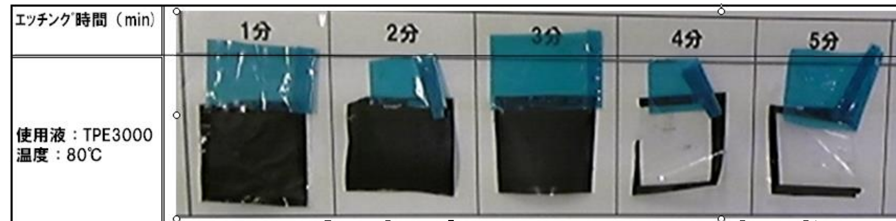
Resistive materials and their patterning methods

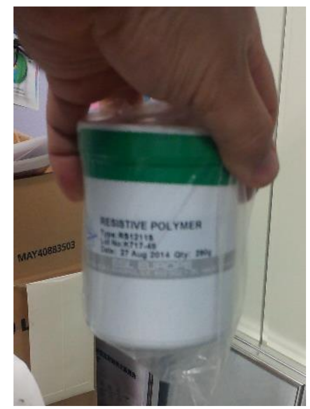
Atsuhiko Ochi
Kobe University

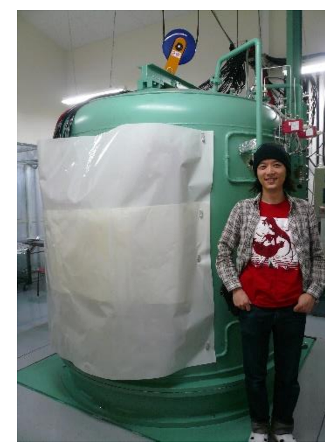
RD51 mini-week@CERN 09/12/2015

Our experiences of resistive materials



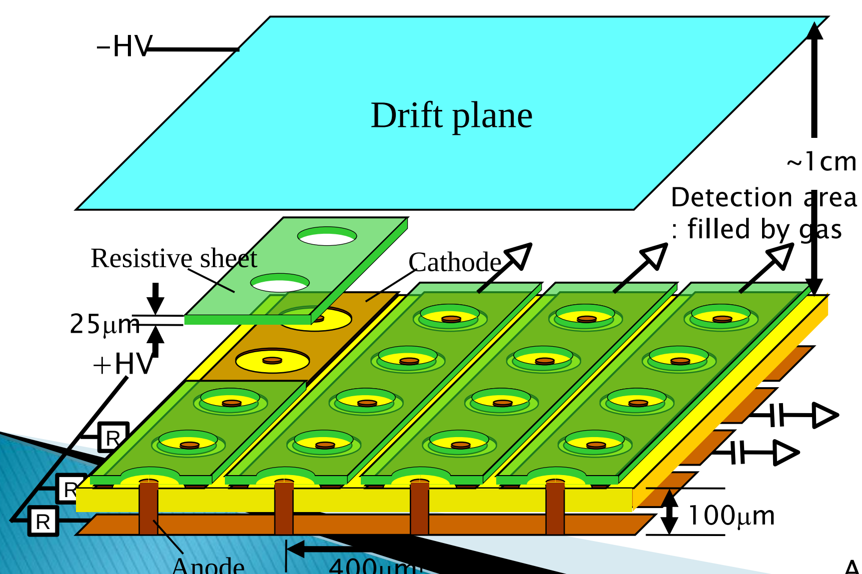
- Resistive Polyimide sheet
  - Dupont Kapton XC series
  - Commercially available (not in Japan, Rui's help was needed)
  - Typically, 2MΩ/sq. , 25μm thickness
- Resistive polyimide paste
  - Produced in Toray
  - It is not commercially available
  - A few MΩ/sq. , 10-20μm thickness
- Resistive epoxy paste
  - ESL RS12500 series
  - Commercially available
  - Typically, 1MΩ/sq. , 10μm thickness
- Carbon sputtering
  - Carbon deposition by dry sputtering
  - 100kΩ/sq. - 100MΩ/sq. , 0.1μm thickness

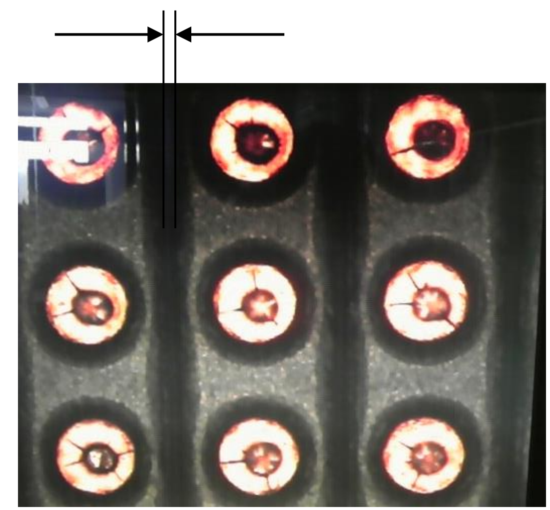




Resistive polyimide sheet + μ-PIC

- Dupont XC seriese
- Our first trial for resistive MPGDs (2010, Kobe Univ.)
- Etching is available by Raytech Inc.
- First prototype of μ-PIC have been developed
- Max gain > 10000, however not stable
  - No reduction of the spark
- Problems:
  - it was difficult to avoid the etching for substrate polyimide
  - Cracks are seen inside the polyimde

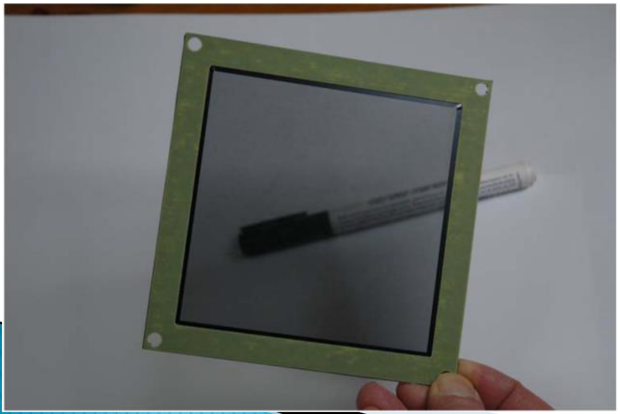


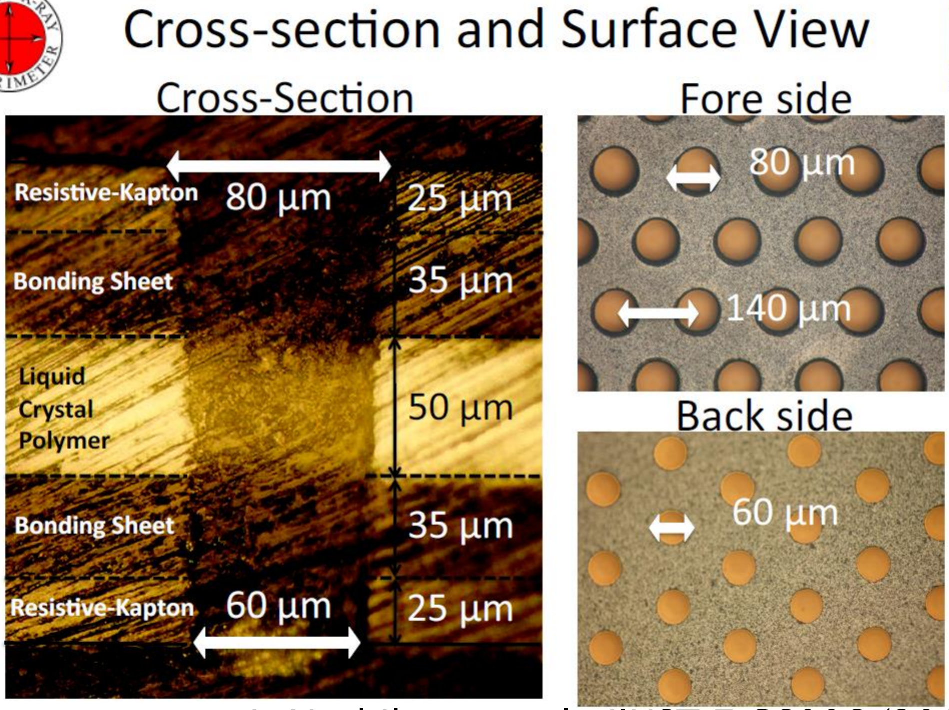


A.Ochi et.al., JINST 7 C5005 (2012)

Resistive polyimide sheet + GEM

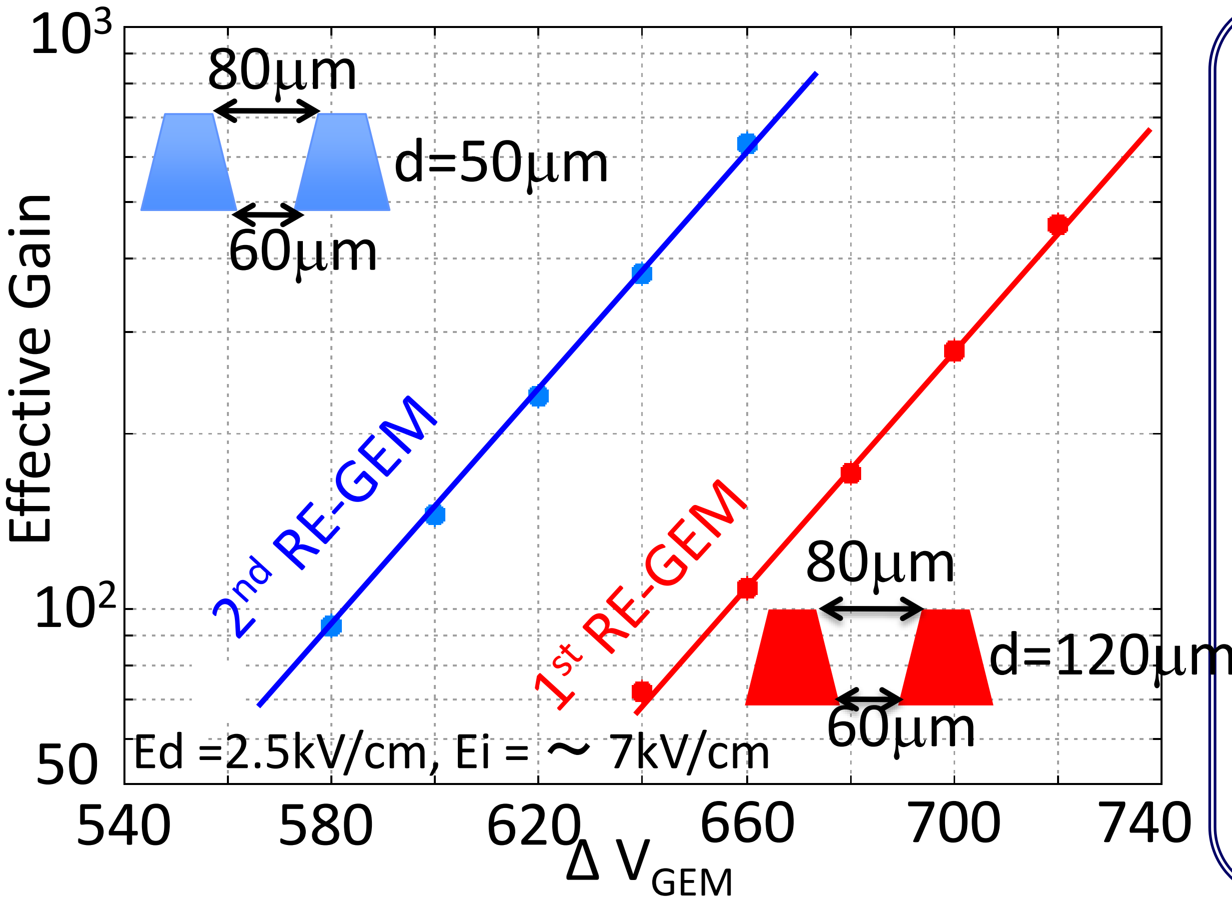
- Prototype of resistive GEM was developed in RIKEN group
- LCP is sandwiched by resistive polyimide, and holes are drilled by laser
- They success to get signals, but it was not clear whether sparks was reduced or not.

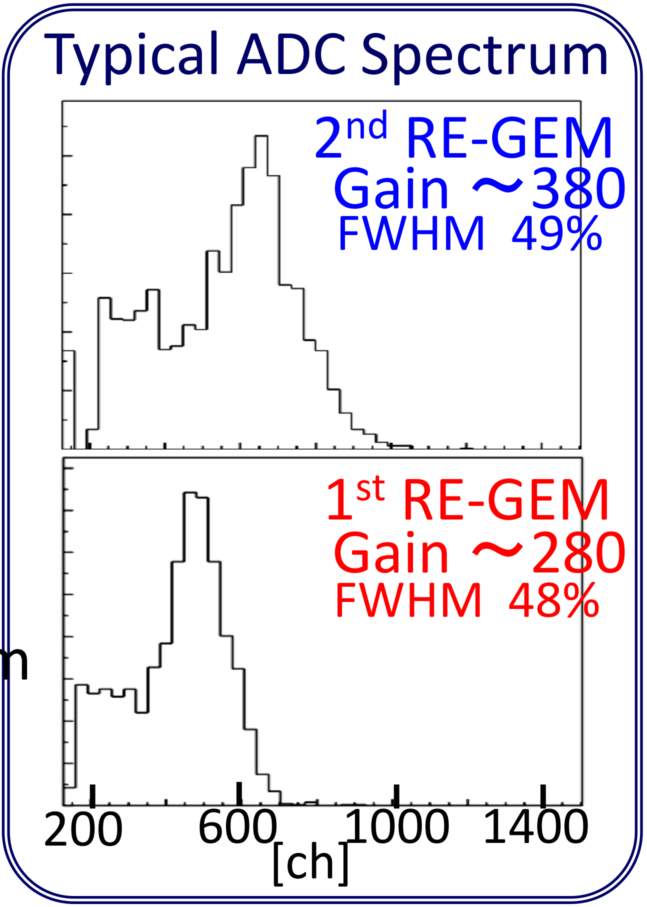




A. Yoshikawa et.al., JINST 7 C6006 (2012)

3-2. Result①: Gain vs ΔV of RE-GEM





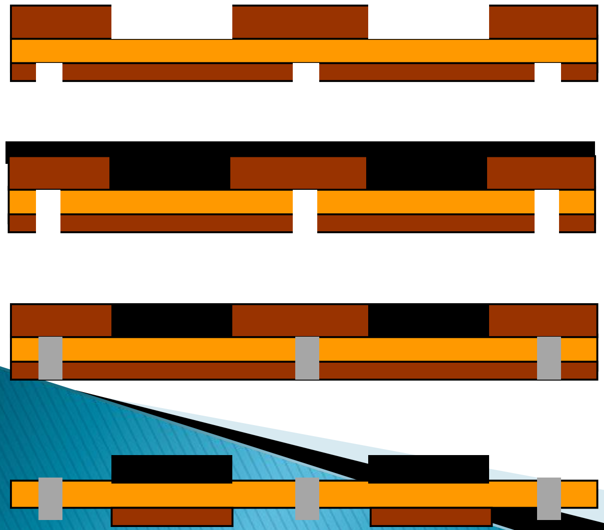
① The slope of the gain curve is almost the same.

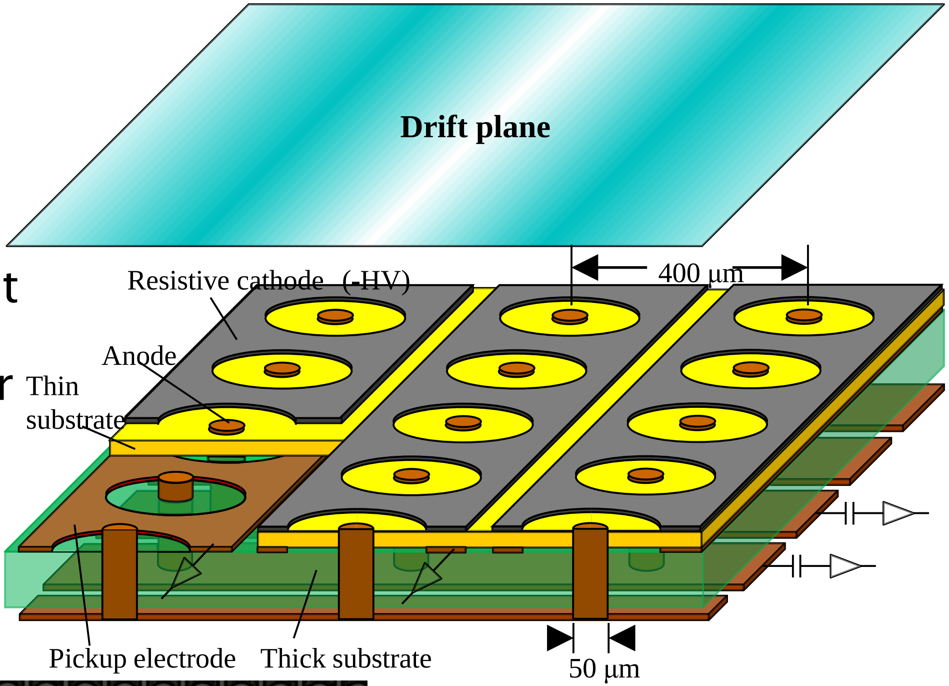
② The gain of 2^{nd} RE-GEM is larger than that of 1^{st}.

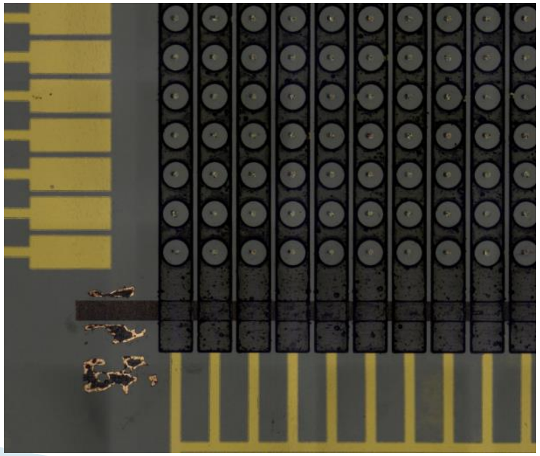
A. Yoshikawa, MPGD2011 slide

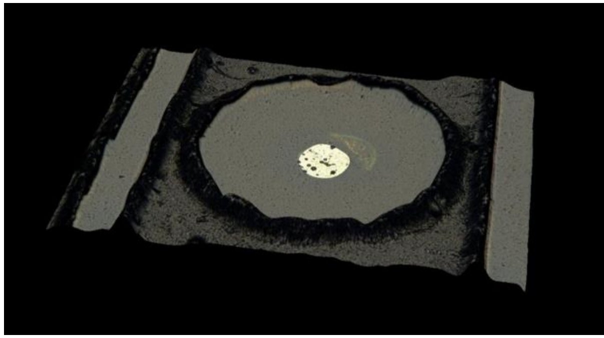
Resistive polyimide paste + μ–PIC

- Resistive polyimide paste is processed by liftoff
- Qualities of the electrodes are better.
- Sparks are strongly reduced (next slide)
- However, there are difficulties for stable operation.
  - Anode pin alignment
  - Short problem in pickup electrodes





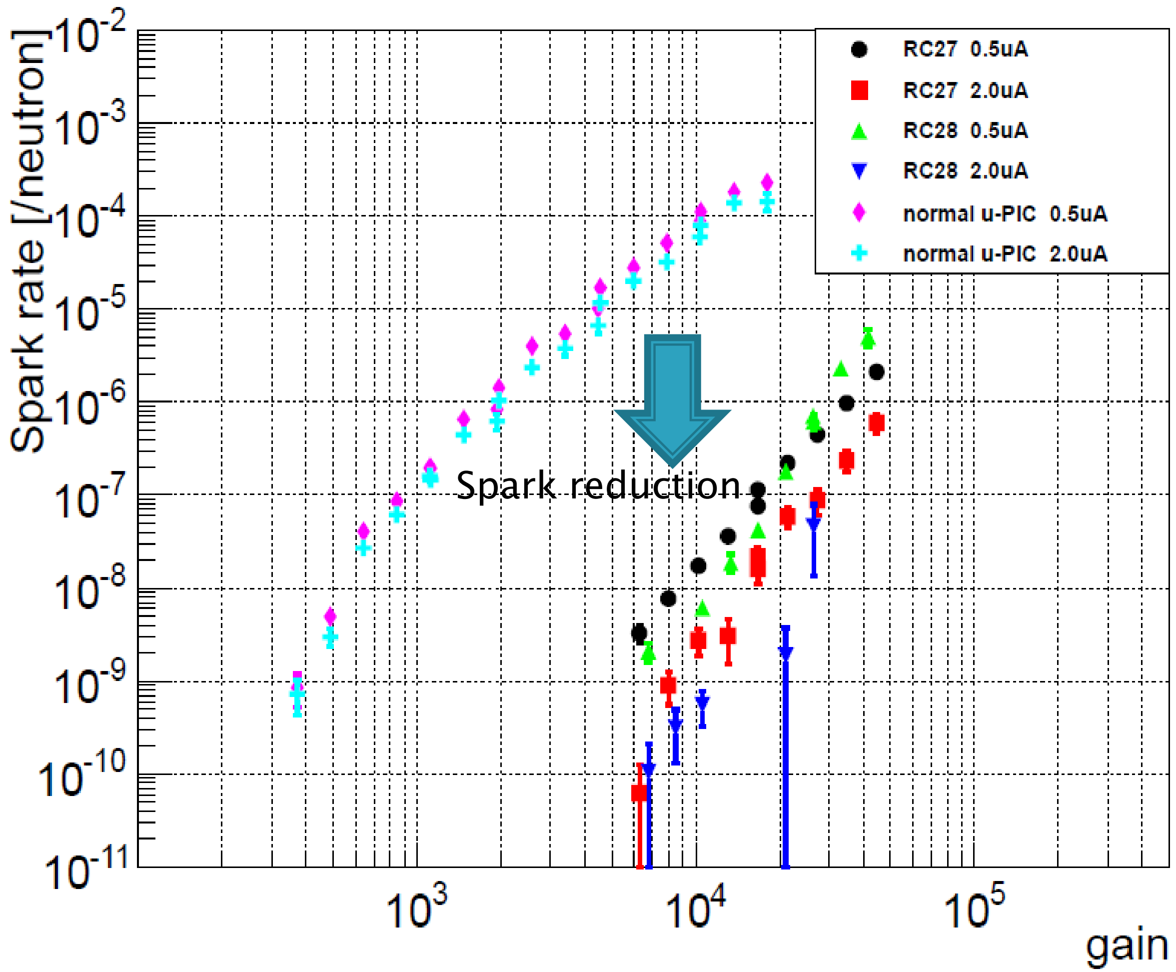




A.Ochi et.al., JINST 9 C01039 (2014)

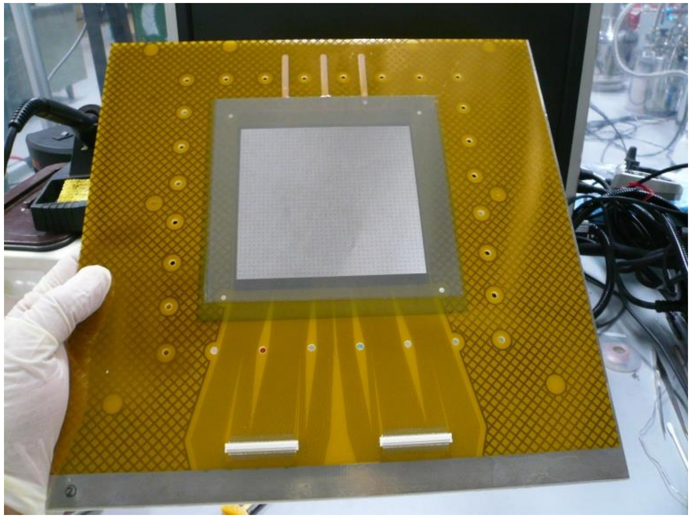
Spark probability for fast neutron (~2MeV)

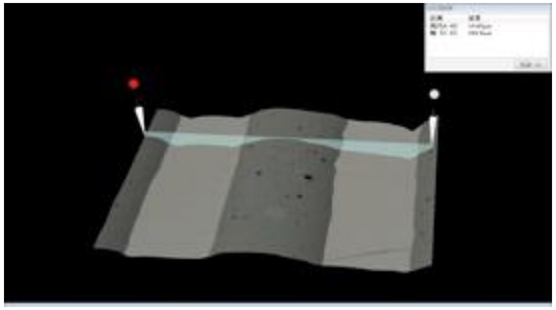
- Conditions
  - Gas: $Ar+C_2H_6$ (7:3)
  - Drift field: 3.3kV/cm
  - Definition of the sparks:
    - Current monitor of HV module shows more than 2μA or 0.5μA.
  - Spark probability = [Spark counts] / neutron
  - The spark rates on normal μ-PIC are are also plotted as comparison (cyan, magenta plots).
- Results
  - Reduction of sparks are obviously found. The rate was 10^{3-5} times less than normal μ-PIC case at same gas gain.



Resistive paste + MM

- Resistive strips are formed by screen printing
- First trial was done in 2012 using resistive polyimide paste.
- Now, we are using resistive epoxy paste for ATLAS NSW production





Printing procedure (Matsuda Screen)

Resistive paste is put on

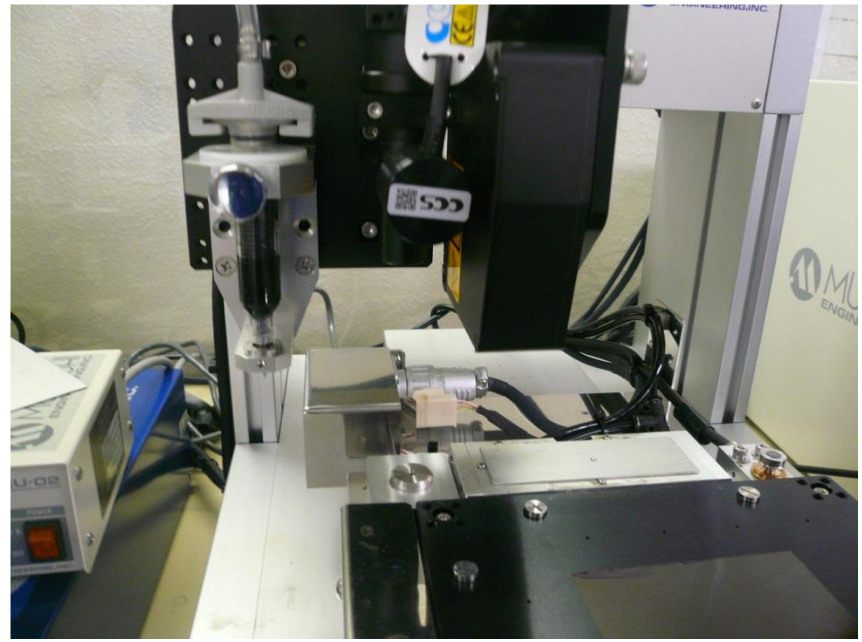
Printing is done

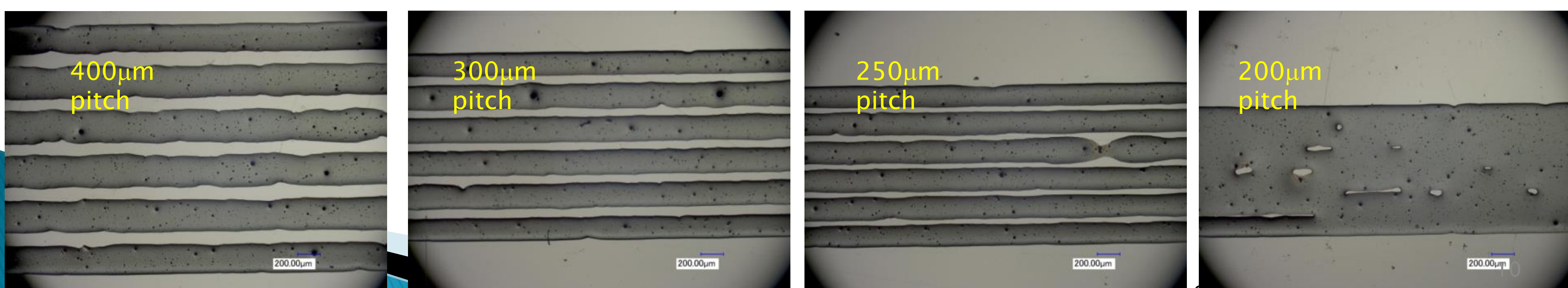
Squeegee is controlled automatically

Drying with 170 degree, 2H.

Another approach for MM strip processing using resistive paste

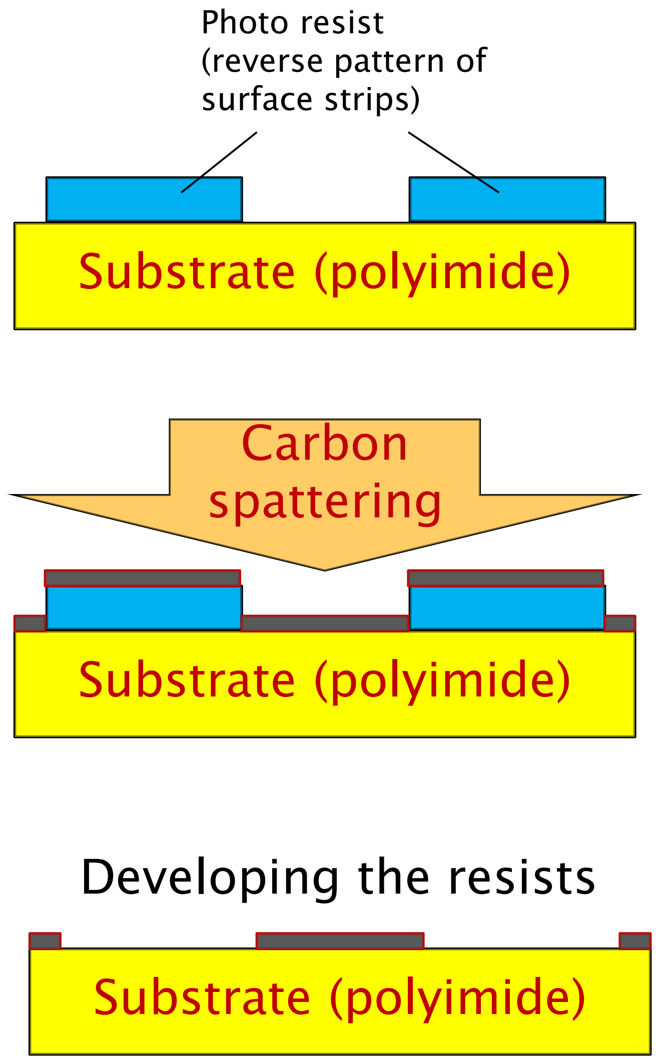
- Strip patterns are written directly by dispenser
- Fine patterns are available
- However, too much time needed for large area

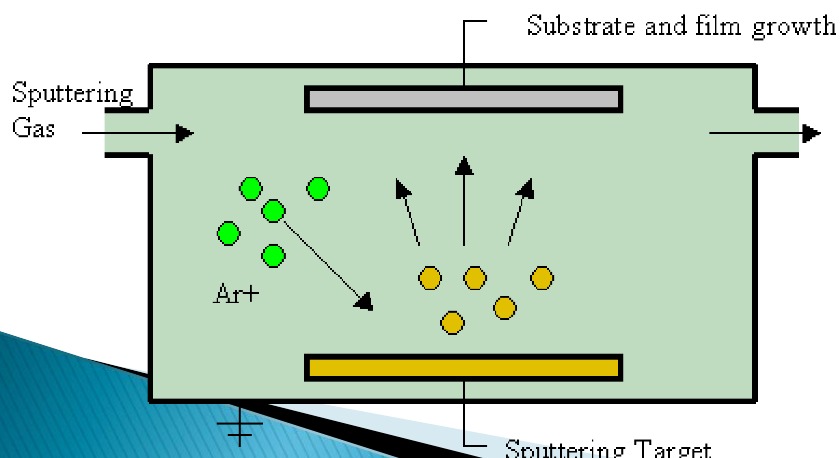




Sputtered carbon

- Sputtered carbon
  - Diamond like, and amorphous structure
  - It means, carbon particles of molecular size!
- Fine structure with proper resistivity is available
  - with liftoff method

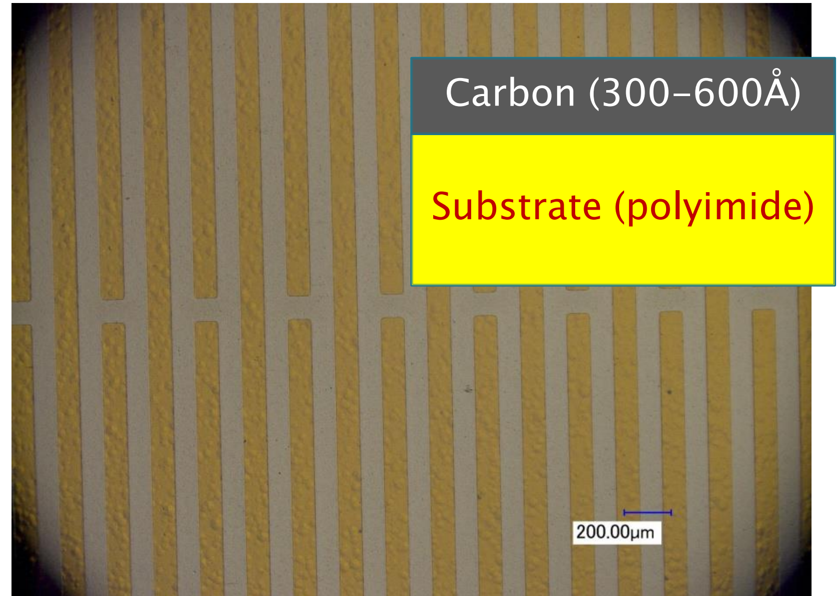


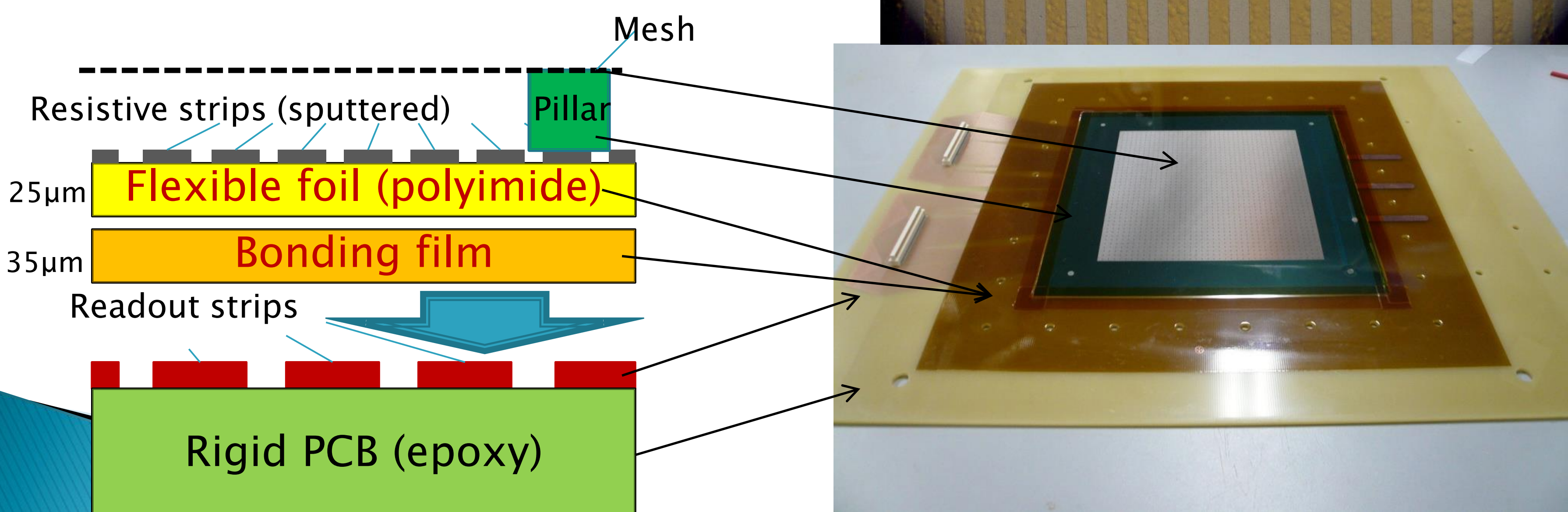


A.Ochi et.al., PoS (TIPP2014) 351

Sputtered carbon + MM

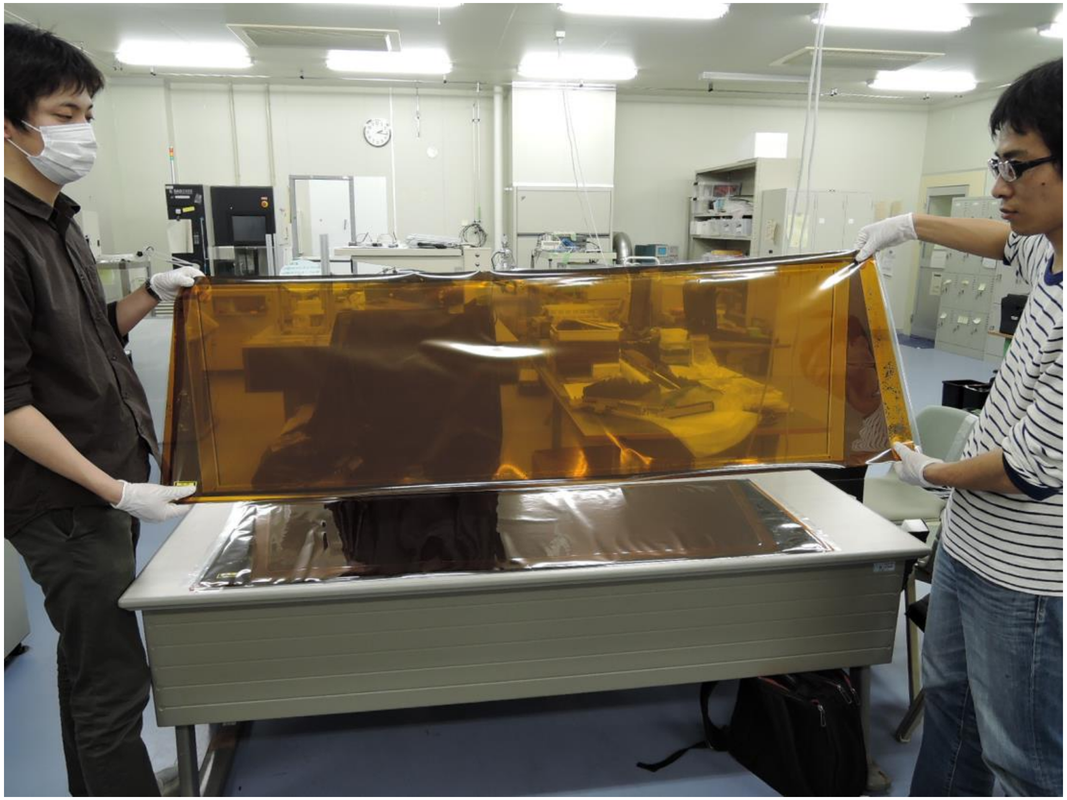
- First attempt to make MPGDs using carbon sputtering (from June 2013)
  - This R&D is aimed for ATLAS NSW MM.
  - Fine strip pitch of 200 μm or 400 μm is formed on 50μm polyimide foil.





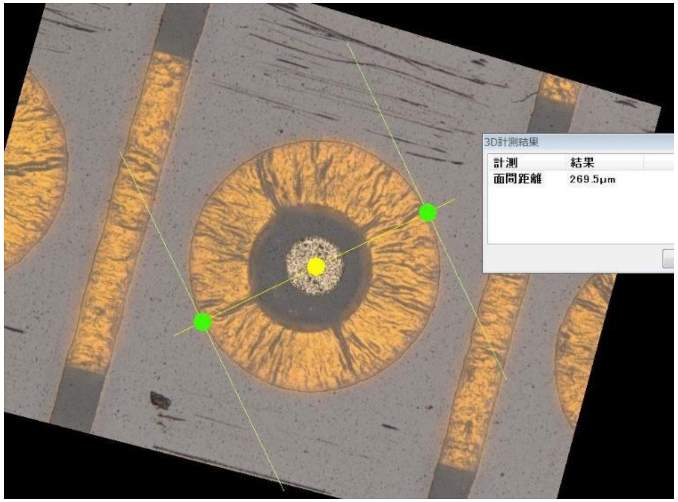
Sputtered carbon + Large MM

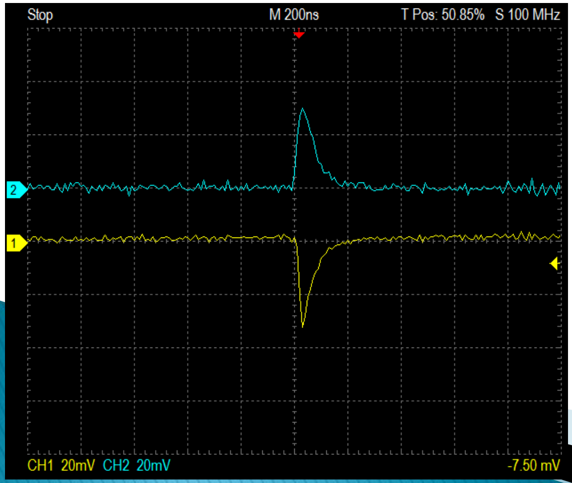
- Large size (maximum 4.5m x 1m) is available with industrial equipment.
- Resistive strips of ATLAS MM for MMSW and module-0 are made from carbon sputtering



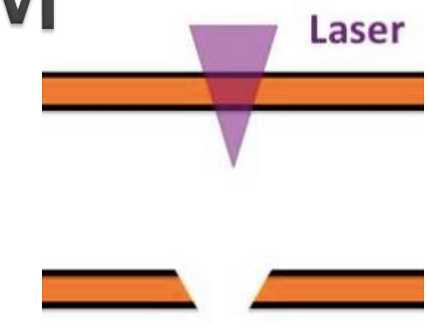
Sputtered carbon + μ-PIC

- Cathode structure should be fine
- Sputtering with liftoff is very good method for those structures.
- Two dimensional signals are observed
  - Gas gain ~ 10000
- More studies needed for stable operation



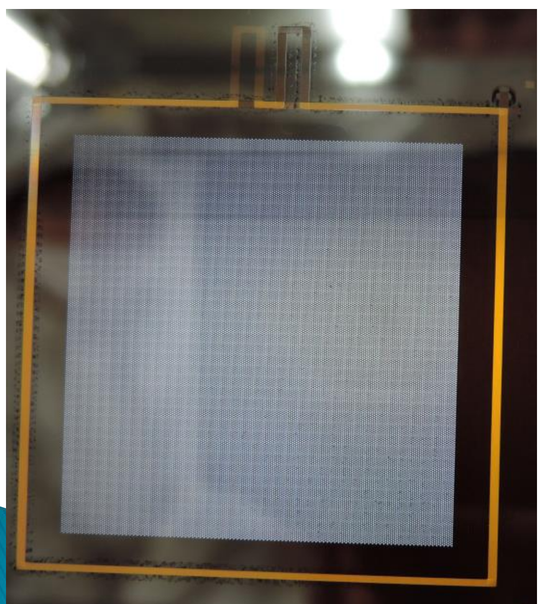


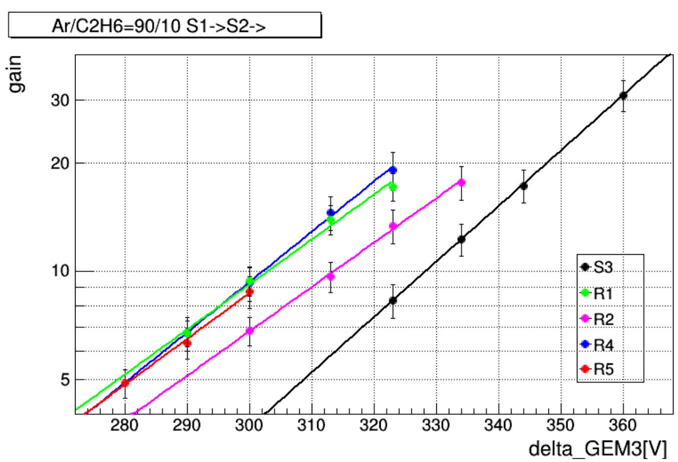
Sputtered carbon + GEM



- Re-GEM was formed by Laser drilling on double sided carbon sputtered foil
- Gas gain is less than 20 (very low)

de-smear





Summary

- Various resistive materials were tested for μ-PIC, MM and GEM prototypes.
- For fine structure, photo lithographic method is suitable.
  - Most fine structure will be formed by carbon sputtering
  - Also huge size (>1m) production is available
- Screen print of resistive paste is very low cost
  - Less fine, but it is enough to ATLAS NSW MM resistive strip

Materials	Resistive sheet	Paste (polyimide)	Paste (epoxy)	Sputter
Resistivity	2M	1M~2M	0.5M~2M	50k~100M
Fineness	~50μm	~100μm	~100μm	~10μm
Process	Etching Laser drilling	Liftoff Screen print	Screen print	Liftoff Laser drilling
Detector	μ-PIC GEM (RIKEN)	μ-PIC MicroMEGAS	MicroMEGAS	μ-PIC MicroMEGAS GEM

Kapton type (EN/HN)

- Kapton HN is commonly used as MPGD substrate (particular in CERN)
- HN type is provided as standard type Kapton by Dupont.
- In Japan, similar series of Kapton foil is provided by Toray-Dupont.
- Standard type (in Japan) is “H” type
  - I think, it is almost same as “HN” type
- Dimensional stability of “EN” is better than “H”

Item	Unit	200EN	200H
Ultimate tensile strength	MPa	350	315
Tensile modulus	Gpa	5.8	3.4
Thermal Coefficient of Linear Expansion (50~200°C)	ppm/°C	16	27
Shrinkage (@200°C)	%	0.01	0.20