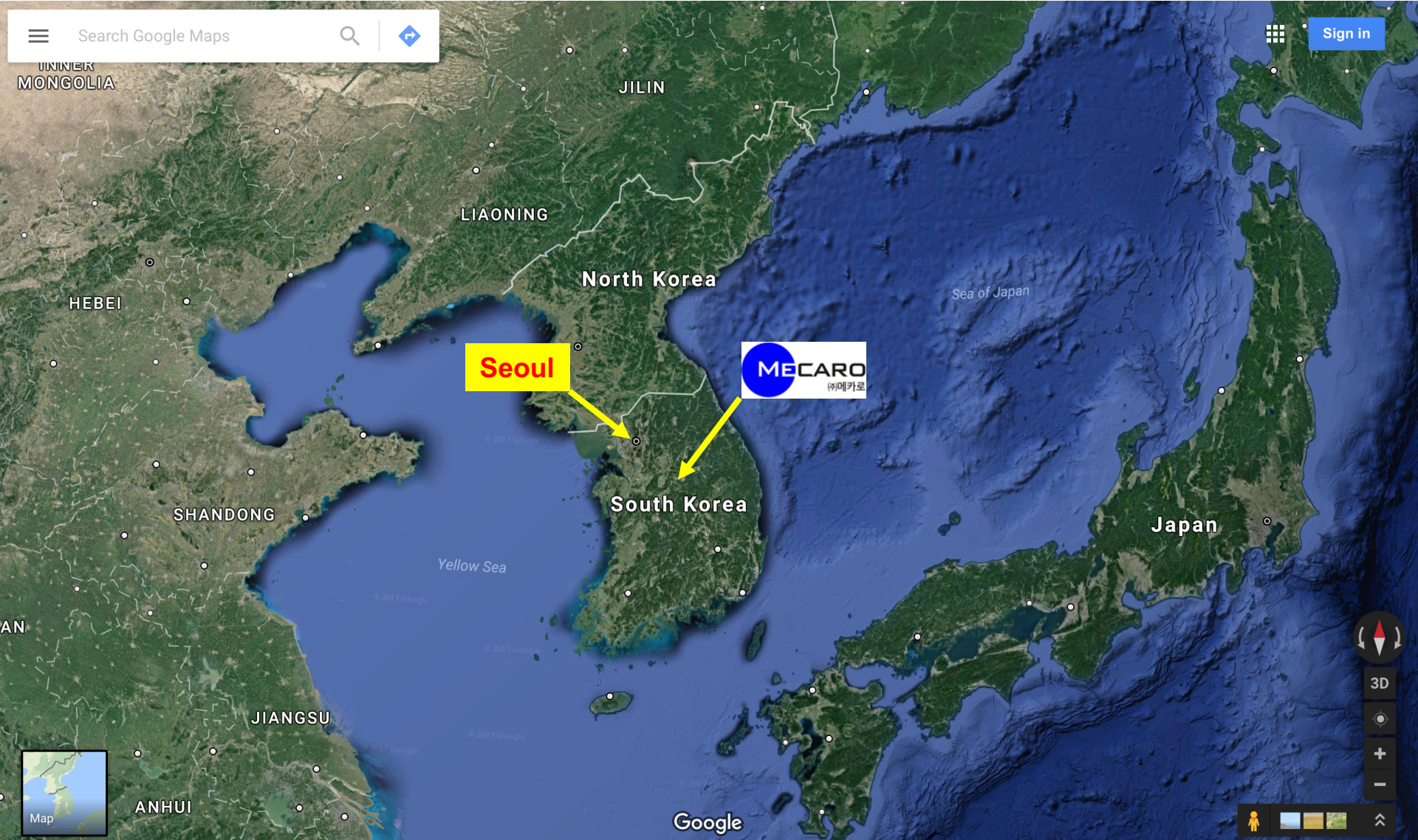
Inkyu Park

On behalf of

University of Seoul, Korea CMS, MECARO

Industrialization

(site & production facilities)



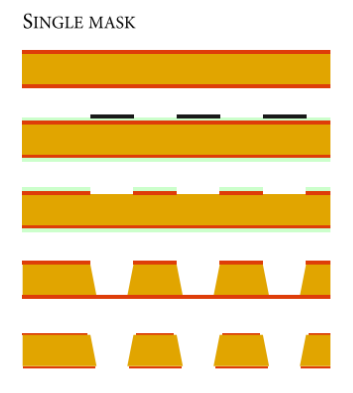
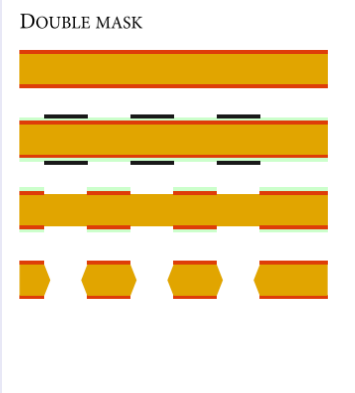
Mecaro Co., Ltd is No.1 Best Semiconductor parts company authorized in parts area by producing optimal semiconductor part of equipment through ceaseless technology development and research for about 15 years.

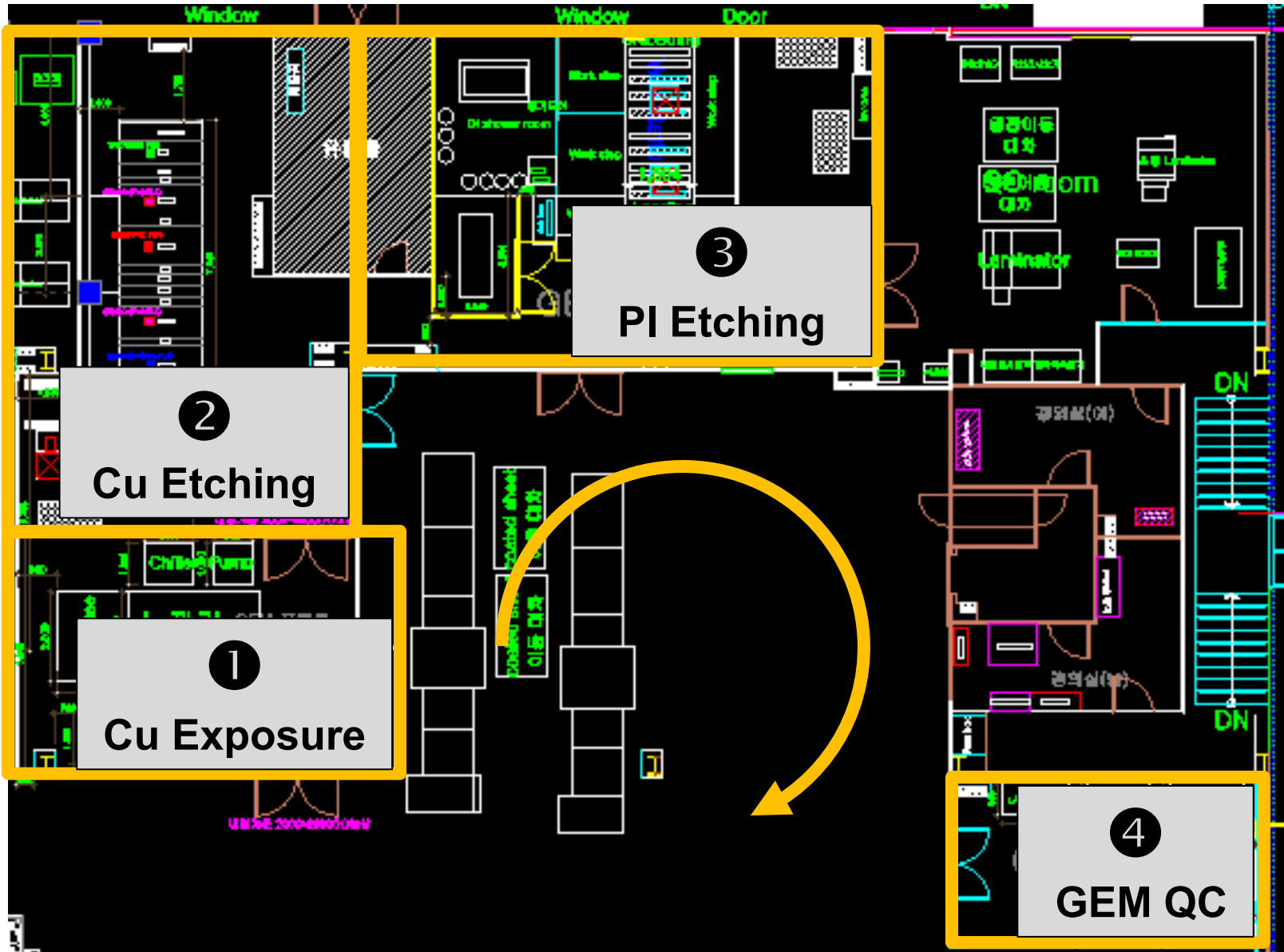
- Company Name : Mecaro CO., Ltd.
- Foundation Date : 2000. 11
- CEO : Jaejung, Lee
- Business Field : Semiconductor Heater Block, Semiconductor Chemical Source, **GEM Foil**, Etc.



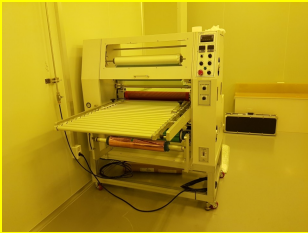
Eumsung factory

- R&D and Production
- Clean room : 1300 m²
- GEM foil production site

	Single-mask	Double mask
Infrastructure	Cheap	Expensive
Mask alignment	No need (film)	Crucial (Glass only)
Pros & Cons in size	Large size capable	Limited in size
Production method	 <p>SINGLE MASK</p>	 <p>DOUBLE MASK</p>
Production process	Complicate	Simple
Production time	Long	Fast
Labor cost	Expensive	Cheap



DFR Film coater



Large Bipolar Exposure



DFR Film Developer



Cu layer etcher



commissioning done & ready (2017/07)

ready since 2017/03

Inspection & QC



ready

Cleaner & Dryer



ready

PI etching machine



ready

Cleaner & Dryer

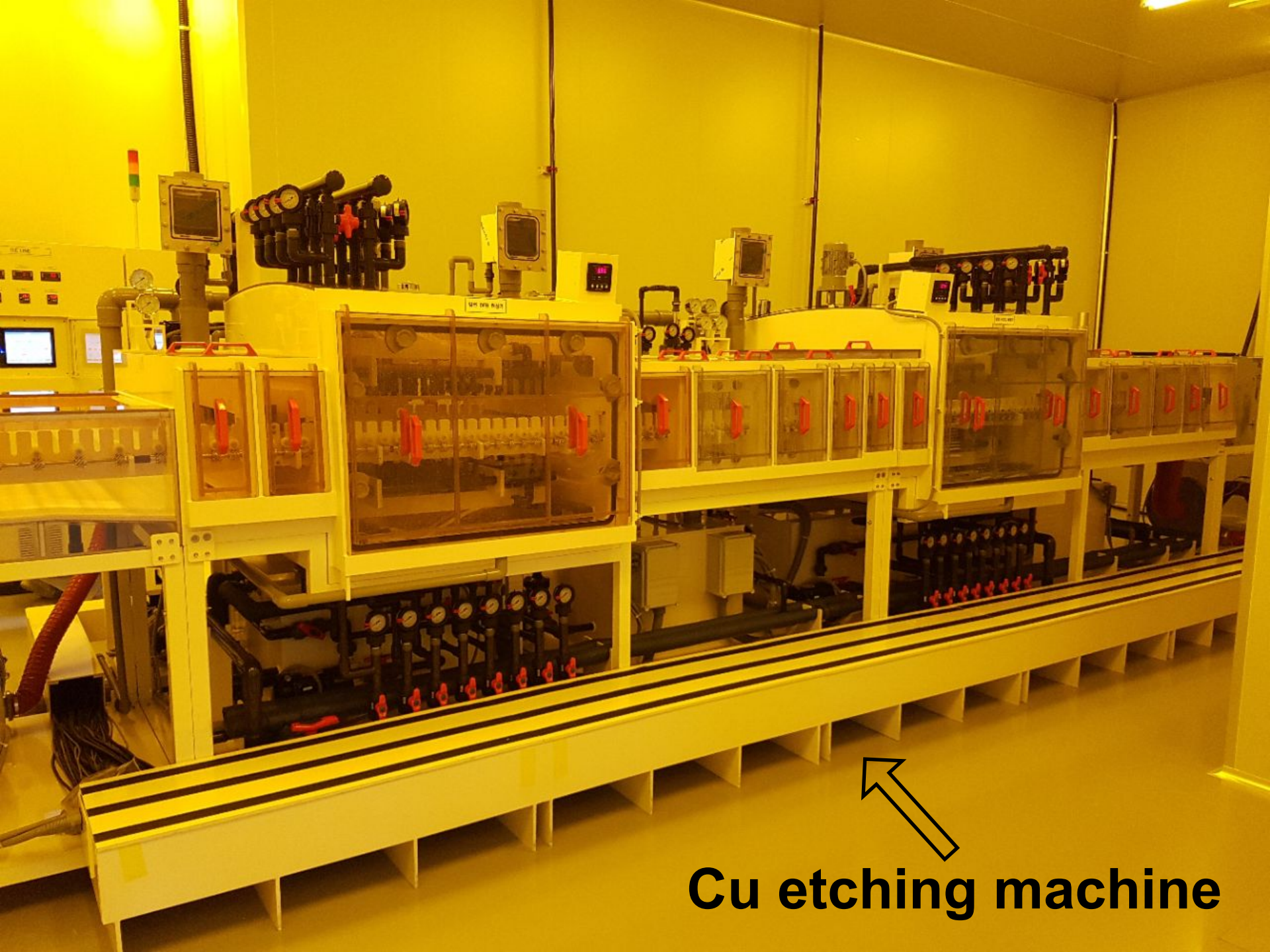


ready

Facilities completed in 2013~2016

Large Bipolar Exposure





Cu etching machine



Small size etching bath



Mid size etching bath



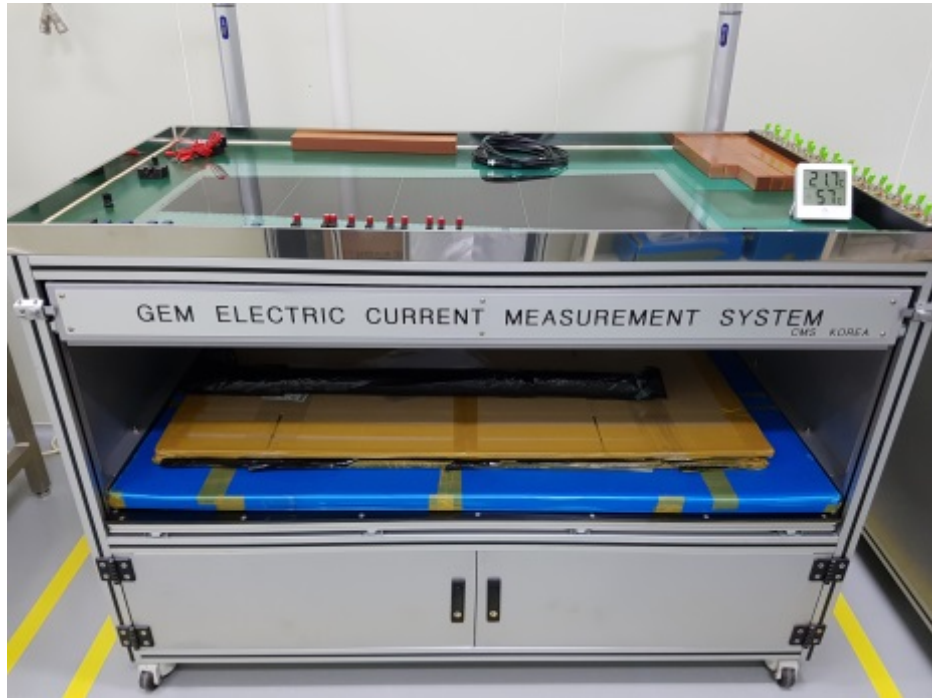
Large size etching bath

□ Multiple etching baths are ready for various sizes of GEMs

- Small: 10cm x 10cm, 30cm x 30cm
- Middle: 50cm ~ 1m
- Large: > 1m



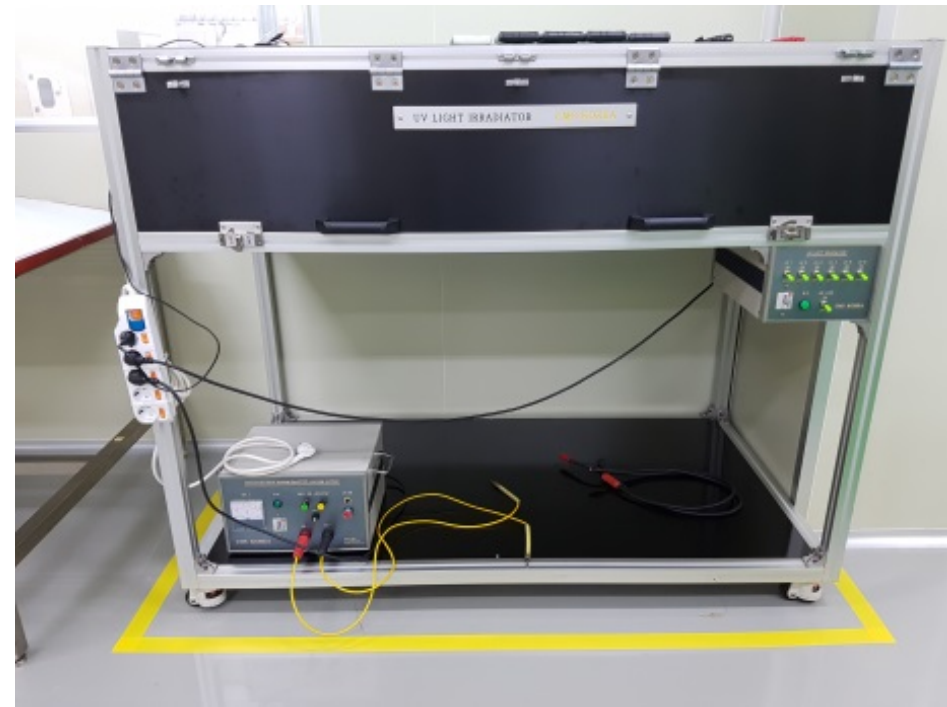
Small size leakage current test



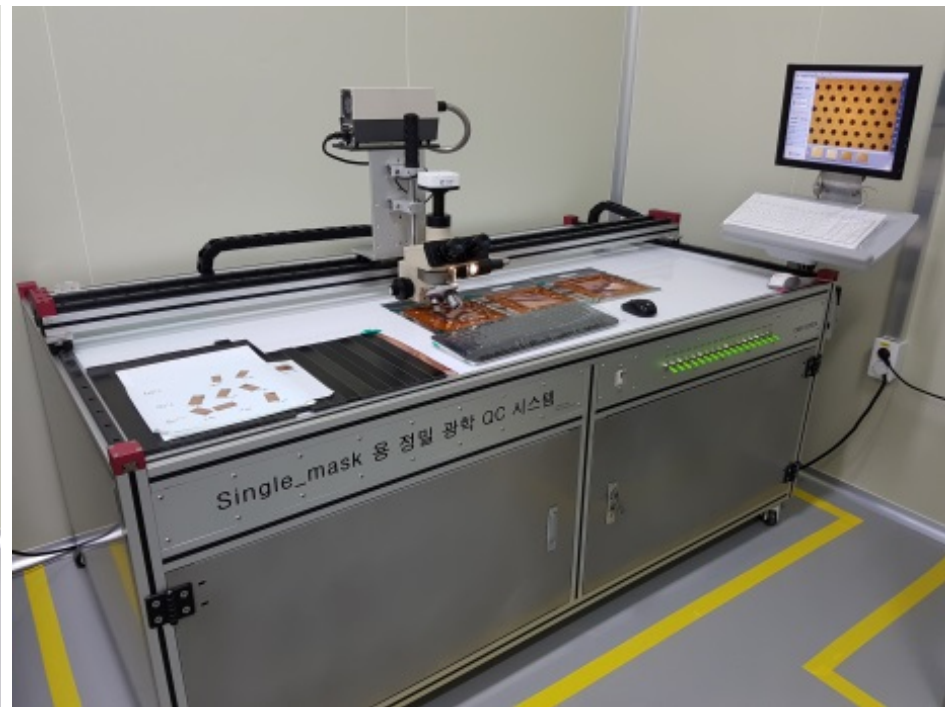
Large size leakage current test

□ Leak current measurement with/without gas system

- Small: 10cm x 10cm, 30cm x 30cm
- Middle: 50cm ~ 1m
- Large: > 1m



UV light system



Optical inspection table

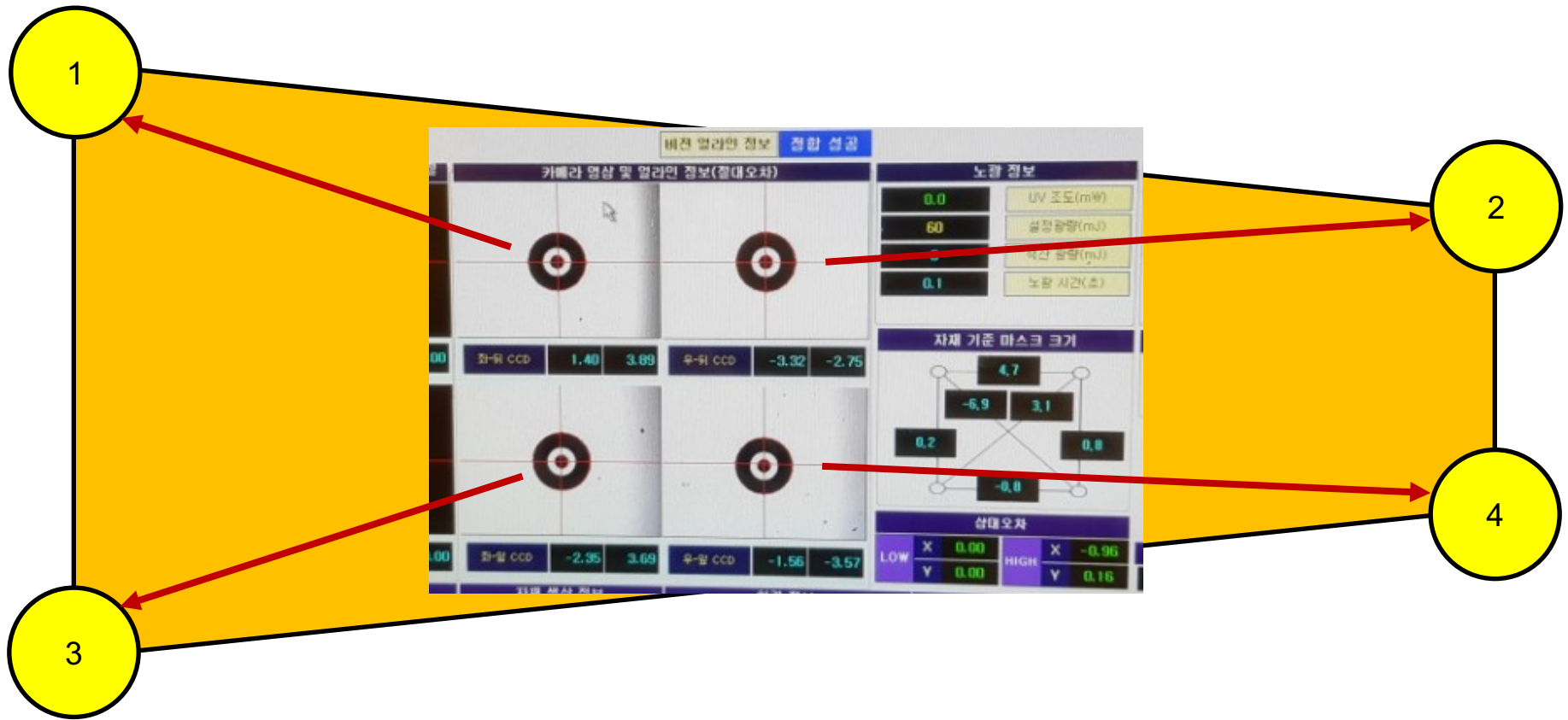
□ UV curing facility, Semi-automatic Optical inspection

- for all sizes
- fully automatics whole area scanning will be available

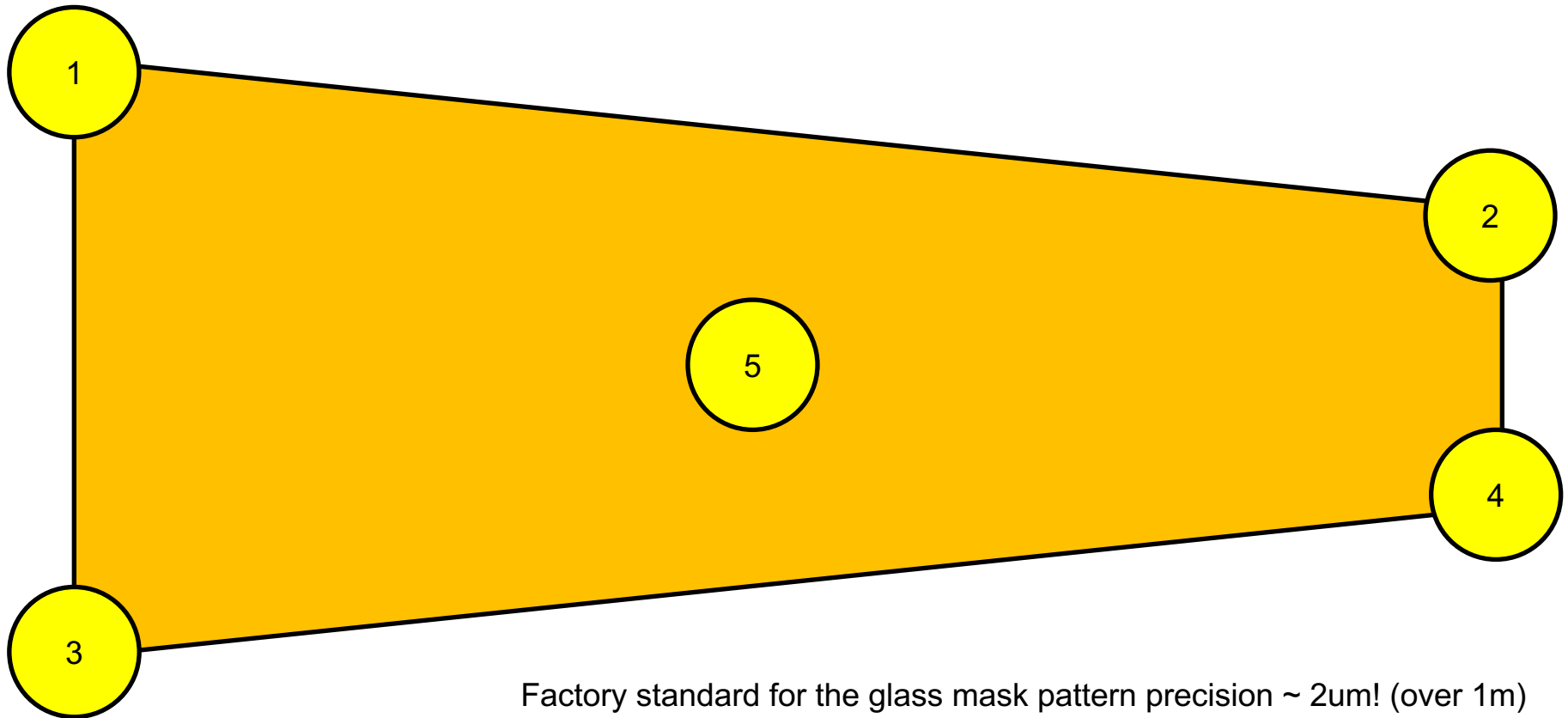
Large GEM foil production

GE11

□ 4-view bifocal microscope is used to align the top & bottom masks

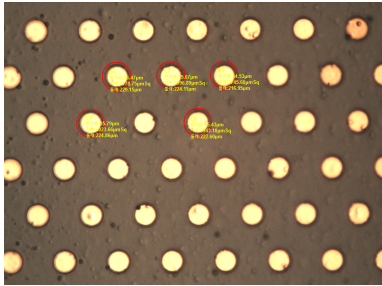


- 1,2,3,4,5 are aligned almost perfectly
 - residual misalignment is less than 3 micron
 - hard to identify any misalignment in microscope image.

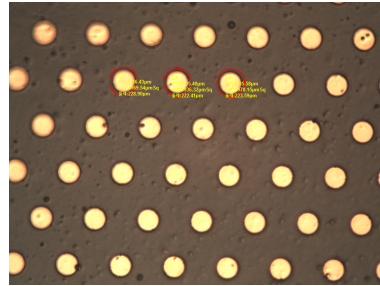


Factory standard for the glass mask pattern precision ~ 2um! (over 1m)

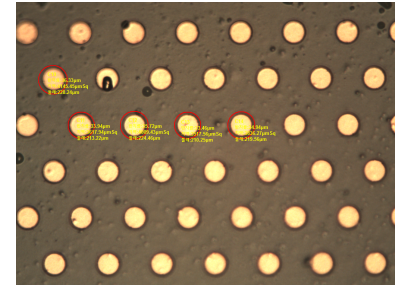
After DFR film development



left

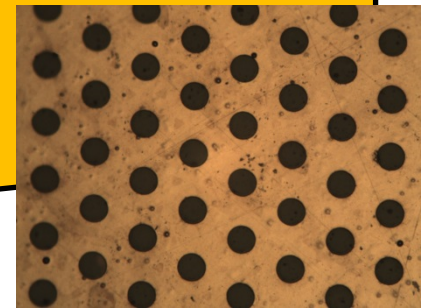
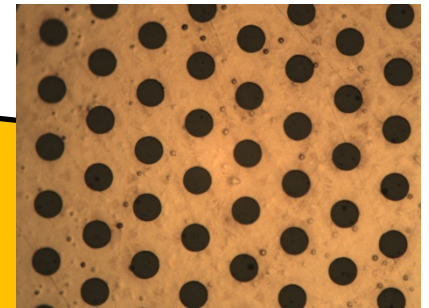
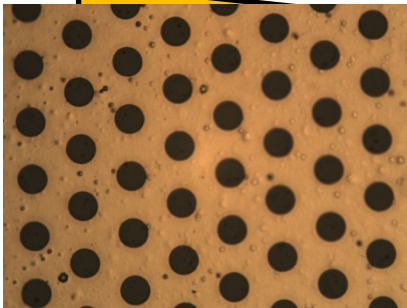


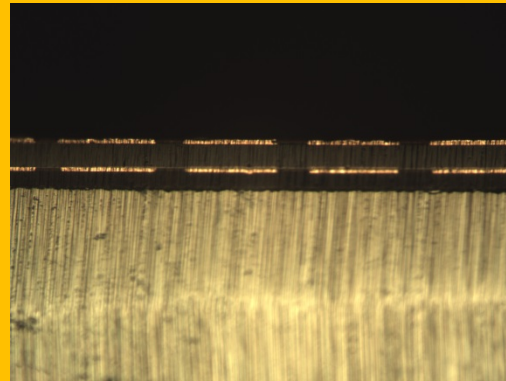
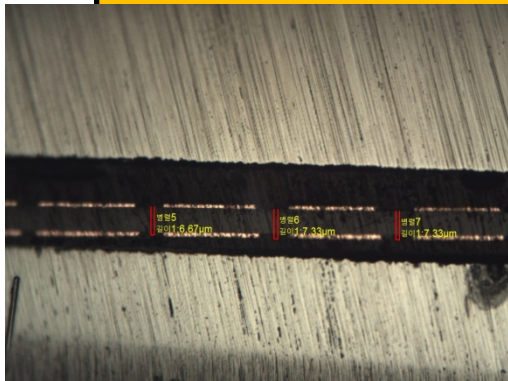
center



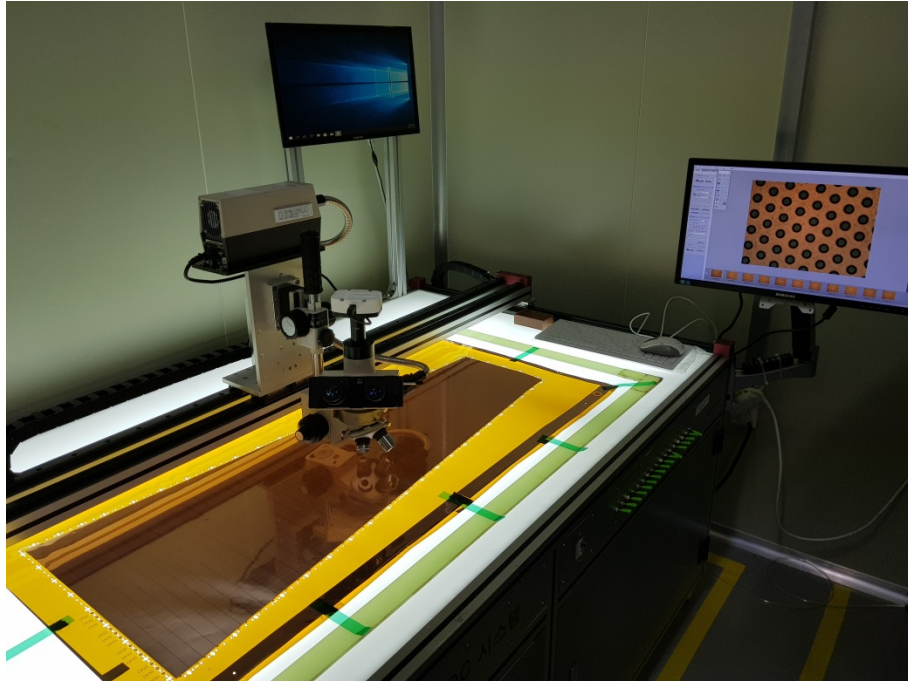
right

After Cu etching

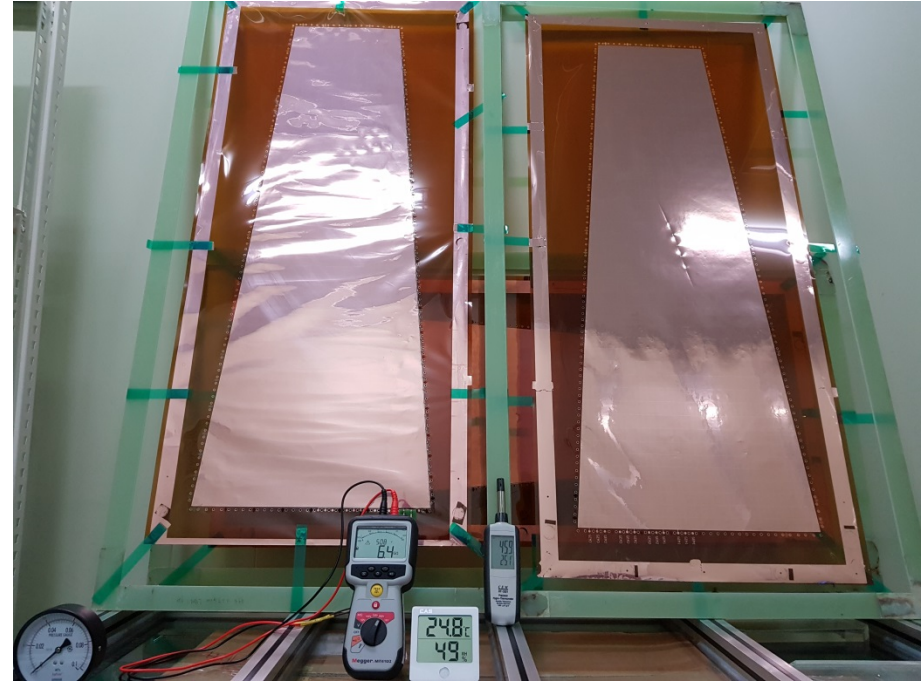




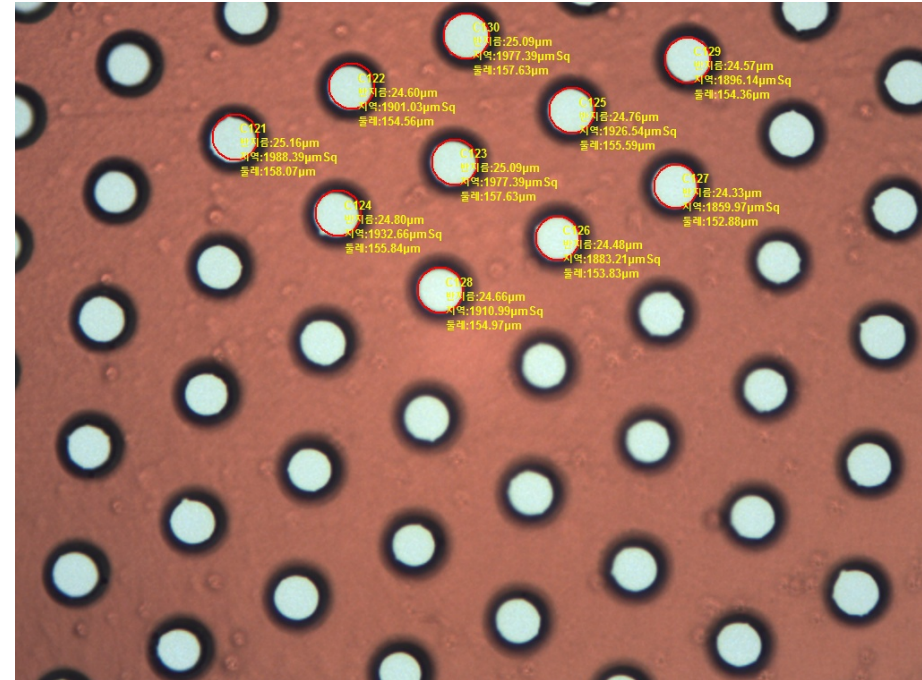
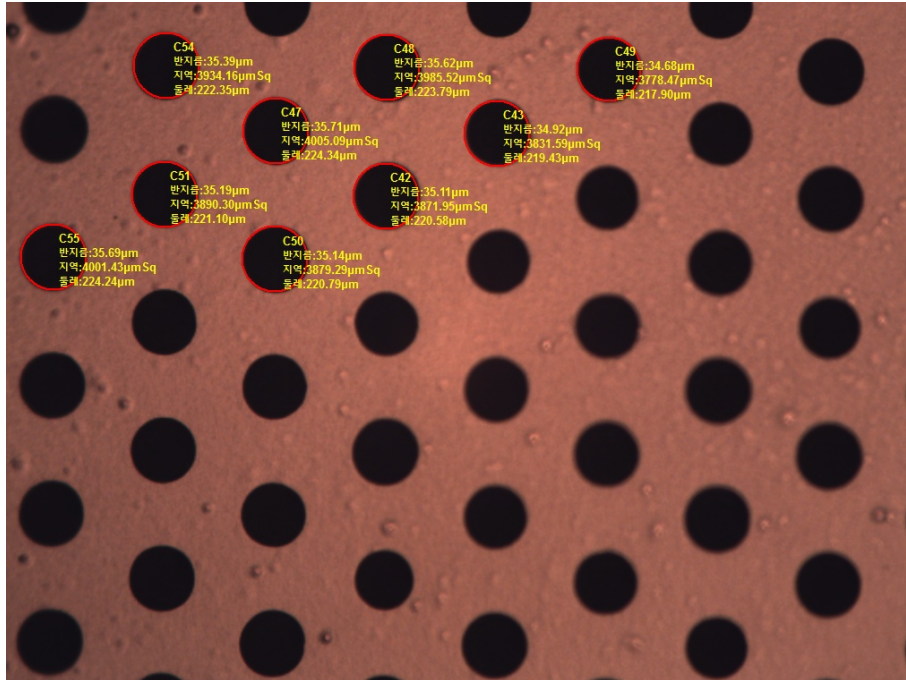
QC at MECARO



Optical Inspection

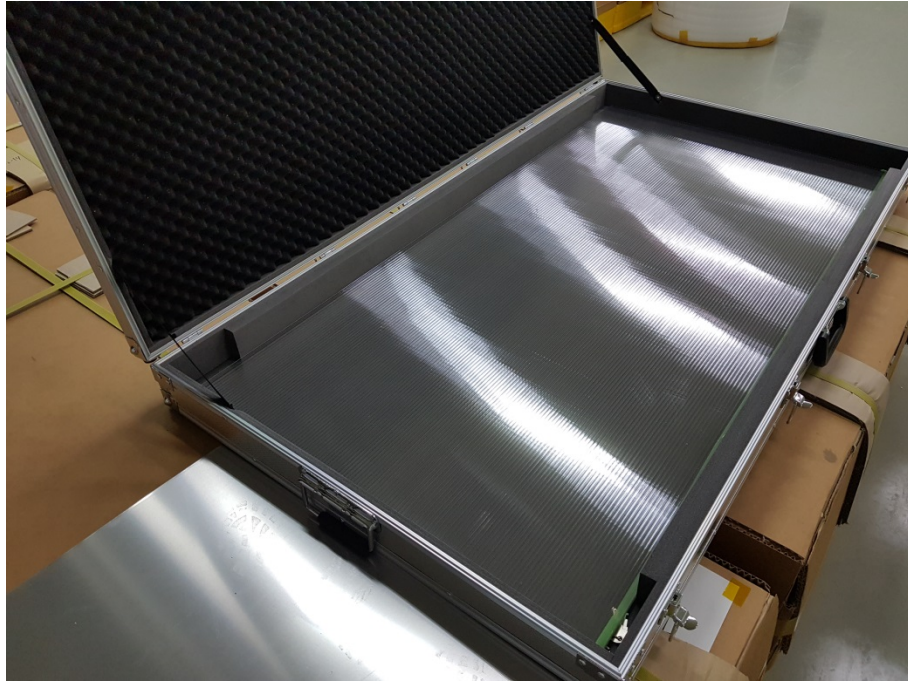


Leakage current measurement



- Outer hole sizes are 68 ~ 72 μm. (goal was 70μm)
- Inner hole size are 48 ~ 52 μm. (goal was 50 μm)

SAMPLE NAME	VOLTAGE	IMPEDENCE (HUMIDITY)	LEAKAGE CURRENT	HOLE SIZE (OUTER/INNER)	NB
A	500V	20~21 Gohm (45%)	23~24 nA	70um/50um	
B	500V	24~25 Gohm (45%)	20 nA	70um/50um	
C	500V	27~28 Gohm (45%)	17~18 nA	70um/50um	
D	500V	13~15 Gohm (45%)	30~40 nA	70um/50um	
E	500V	13~15 Gohm (45%)	30~40 nA	70um/50um	
F	500V	13~15 Gohm (45%)	30~40 nA	70um/50um	
G	500V	13~15 Gohm (45%)	30~40 nA	70um/50um	
H	500V	13~15 Gohm (45%)	30~40 nA	70um/50um	
I	500V	13~15 Gohm (45%)	30~40 nA	70um/50um	
J	500V	13~15 Gohm (45%)	30~40 nA	70um/50um	
K	500V	10~11 Gohm (45%)	45~50 nA	70um/50um	
L	500V	13~15 Gohm (45%)	30~40 nA	70um/50um	Over Cleaning
M	500V	13~15 Gohm (45%)	30~40 nA	70um/50um	1 Section Defect
N	500V	2~3 Gohm (45%)	150~200 nA	70um/50um	1 Section Defect



- **Hard cases were used, between GEM sheets and seats, anti-static film, shock absorber and polycarbonate.**

**Shipping to CERN
&
Chamber construction**

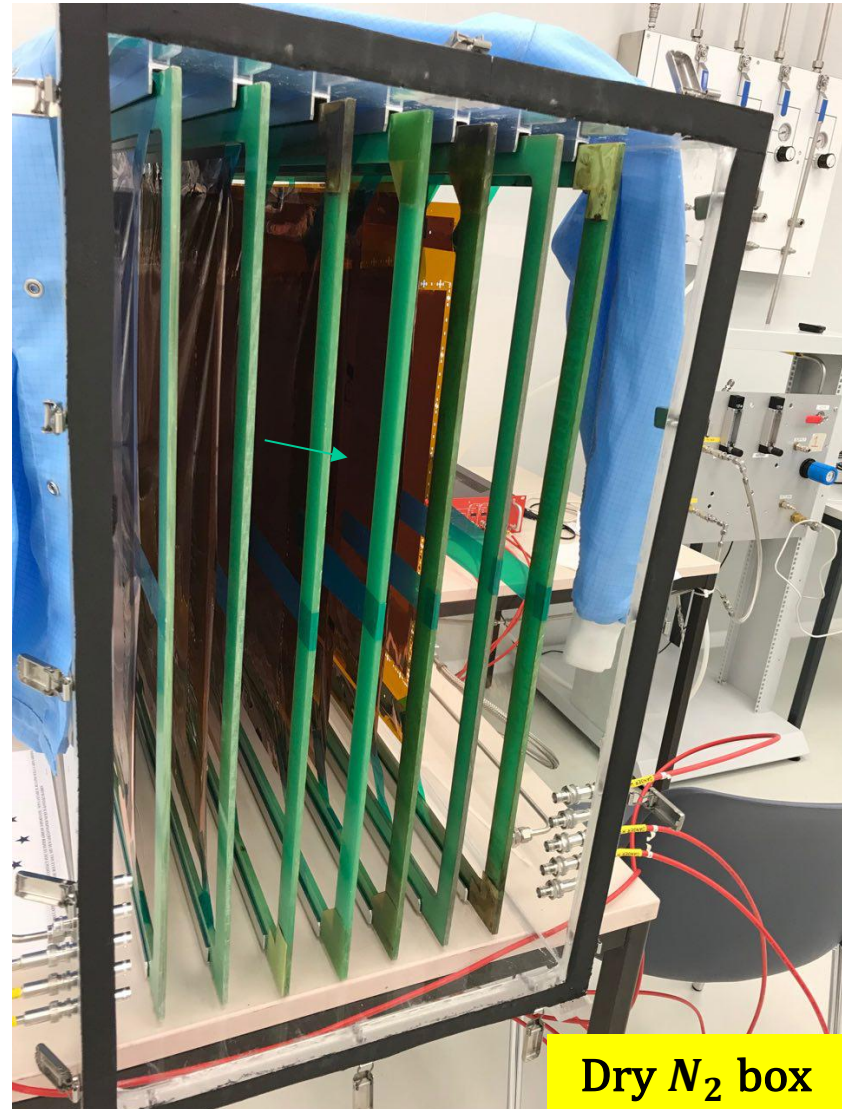
- 14 foils were delivered on Dec. 2
 - 10 good foils for use
 - 4 bad foils for test

- Problems found
 - missing silver epoxy on HV contact (fixed at CERN)
 - exposed to dust (needed clean again at CERN)

Many thanks to Rui's Lab !!



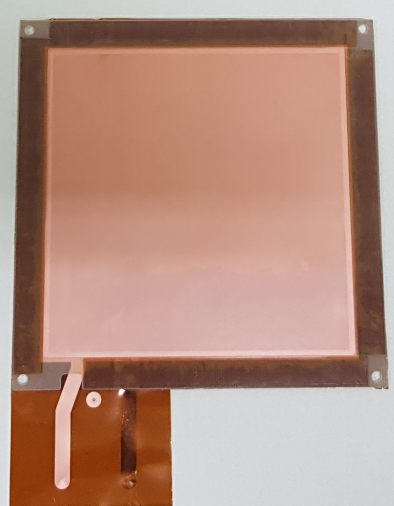
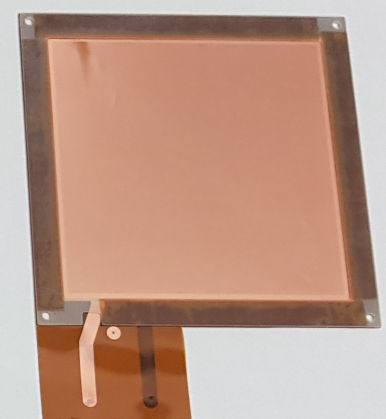
- ❑ Finally 6 foils were ready to CMS QC
 - the rest of foils need to be fixed
- ❑ QC2-Fast: done.
 - 550 V for 10min & measure impedance and number of discharges (in the air)
 - requirement: impedance > 15 G Ω
- ❑ QC2-Long: ongoing.
 - variable voltage up to 600 V for 24h & measure impedance (in dry N₂)



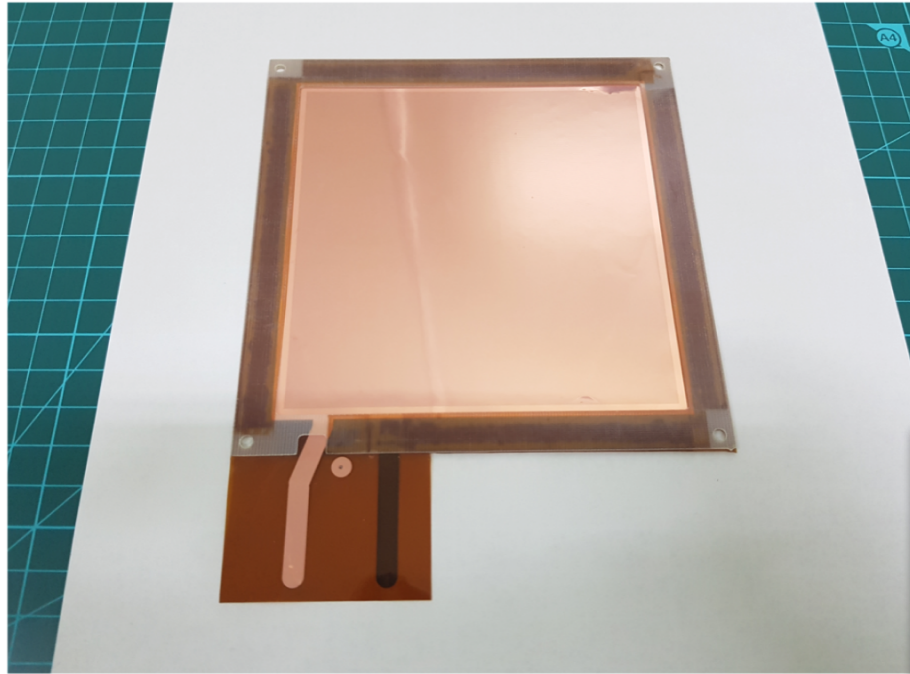
- ❑ build GE11 chamber
 - by Dec. 19
- ❑ hopefully proceed the Chamber QC as much as possible
 - before Christmas
 - continue in Jan. 2018
- ❑ The 2nd chamber will be build in Jan. and for aging and other discharge test.



Standard 100 x 100 GEM foil production & test @ CERN



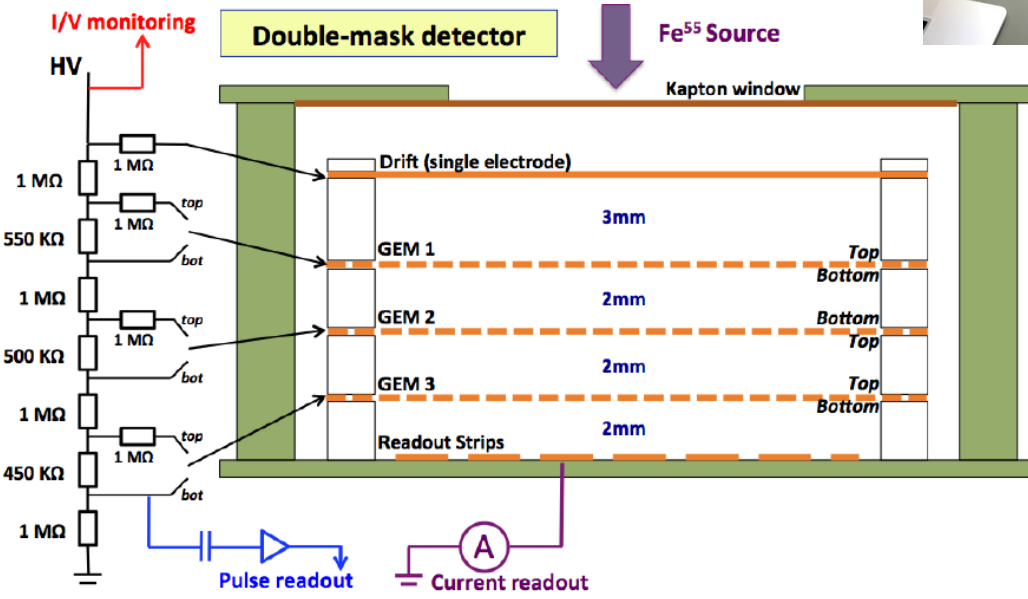
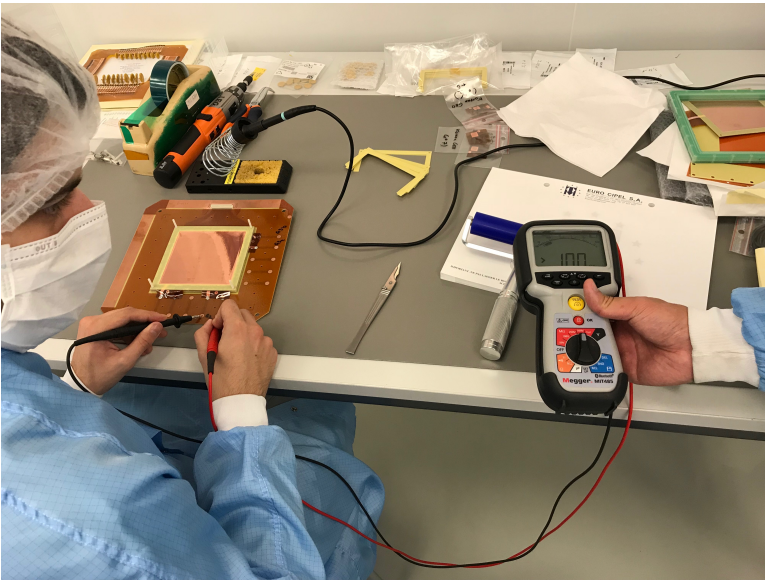
10 15 20 25 30 35 40 45 50 55 60 65



← Stacking 5 GEMs

Packing for a set of 5 GEMs →





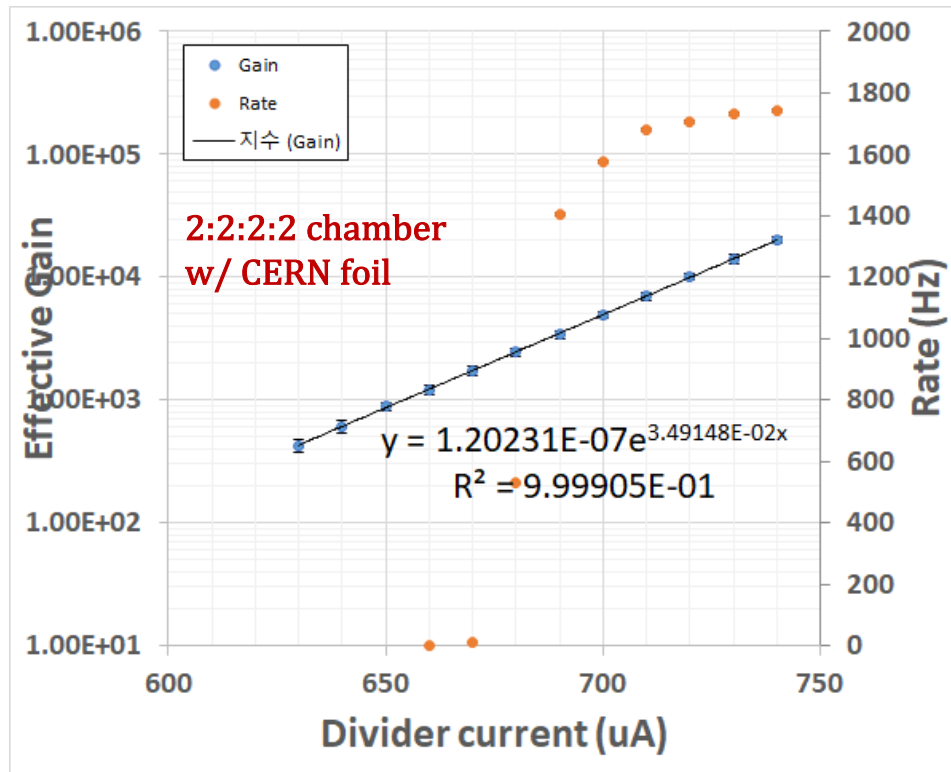
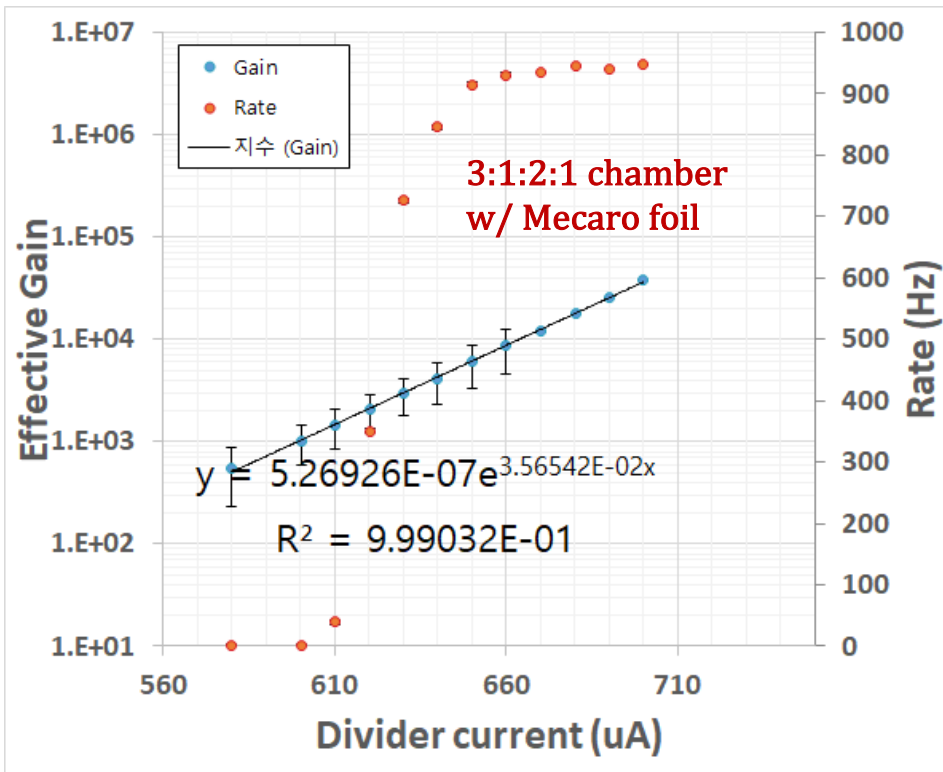
***GEM foils produced in 2015**

MECARO foil chamber (3mm:1mm:2mm:1mm)

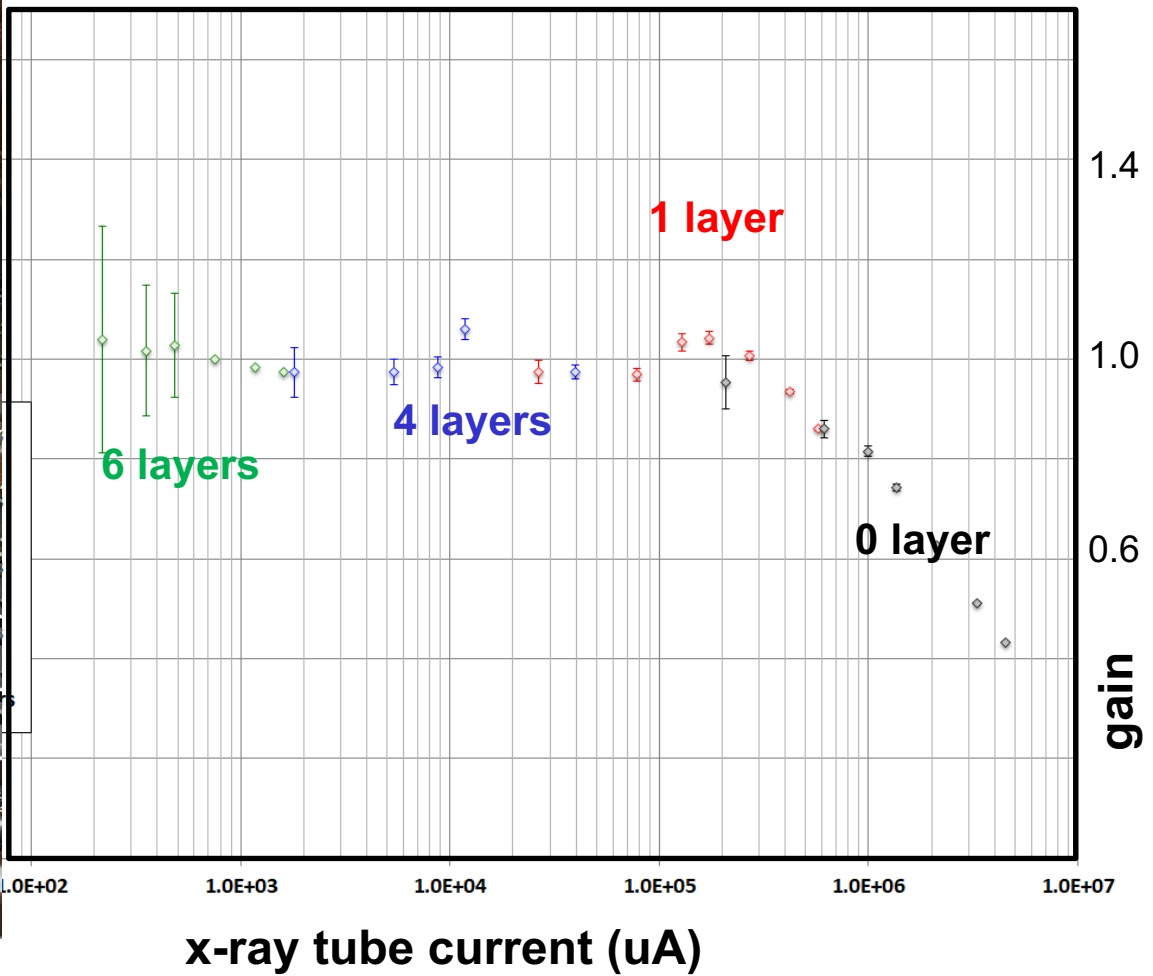
Gain $\sim 10^4$ at $V_{GEM} = 330 V$

CERN foil chamber (2mm:2mm:2mm:2mm)

Gain $\sim 10^4$ at $V_{GEM} = 360 V$

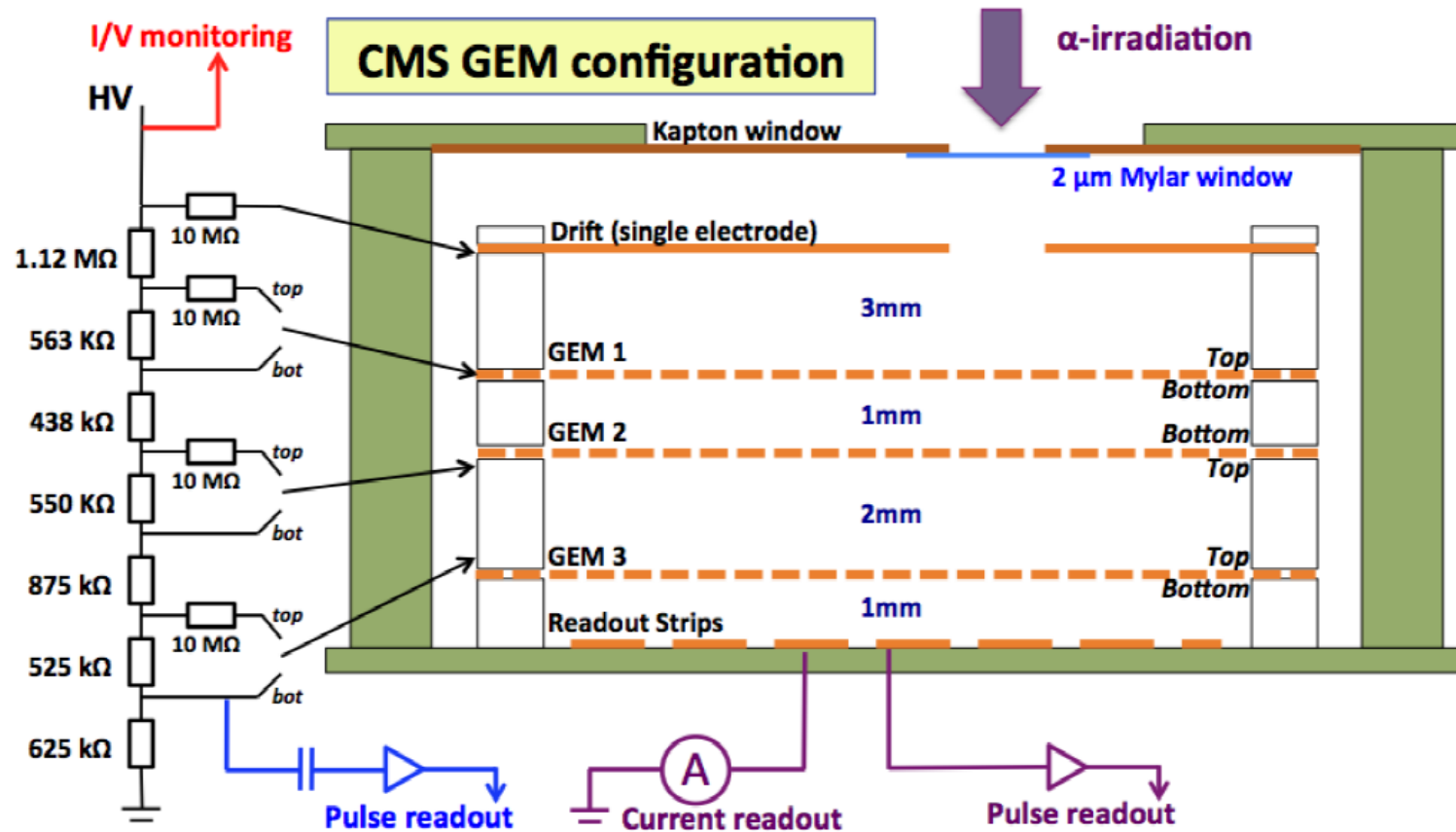
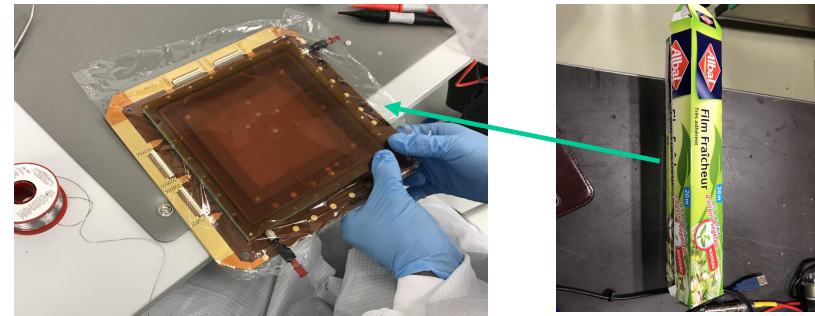


Rate capability is the most important factor of GE11 project, as the GE11 will be installed in high flux region around beam pipe. Maximum expected rate can be $5 \times 10^1 \text{ Hz mm}^{-2}$

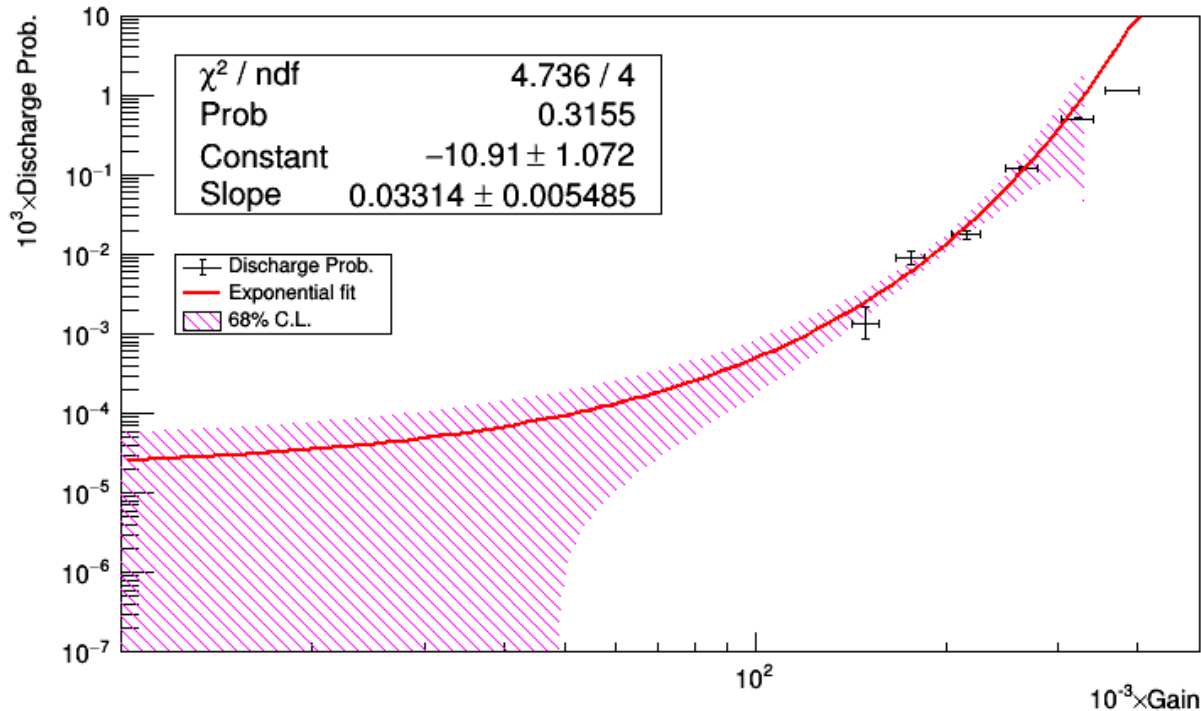


Flux = counts/60 s/3.14 mm²

To make intentional discharge, α from ^{241}Am is irradiated to the chamber



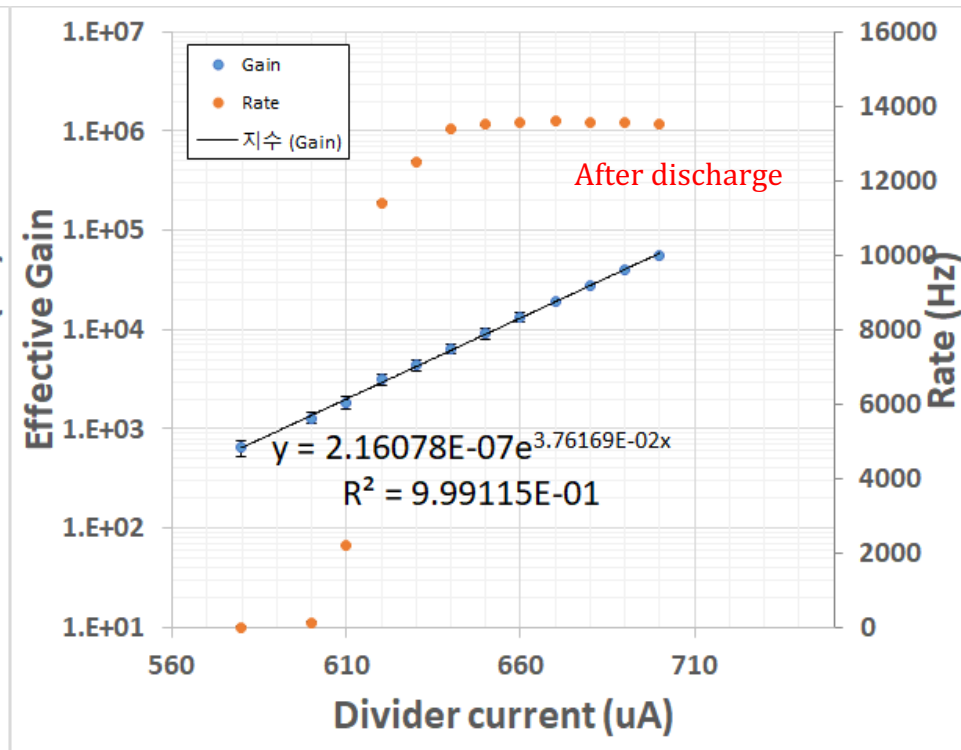
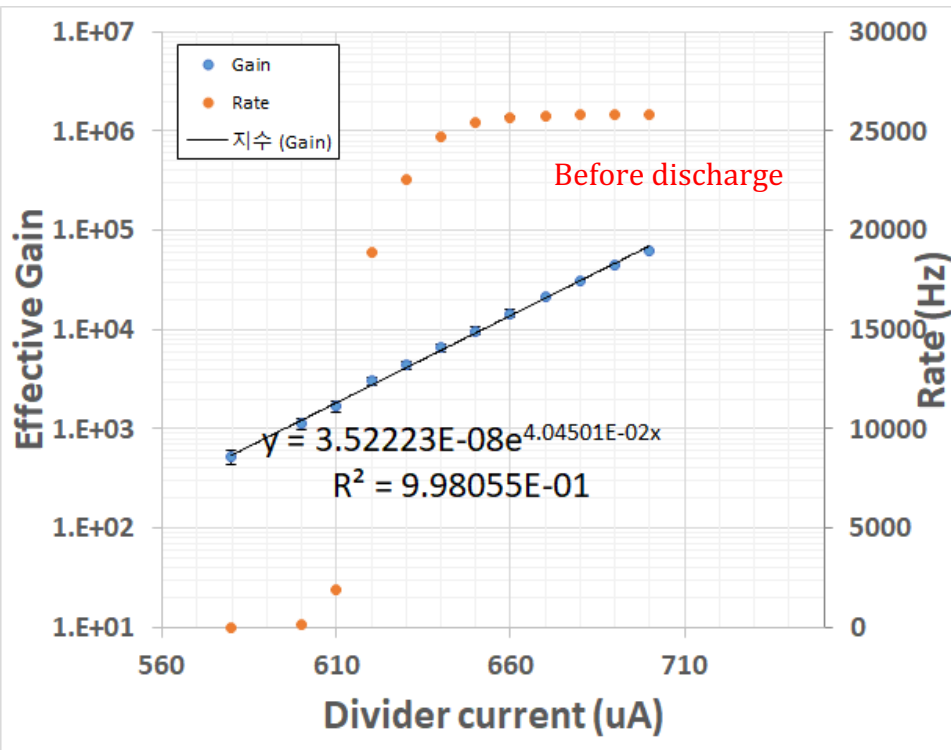
Discharge Prob. vs Gain, 5.5 MeV α



At $gain = 1 \times 10^4$, $Prob. = 2.5 \times 10^{-5} + 3.2 \times 10^{-5}$

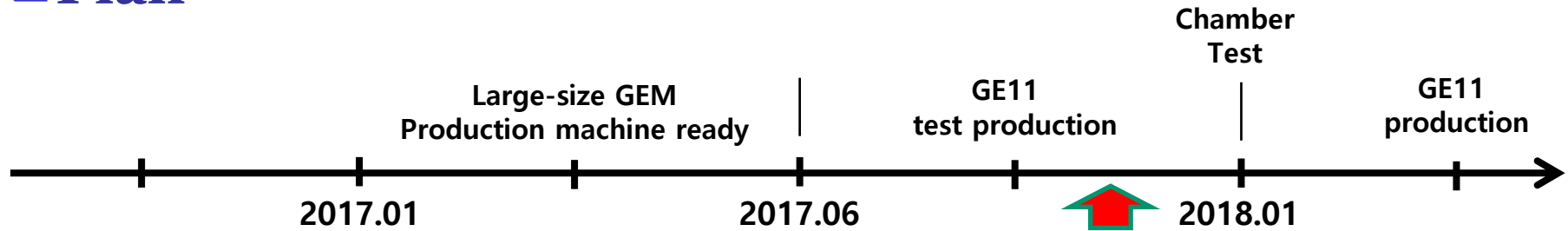
At $gain = 2 \times 10^4$, $Prob. = 3.5 \times 10^{-5} + 4.2 \times 10^{-5}$

For MIP, discharge Prob. is 1/100 times smaller



During the measurement, we've observed at least 15,000 discharges. However no degradation of chamber performance is observed.

□ Plan



□ Korea GEM TF → Extremely successful so far

–Small size GEM detectors

- **10cm x 10 cm mass production: ~60 foils/week, ~3000 foils/year**

–Mid-size GEM detector

- **30cm x 30 cm & custom design GEM: order-based**

–Large size GEM (GE11)

- **GE11 production rate of 20 foils/week**

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backup