Technology aspects in constructing the basic components of MPGDs

Rui de Oliveira

CERN PCB workshop

20 persons
Building :1000 sqr meters
Making PCBs since 1960

-PCB
- -Rigid
- -Flex
- -Flex-rigid
- -Microvias
- -fine line (10um)
- -large size (up to 2m)
- -Thick film Hybrids
- -Thin film Hybrids

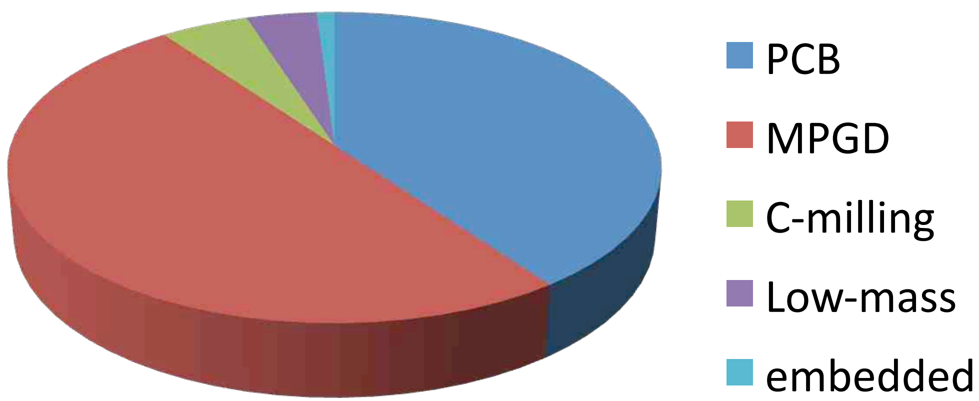
-Chemical milling
- -Cu, Fe, Al, Au, Ag, W, Mb, Ti, Cr, Ni

-MPGD
- -GEM/thinGEM/THGEM/RETHGEM
- -MSHP/Cobra
- -MICROMEGA/ Bulk/ Micro-BULK
- -RES BULK
- -Resistive MSGC

-Low mass circuits
- -Multilayer flexes with aluminum strips
- -embedded heat sinks (carbon, graphite, metals, diamon)

-Embedded components
- -passive
- -Active

Activities



CERN PCB Workshop MPGD history

'96: GEM 50 x 50mm with a gain of 10.

'97: GEM 100 x 100mm with gain of 1000.

'98: GEM 400 x 400mm; 1D and 2D readouts; micro-groove and micro-well detectors.

'00: 3D GEM readout; 1D readout for Micromegas in COMPASS.

'01: PIXEL GEM readout; 2D Micromegas readout.

'03: PIXEL Micromegas readout.

'04: Bulk Micromegas detector 100mm x 100mm. Micro BULK detectors

'06: Half cylindrical GEM detector.

'08: first large GEM 1.2m x 0.4m. First spherical GEM

'09: first large BULK Micromegas 1.5m x 0.5m

'11: First resistive Bulk Micromegas 100mm x 100mm

'12: First 30cm x 30cm NS2 GEM detector

'12: First 1m2 Resistive Micromegas

'12: First 2m2 Resistive Micromegas

'12: First NS2 GEM detector 1.2m x 0.5m

'12: Full cylindrical GEM detector

'14: GEM 2m x 0.5m ?? Micromegas 3.4m x 2.2m ??

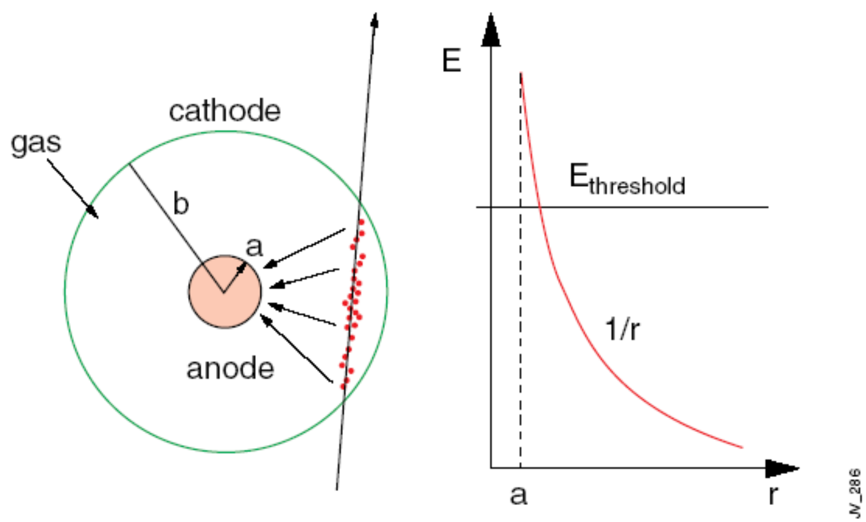
outline

- ***MPGD structures introduction***
- **Mechanics**
- **Chemistry /electro chemistry /photolytography**
- **Screen printing**
- **Laser**
- **Vaccum deposition**
- **Plasma**
- **Ink jet printing**

How to make a detector?

First , a gas amplifying structure is needed

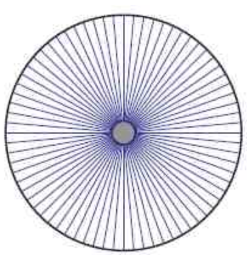
High local fields structures are needed to create a detector



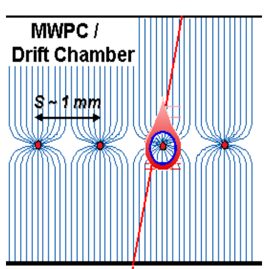
Electrons liberated by ionization drift towards the anode wire.

Electrical field close to the wire (typical wire Ø ~few tens of μm) is sufficiently high for electrons (above 10 kV/cm) to gain enough energy to ionize further → avalanche – exponential increase of number of electron ion pairs.

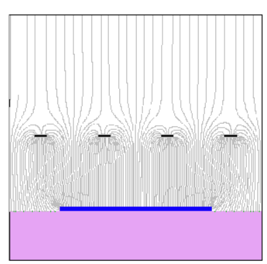
Cylindrical geometry is not the only one able to generate strong electric field:



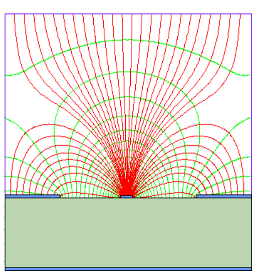
wire



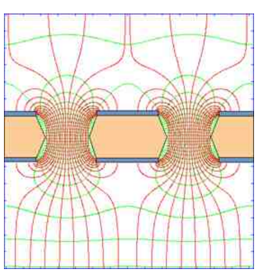
mwpc



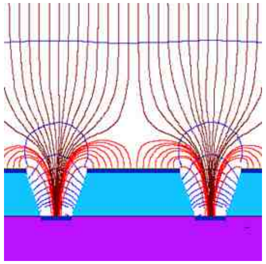
parallel plate



strip



hole

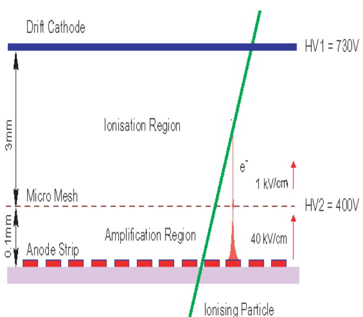


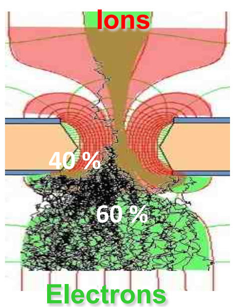
groove/well

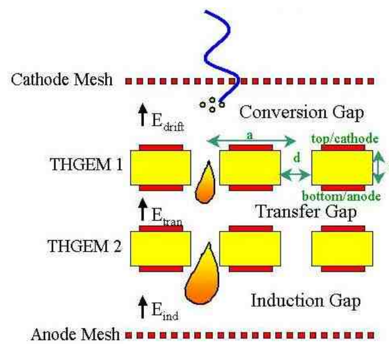
By reducing sizes MPGDs have improved a lot the detector capabilities in many domains

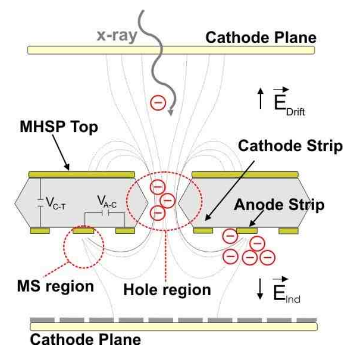
- Micromegas
- GEM
- Thick-GEM, Hole-Type Detectors and RETGEM
- MSHP
- MPDG on ASICs : Ingrid

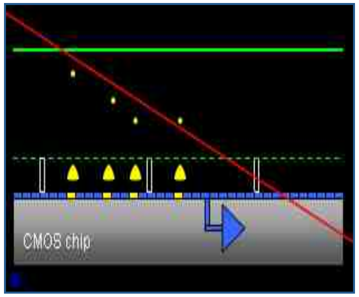
- Higher rate
- higher granularity
- friendly gases
- less aging
- better energy resolution
- IBF reduction

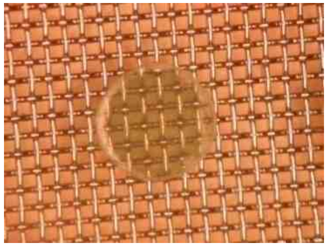




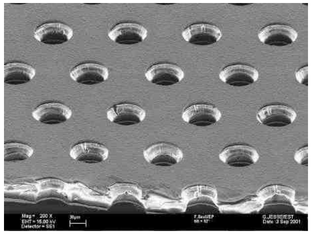




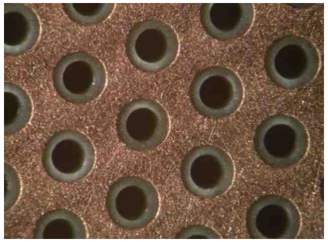




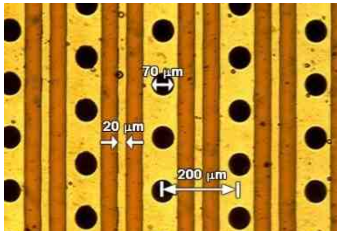
Micromegas



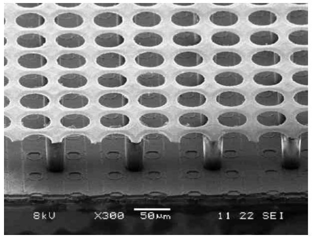
GEM



THGEM

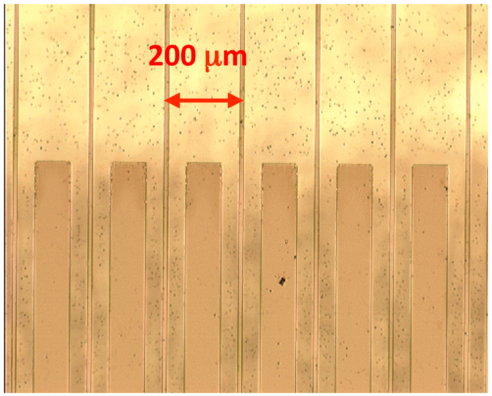


MHSP

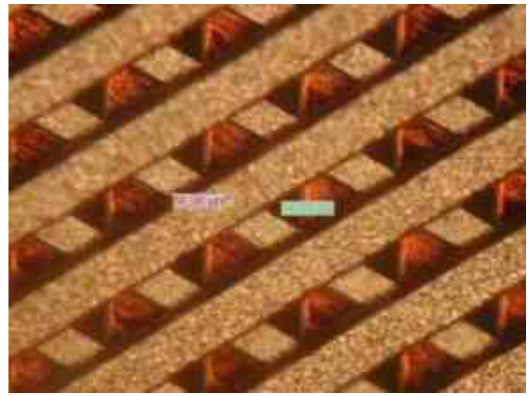


Ingrid

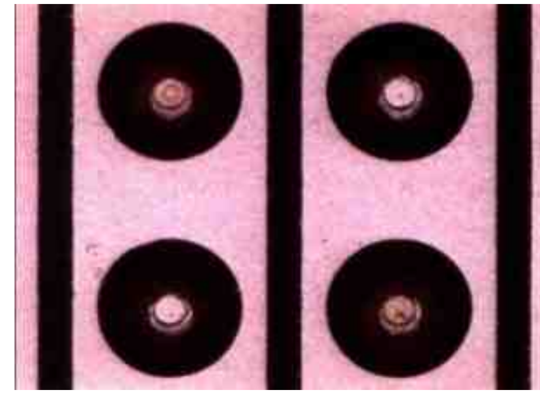
Other examples : less successful , I will say not mature



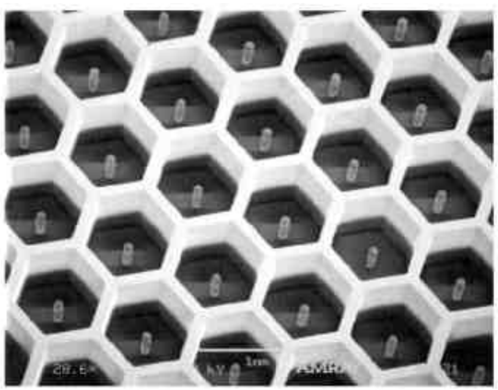
MSGC



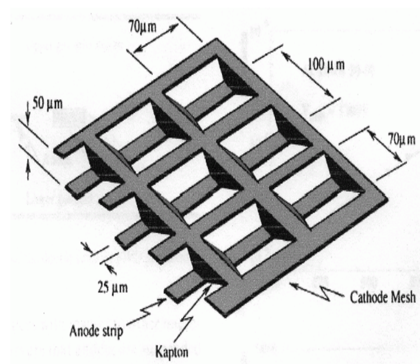
FGLD



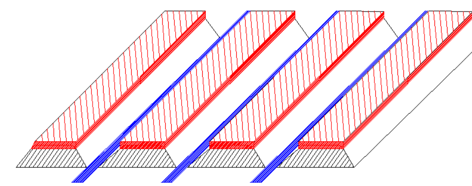
Dot structures



Mico dot structures



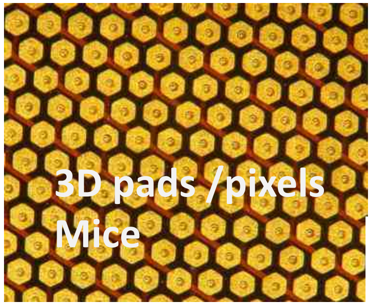
Micro-slit

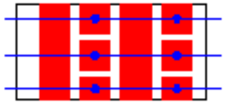


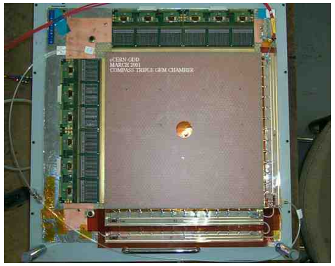
Micro well and groove

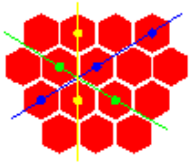
Secondly , collect the charges

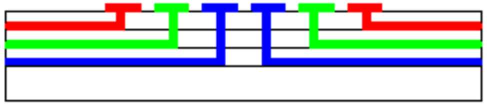
Read-out structures

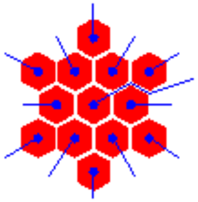


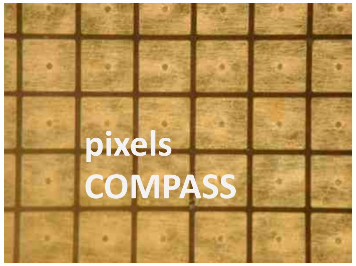


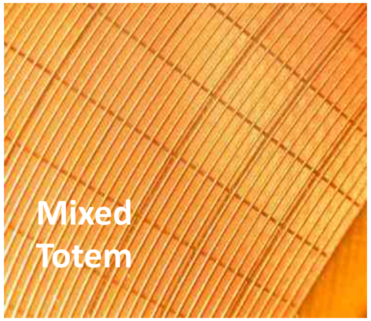






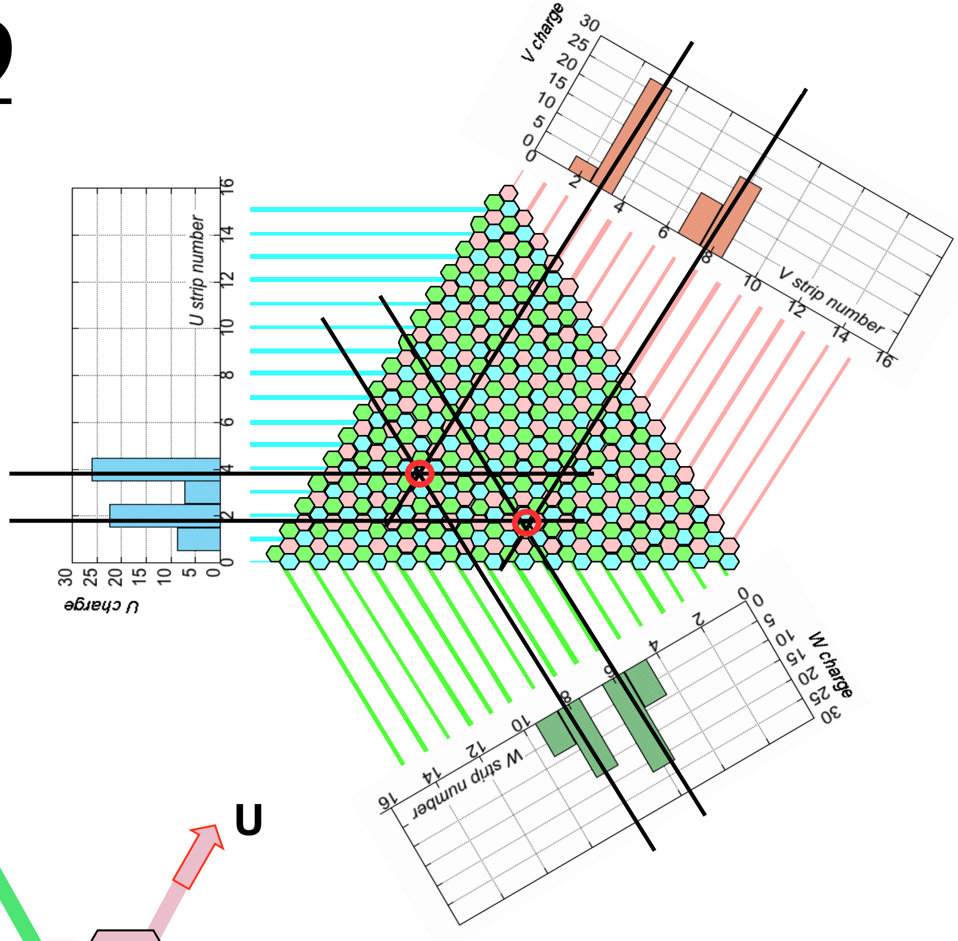


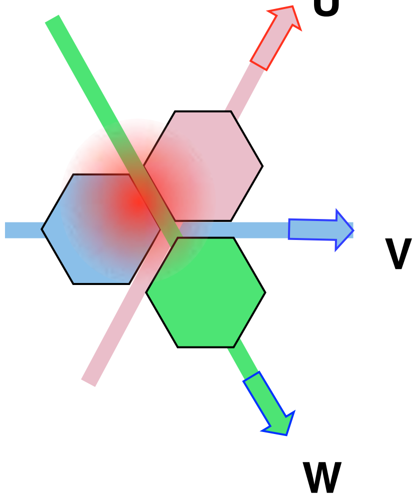


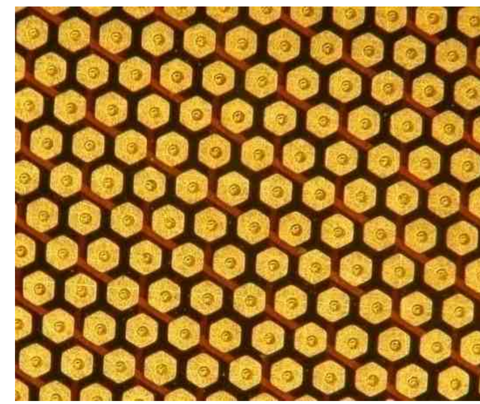


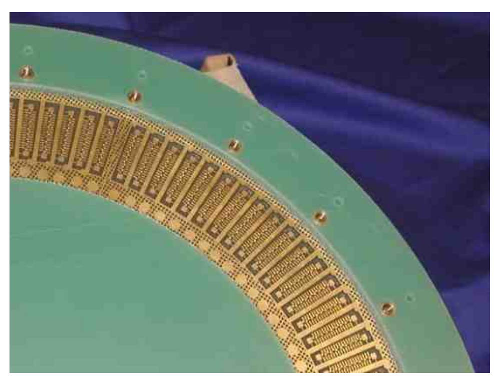
3D

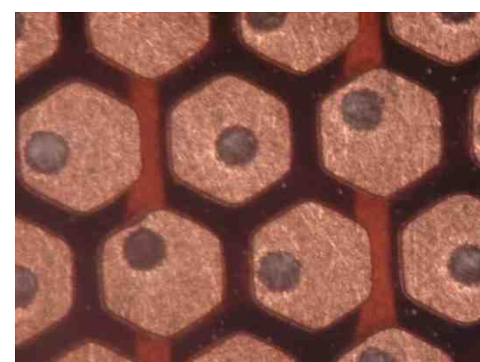
Mice Experiment, 350um cell
30cm active area



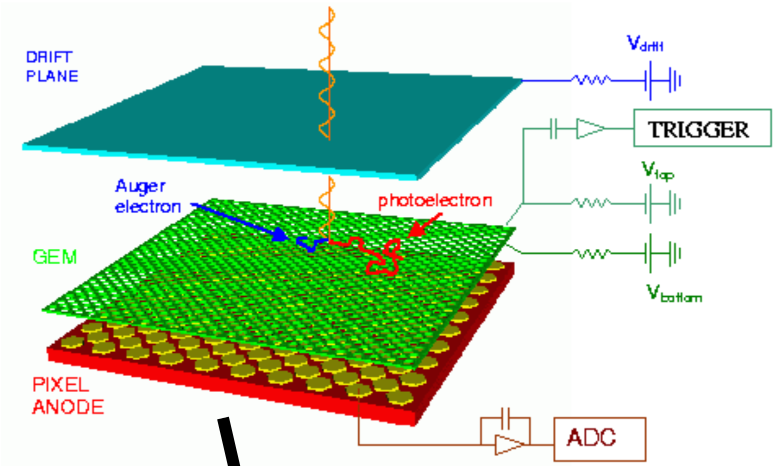




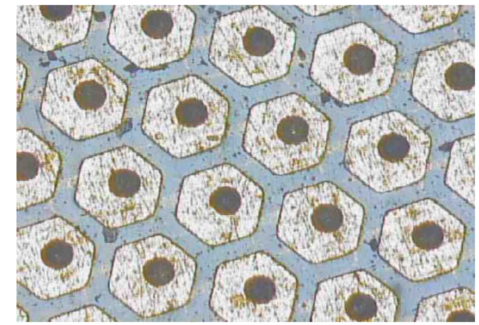




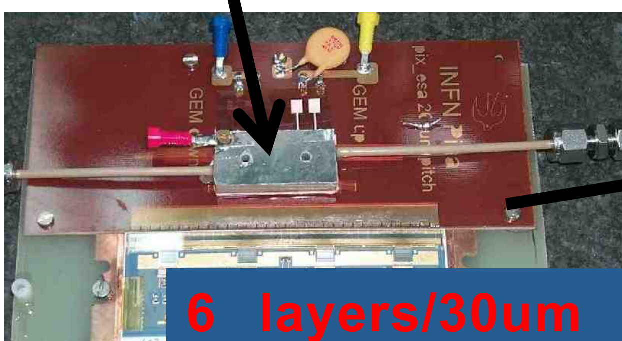
Pixel read out

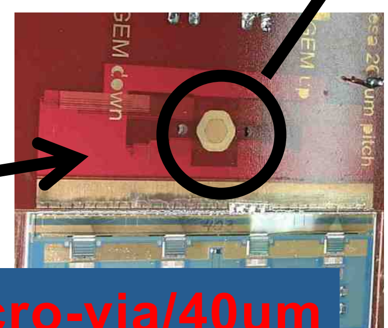


Read out plane



Read out pitch: 260 um !

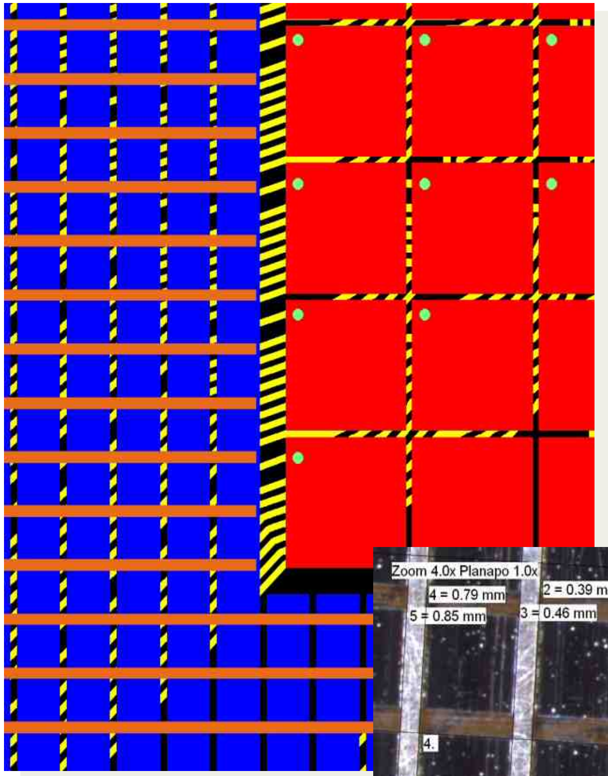




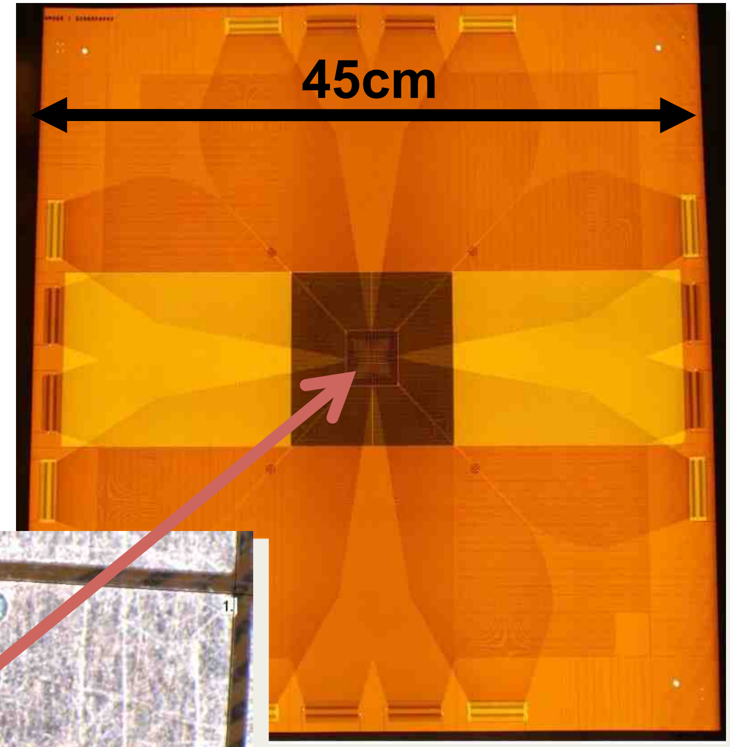
512 electronic channels from a few mm² active area are individually read out by means of a multi-layer PCB fan out

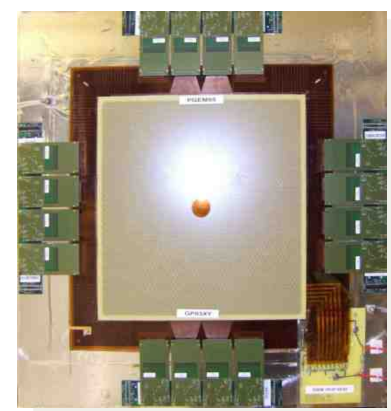
6 layers/30um micro-via/40um lines

-X-ray polarimetry (220um pads)

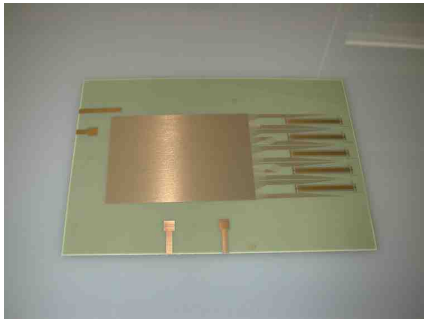


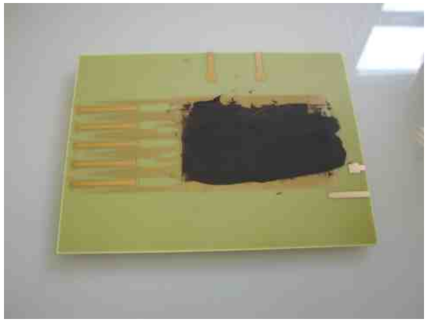
COMPASS PIXEL + strips

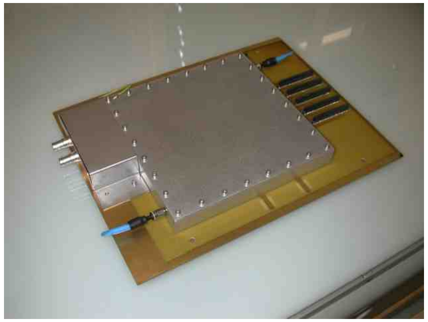




3 , protect your detector

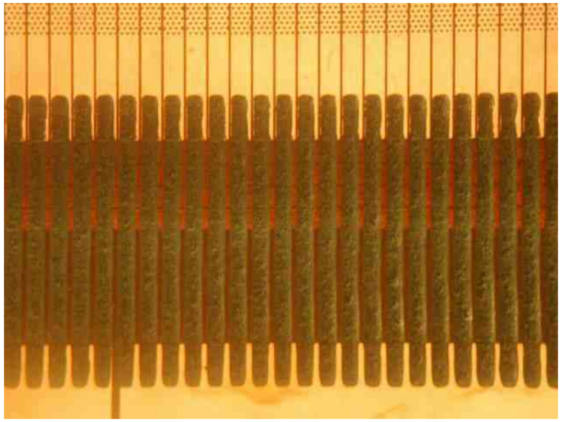


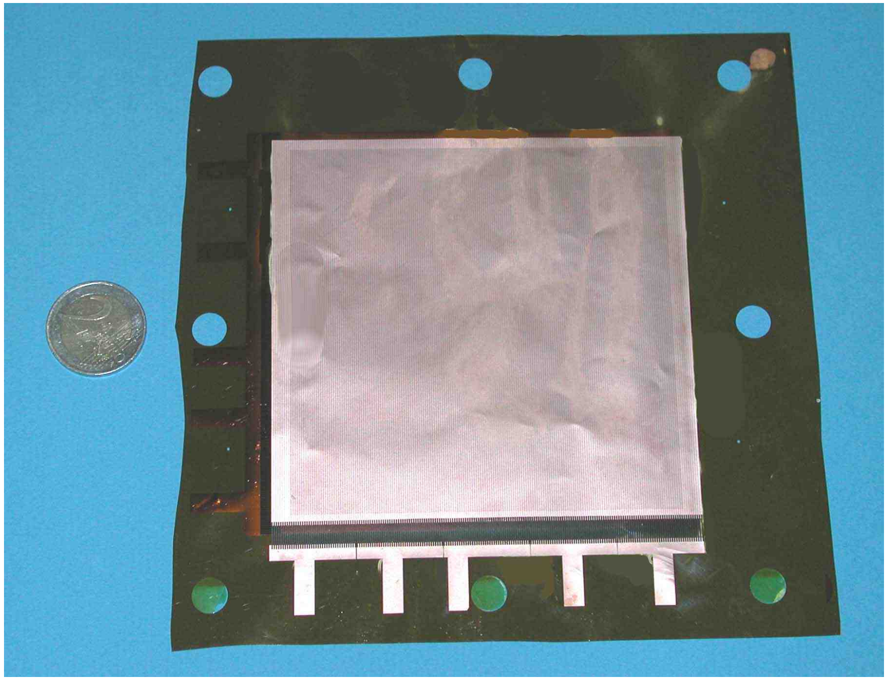


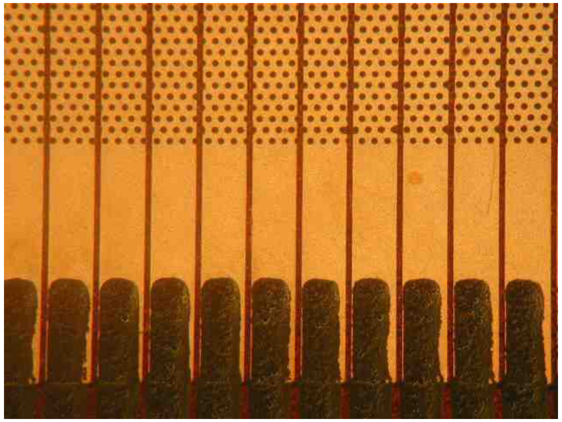


Examples

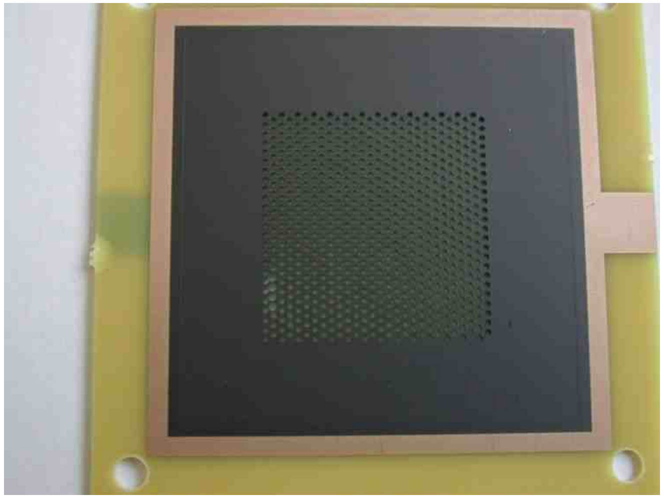
Small spatula



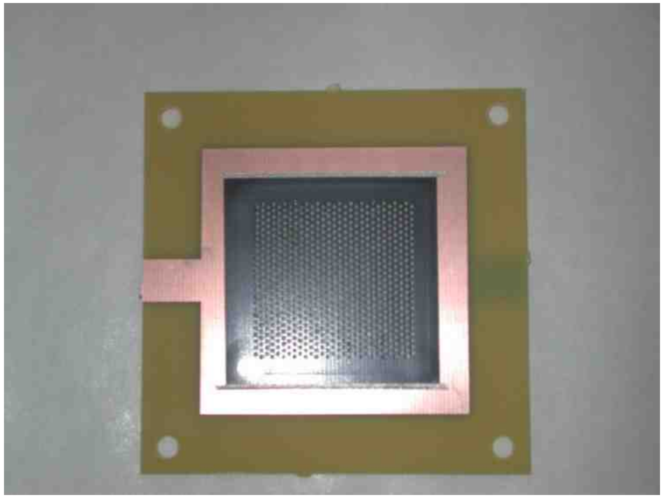


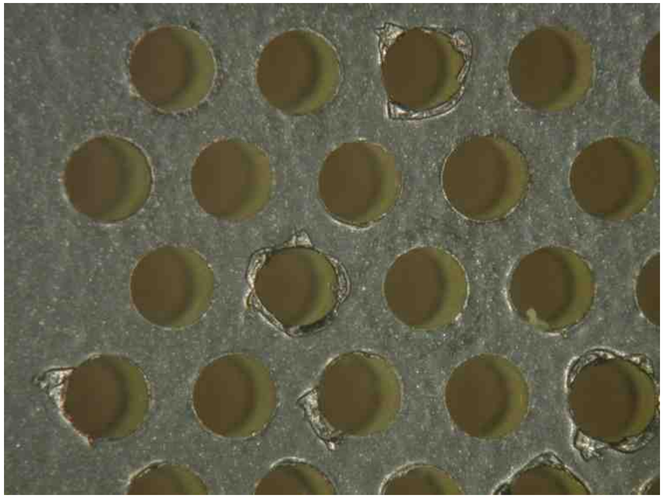


Fine segmentation test with printed polarization resistors



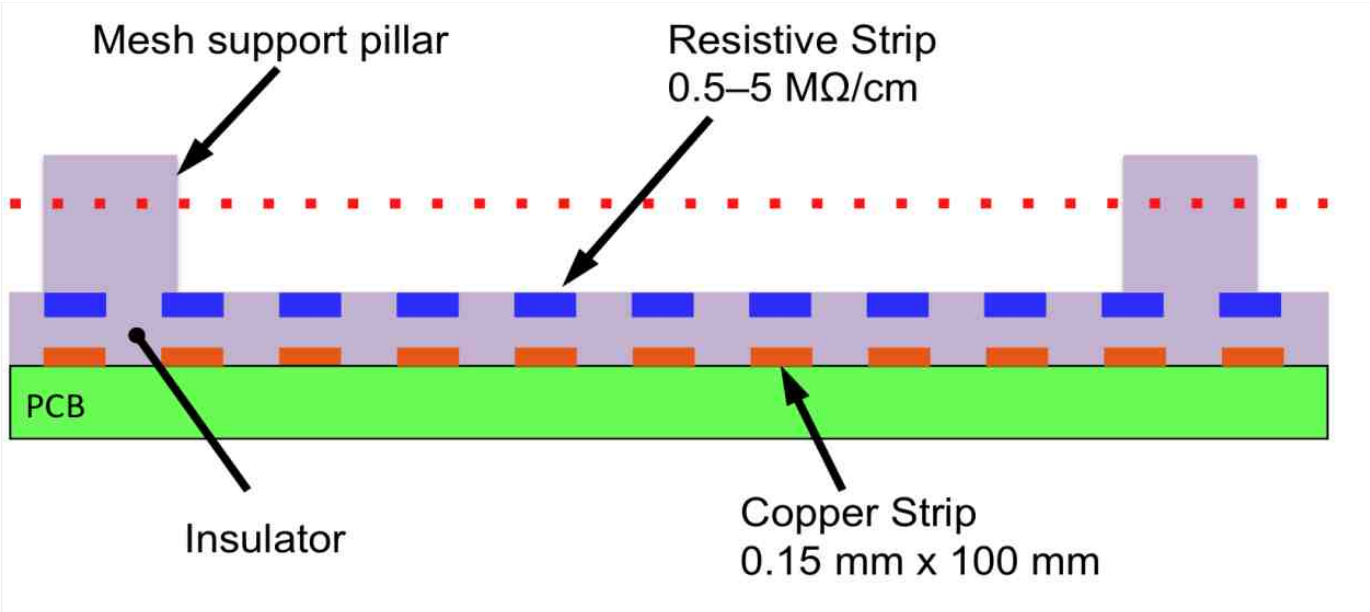
Paste from 10 Ohm/square to 1 MOhm/square





Polyimide resistive sheets 200 Ohm/square or 1 MOhm/square

Resistive Bulk Micromegas



outline

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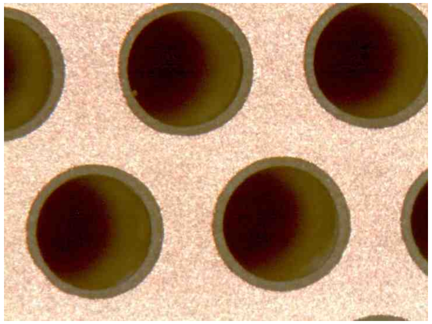
- ***Mechanics***
- **Chemistry /electro chemistry /photolithography**
- **Screen printing**
- **Laser**
- **Vaccum deposition**
- **Plasma**
- **Ink jet printing**

Example1: THGEM

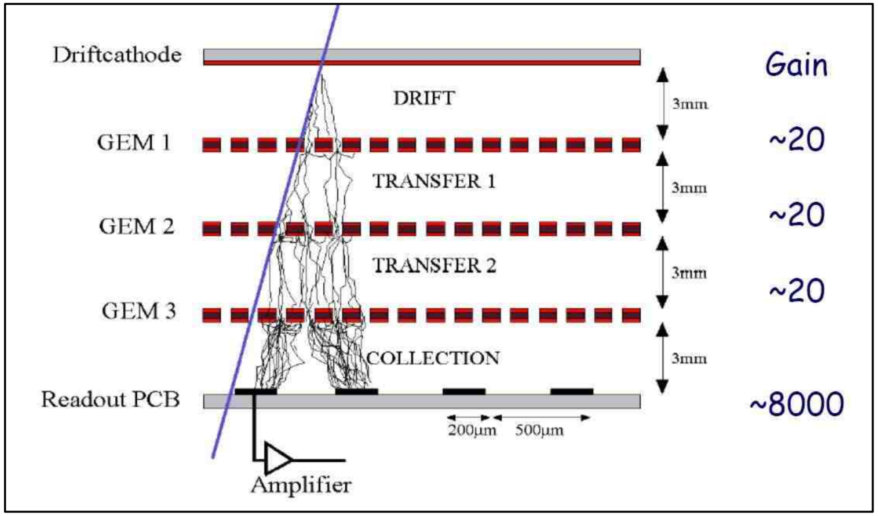


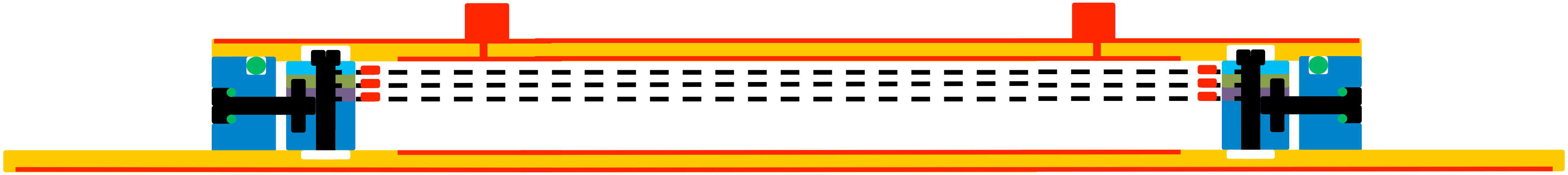


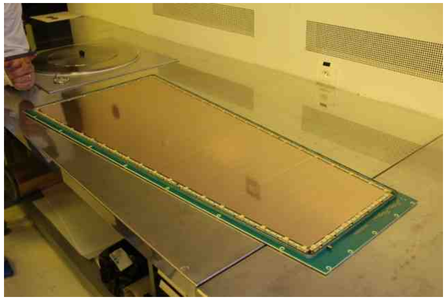
600 x 600 mm² THGEMs produced at ELTOS (Arezzo, Italy) for the Trieste INFN group

<u>CNC drilling machine</u>
-Min diameter 0.2mm
-0.05mm for blind hole
-180 000 RPM
-0.1 to 3mm thick plates
-Glass epoxy base material
-Tungsten carbide tools
-1000 to 2000 holes per tool
-Rate 3 to 10 holes/seconds

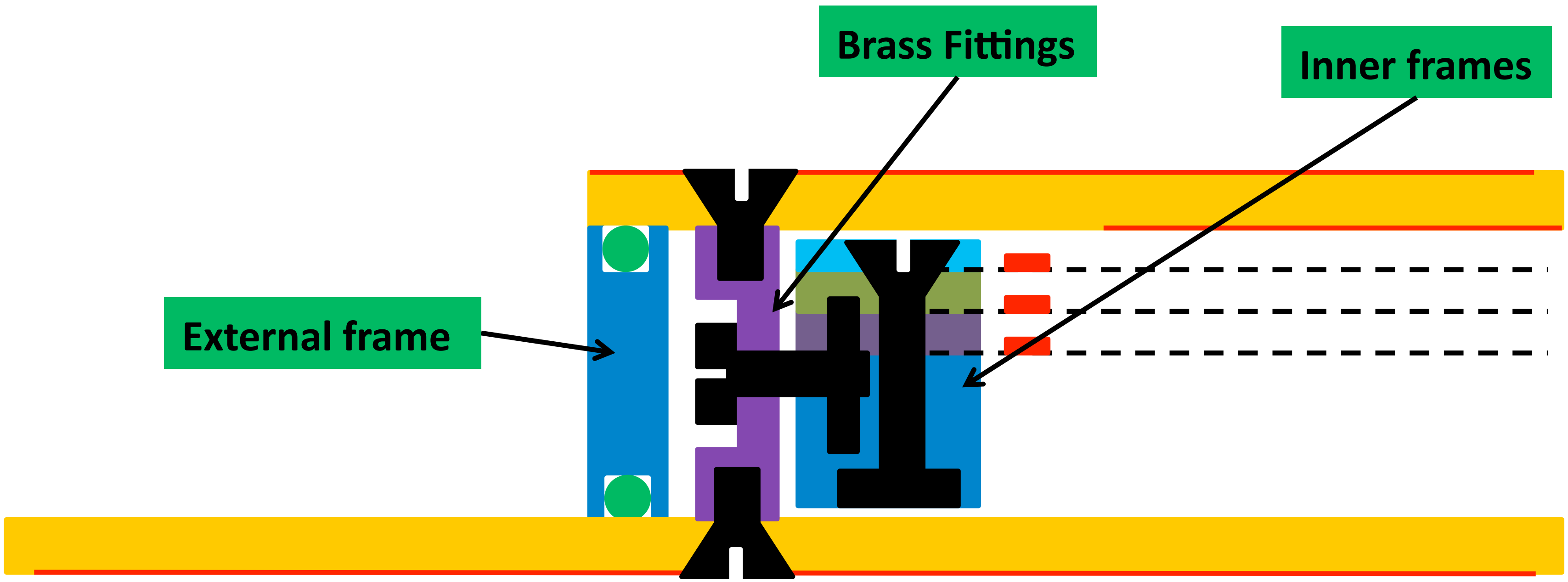
Example 2 : NS2 assembly of triple GEM detectors







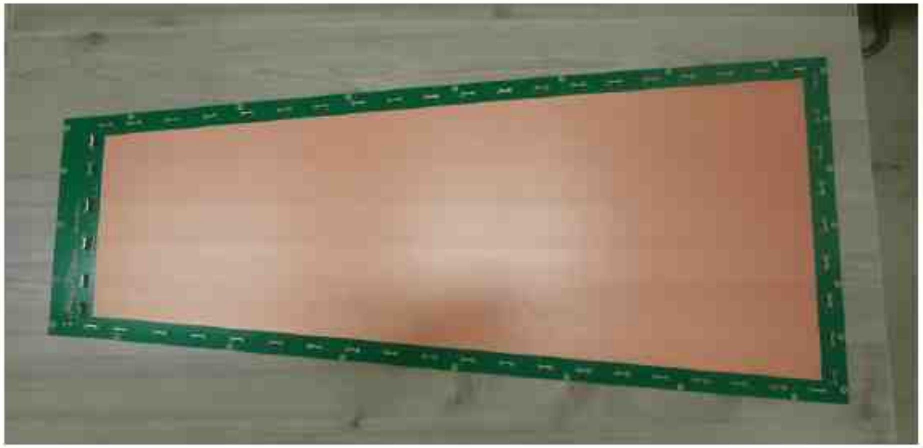
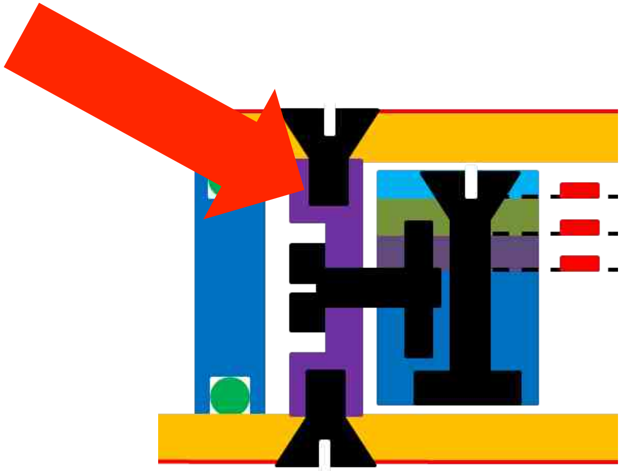
NS2 last version (CMS GE1-1base line):



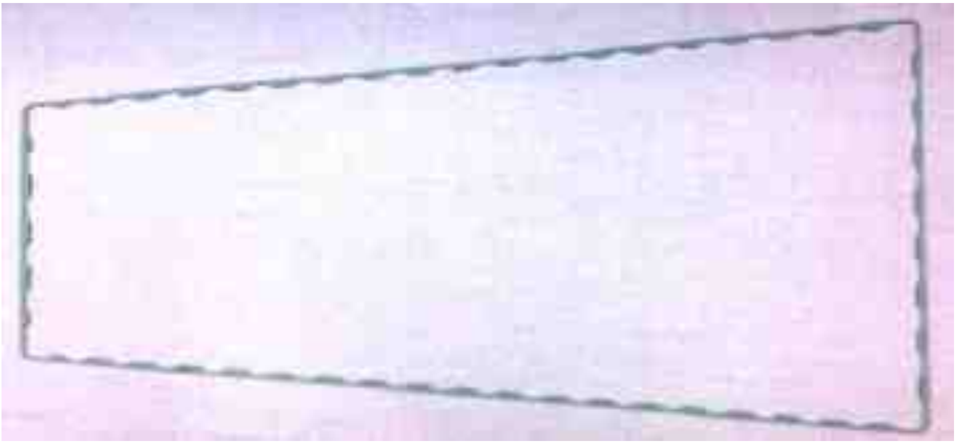
- -Many parts are made with a CNC milling machine
- -Min milling diameter 0.5mm
- -50 000 RPM
- -Glass epoxy base material
- -Tungstene carbide tools
- -Up to 12mm thick boards

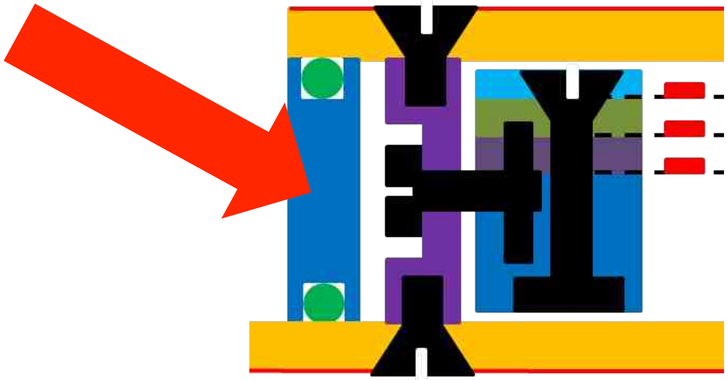
NS2 Brass fittings assembly

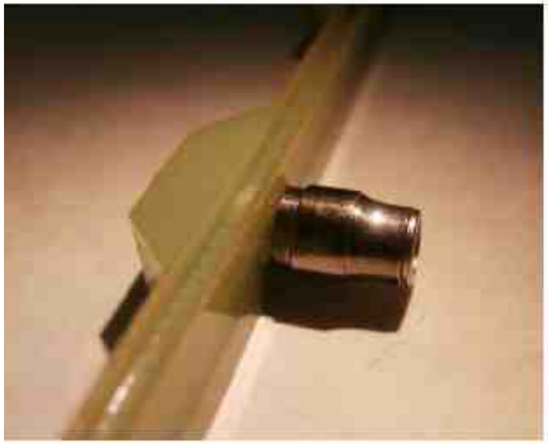


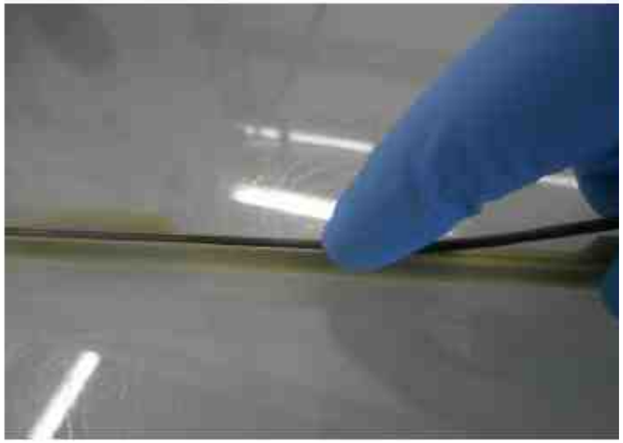




External frame



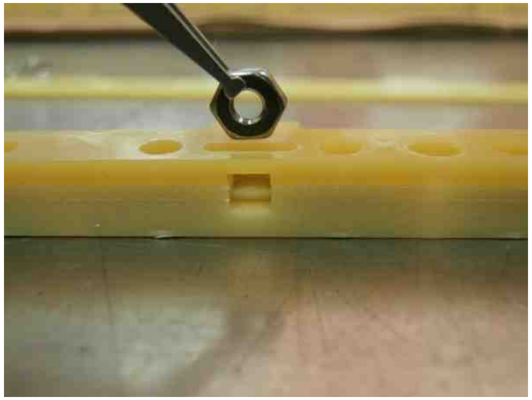


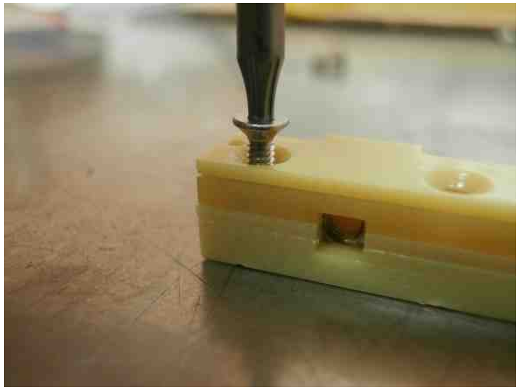


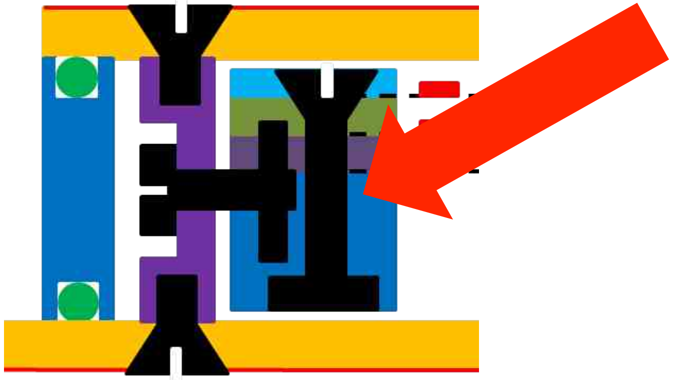


Made from a glass epoxy panel 7mm thick by CNC milling

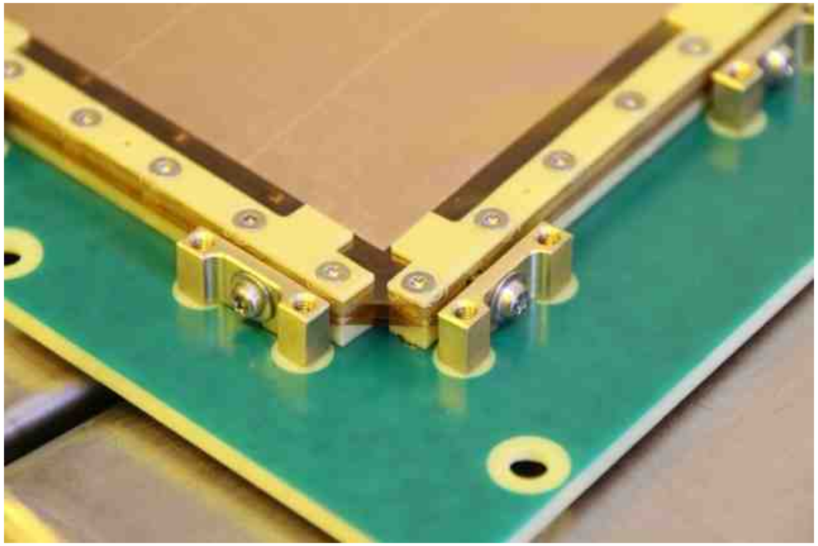
Internal frame parts

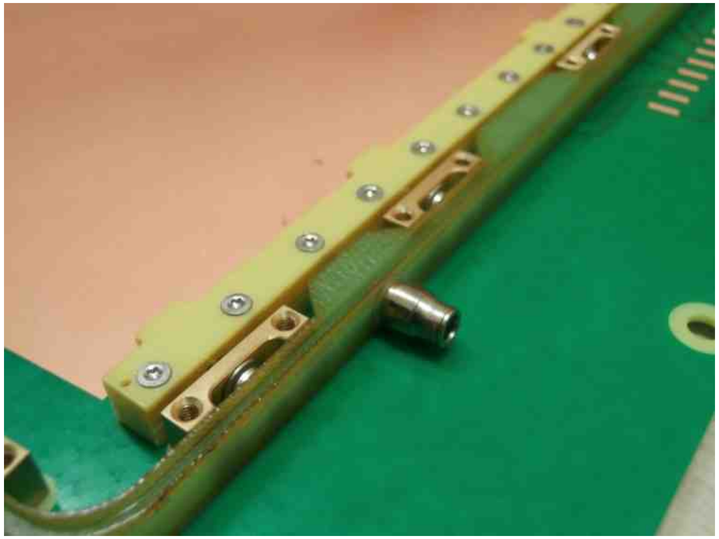


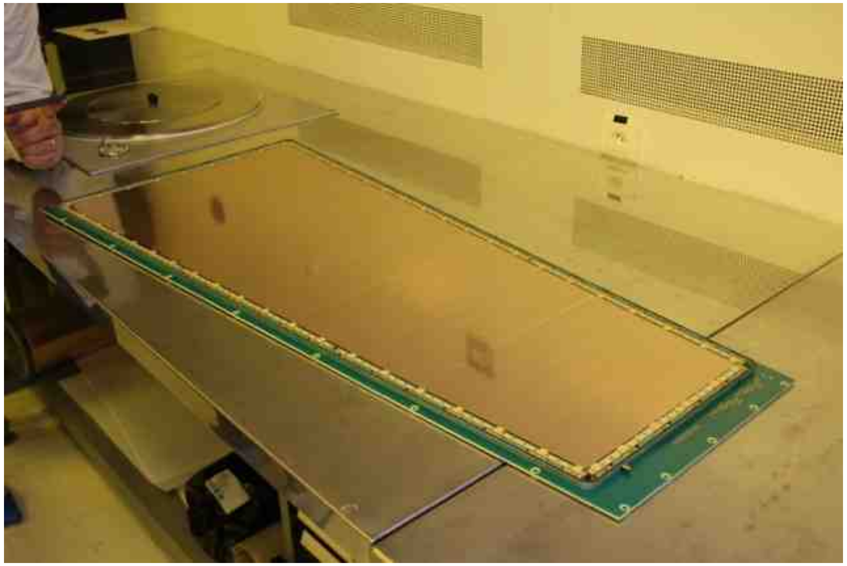




Final detector assembly

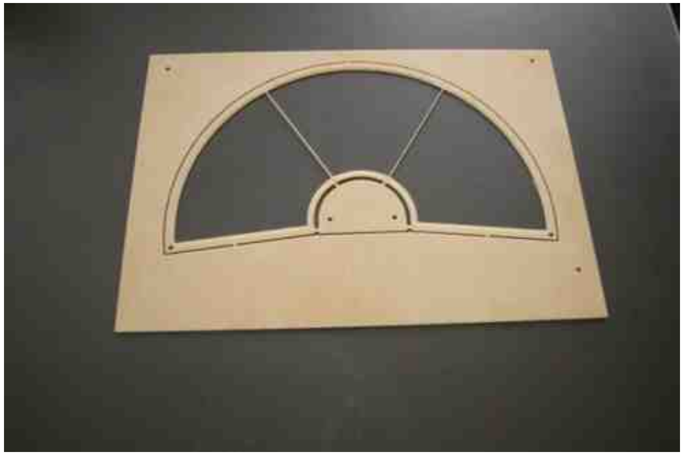


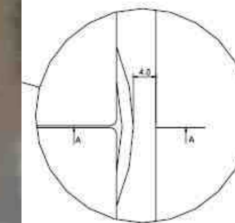


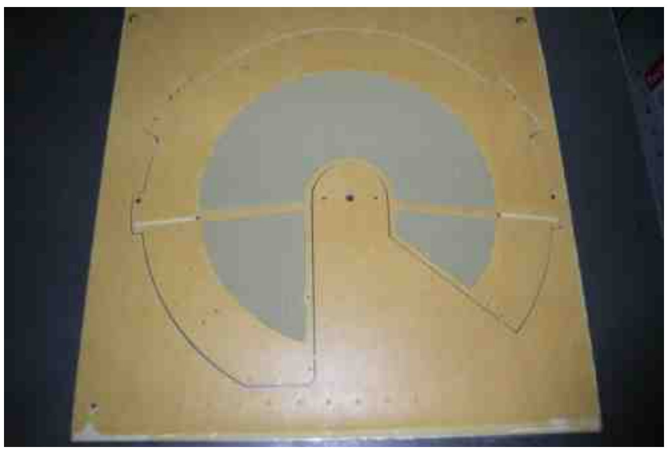


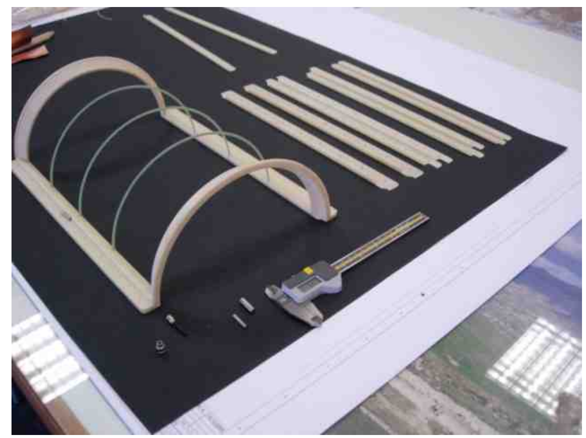
-With this method the assembly time
Is reduced to 3 hours / detector
-It was close to one week with gluing
Processes
-The detector can be reopened at any time
- The read-out panel can be upgraded

Example 3 : Frames and support









- Mechanical rigidity after foil stretching and gluing !
- Spacers with extra thin wall : 0.3 mm width and 2 mm height
- Gas flow channels; gas connectors
- Glue flow preventing grooves

- CNC machine
- 3D printing

Example 4 : Micromegas meshes on frames

Mesh stretching

outline

- **MPGD structures introduction**
- **Mechanics**
- ***Chemistry /electro-chemistry /photolithography***
- **Screen printing**
- **Laser**
- **Vaccum deposition**
- **Plasma**
- **Ink jet printing**

Basics of photolithography

- **1 /deposition of a photosentitive layer on a support**
- **2/ expose with UV light through a mask**
- **3/ remove the non exposed part by chemical development**
- **4/ dip in chemistry to etch the support**
- **5/ the pattern is transfered from the mask to the support**

Possibilities

- **3D structures down to 100 um can be realized**
  - **Any material can be etched**
  - **But 2 are really strong (PTFE and Silicone)**
- **Definitive photopolymers are existing**
  - **Photoimageable coverlays**
  - **Photoimageable polyimide**
- **Photo imageable mineral materials exist also**
  - **Glasses**
  - **Ceramics**

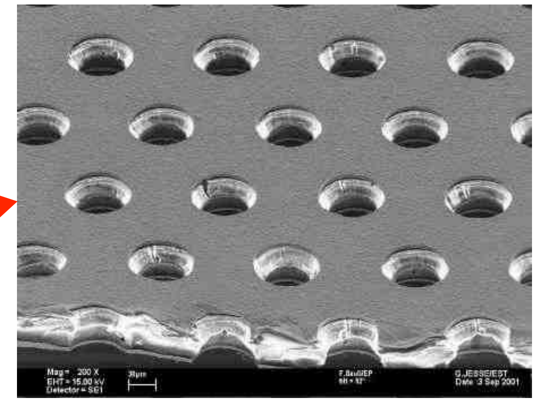
Metal deposition by chemical means

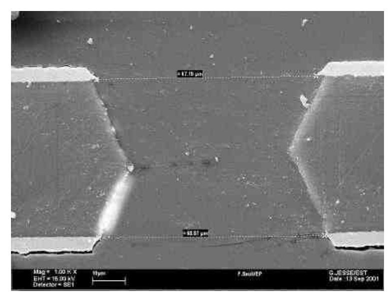
- **Cu , Ni , Au, Ag, Sn, Pb, Cr, Pt ,Pd**
  - **Electro-plating**
  - **Chemical deposition**
  - **Electro-forming**
- **All the others are difficult or impossible to deposit**

Examples of chemical processes application

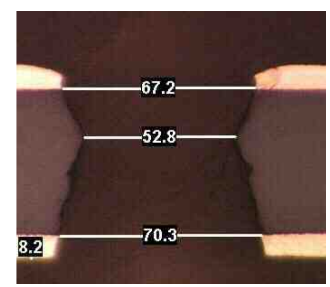
First example : GEM Foil production

- -50um Polyimide foil
- -5 um copper both sides
- -Std pattern 140um pitch/70um holes
- -Any pattern down to 30um holes is feasible





Double mask

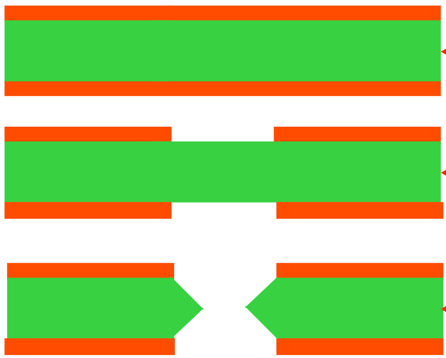


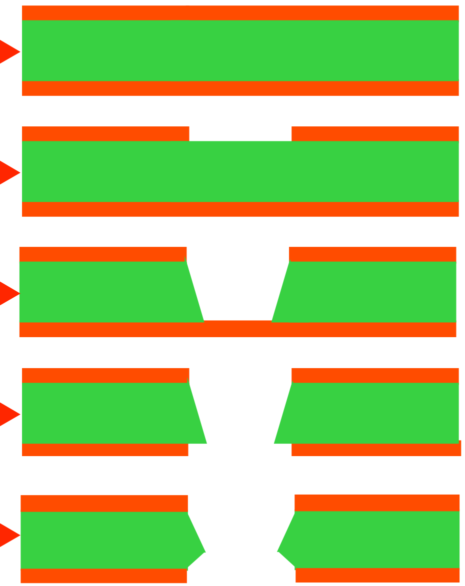
Single mask

Chemical etching and electro chemical etching

•Double mask

•Single mask





•Same base material

•Hole patterning in Cu

•Polyimide etch

•Bottom electro etch

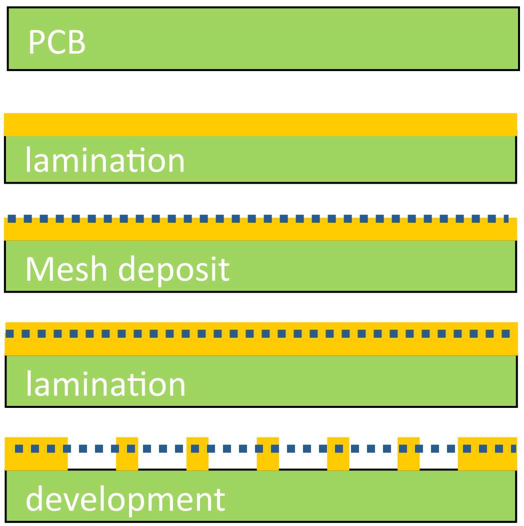
•Second Polyimide Etch

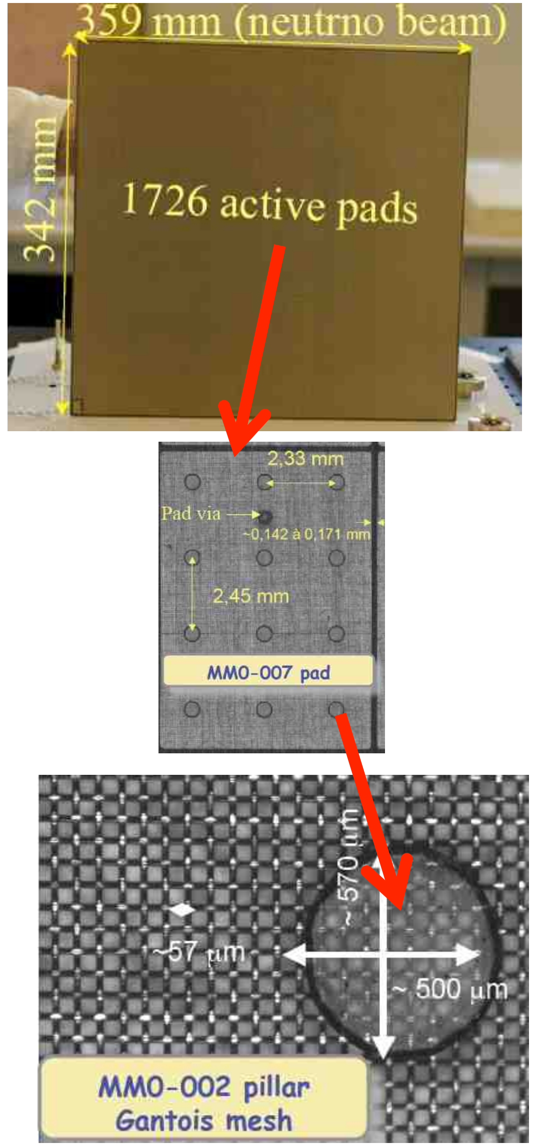
•Limited to 40cm x 40cm due to
- •Mask precision and alignment

•Limited to 2m x 60cm due to
- •Base material
- •Equipment

•Next Challenge

Second example : Micromegas production

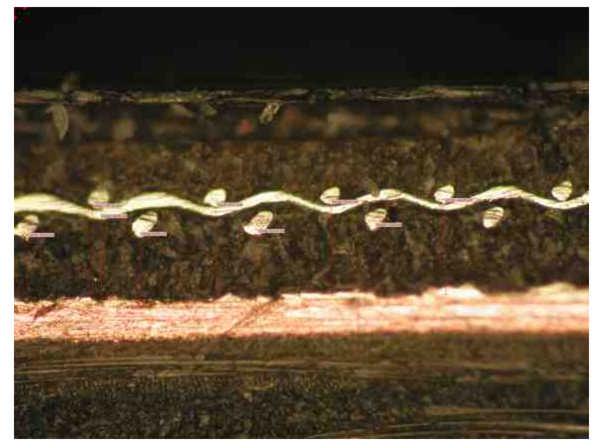




Largest size produced:

1.5m x 0.6m

Limited by equipment



Third example : R-Well (preliminary) *GEM tehchnology mixed with Micromegas protection (INFN Frascati)*

Goal:

-1Mhz/cm2 rate
-<100um spacial resolution
-single foil detector
-spark protected

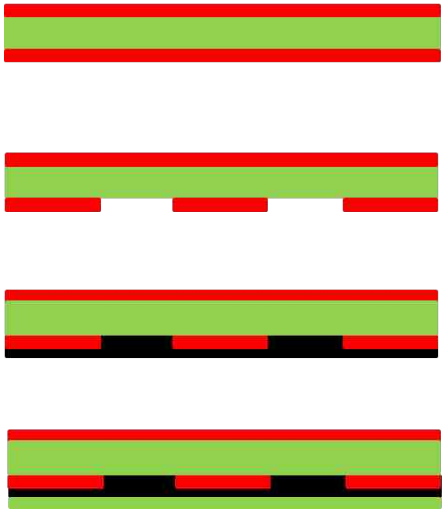
R.Bellazinni idea in 1998

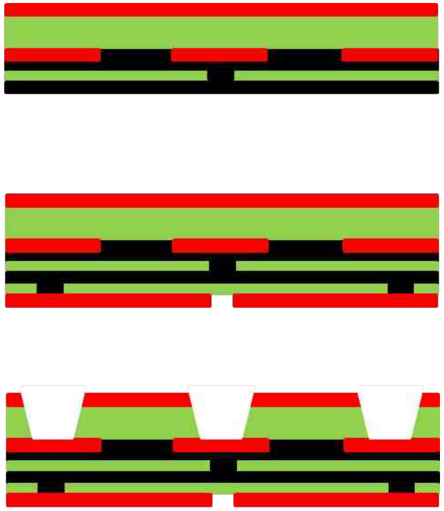
Base material

Bottom patterning

Resistive coating

Dielectric coating



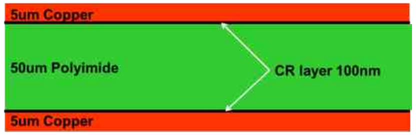


Micro via +
new resistive coating

Diel coating +
Microvia +
Metalic read-out pads

Microwell pattern

Equipments needed to perform photolithographic processes



Base material

Hot roll Laminator

Solid resist deposition

From 15um to 100um

Up to 1.4m width

UV lamp

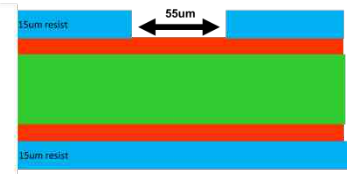
Resist exposure

Scanner : 2m x 0.6m

Static: 2m x 1.4m

Double sided : 0.7m x 0.7m

LDI : 0.8m x 0.6m



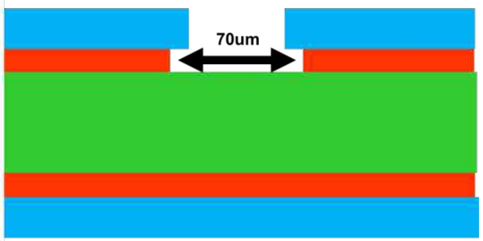
Development machine

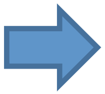
Solid resist development

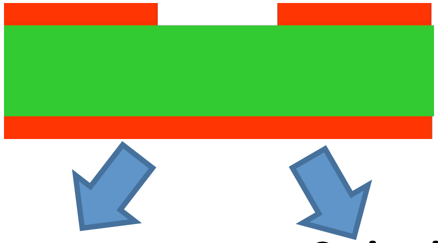
Na_2CO_3 1%

Continuous spray machine

Etching/ stripping







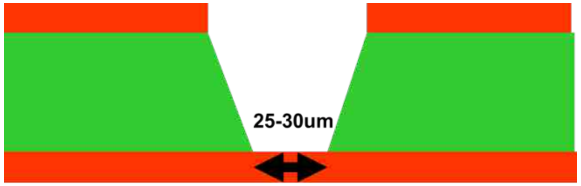
Etching
Copper etching
Ferric perchloride spray
Manual or continuous

Stripping
Alcaline spray Resist stripping
NaOH 5%
Continuous spray

Stripping
Solvent resist stripping
Ethanol
Dead bath

Chemical polyimide etch

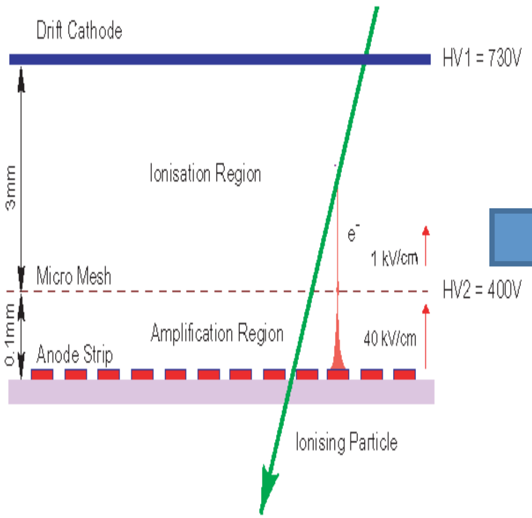
Polyimide etching
Dead Bath in a Hood
Or continuous etching machine

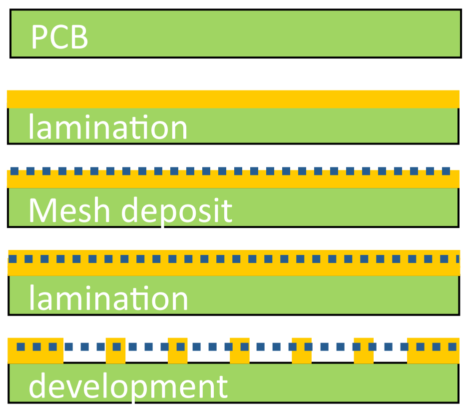


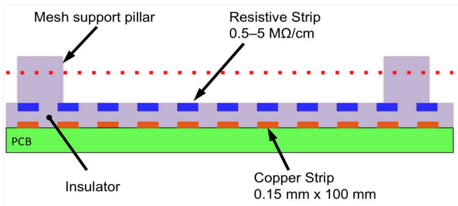
outline

- **MPGD structures introduction**
- **Mechanics**
- **Chemistry /electro chemistry /photolithography**
- ***Screen printing***
- **Laser**
- **Vaccum deposition**
- **Plasma**
- **Ink jet printing**

We have introduced screen printed resistors to protect Micromegas detectors against sparks







Initial Micromegas:
-Electroformed NI meshes
-Fishing wire spacer
-Difficult to produce
-fragile
-Limited application due to detector production complexity and poor spark immunity

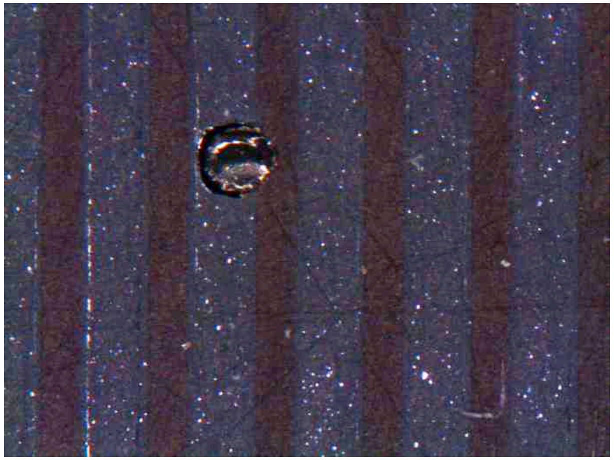
Industrial version: BULK
-STD industrial SS mesh
-Photo imaged pillars
-easy to produce , robust
-Still limited applications due to sparks probability

Protected detector:
-Bulk process
-Resistive strips are added
-High spark immunity
-large size
-Large volume
-Transferred to industry

Atlas CSC replacement project

Double sided Board

Resistive strip deposit



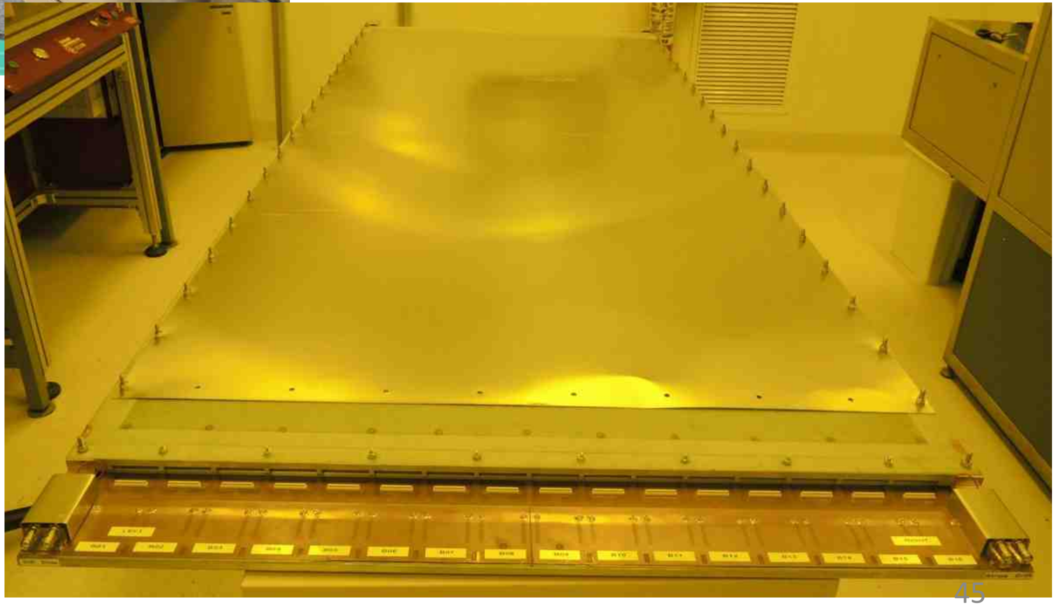
Bulking

Test before closing

Closing

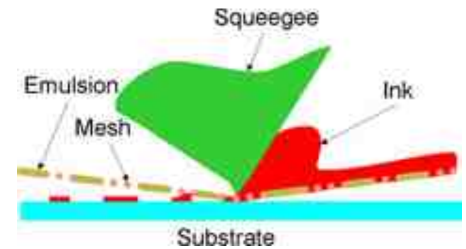
ATLAS NSW upgrade detector 2m x 1m opened

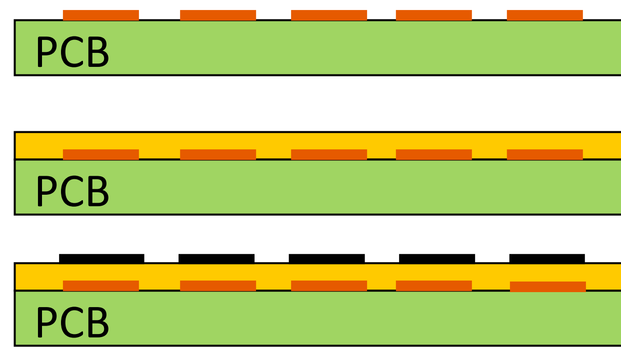
detector closed



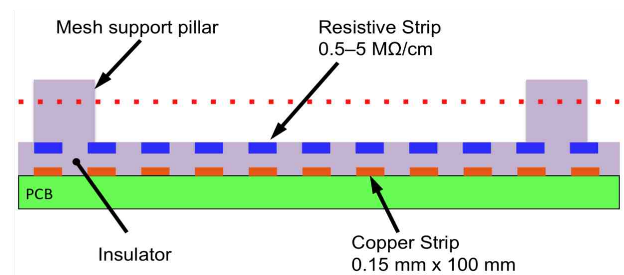
Screen printing equipment

Precise screen printer for R&D
Printing:
Resistor, conductor, dielectric
Min line and space 70um





Large size
Up to 2.5m x 1m
Min line and space 150um



outline

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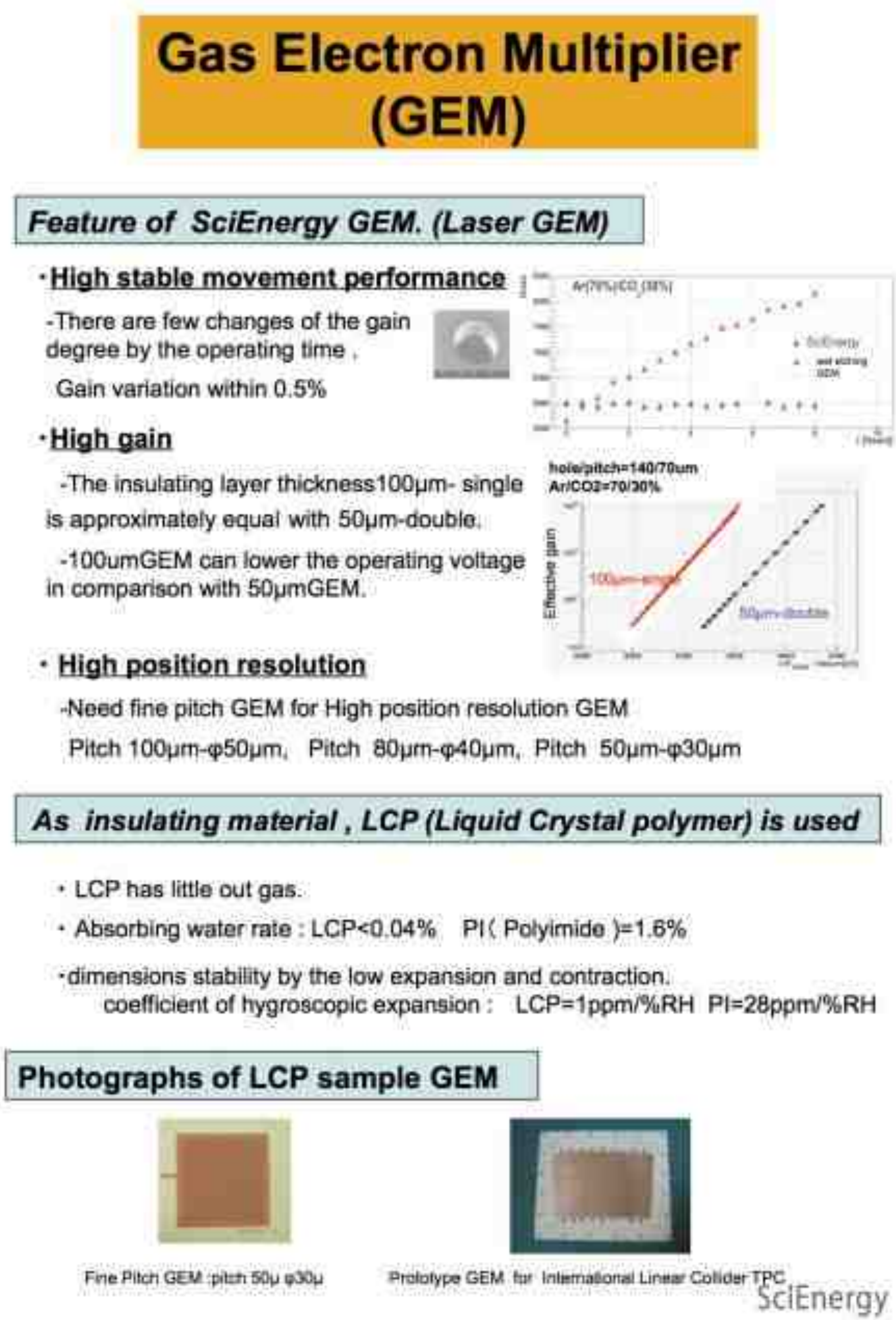
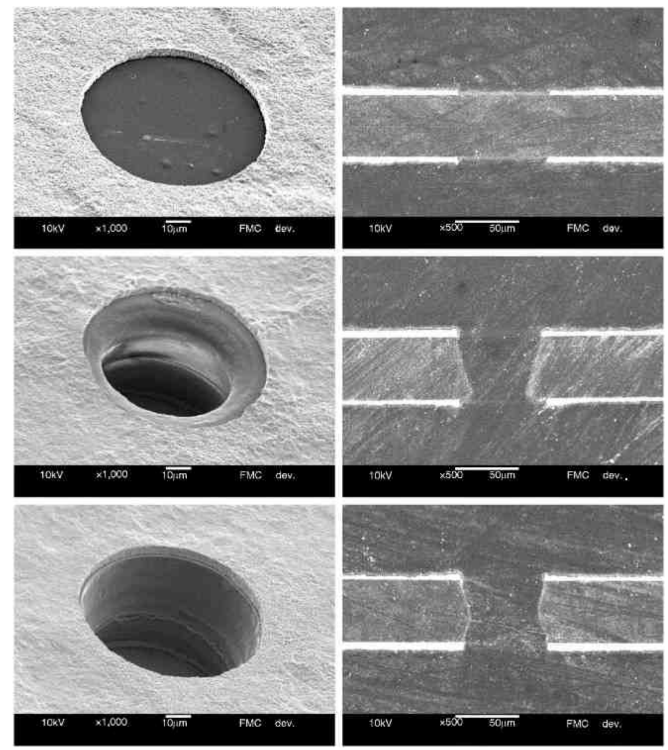
- ***Laser***
- **Vaccum deposition**
- **Plasma**
- **Ink jet printing**

Laser drilling

C02 laser





YAG GEM Laser drilling

- ***A new generation of multi beam UV laser are now available on the market***
  - ***-Drilling speed near 800 holes per sec with 8 beams working in parallel (200 holes-sec for laser of previous generation)***
  - ***-Some positive test have been performed (10cm x 10cm)***
  - ***-30cm x 30cm GEM test are in progress***

- ***The final GEM cleaning is critical due to carbonization.***

- ***For large volume (5000 m2) , taking in account only the yearly Laser maintenance (not the laser cost), prices in the range of 1600 CHF/m2 could be reached. With similar volumes the chemical GEM price is around 800 CHF/m2***

- ***The maximum throughput of one machine is approximately 1m2 per day (18 hours). So in case of large volumes many machine should run in parallel.***

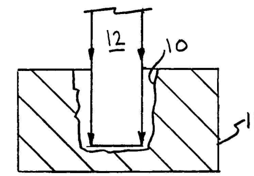


FIG. 1

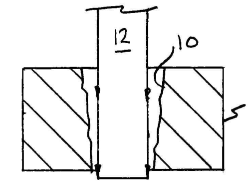


FIG. 2

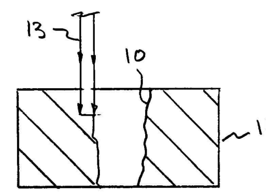


FIG. 3

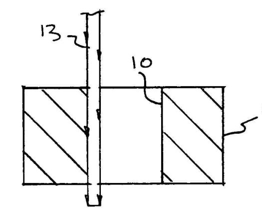
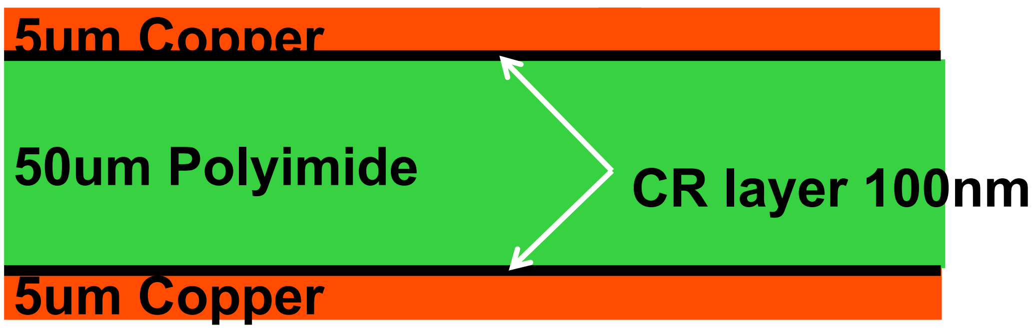


FIG. 4

outline

- **MPGD structures introduction**
- **Mechanics**
- **Chemistry /electro chemistry /photolithography**
- **Screen printing**
- **Laser**
- ***Vaccum deposition***
- **Plasma**
- **Ink jet printing**

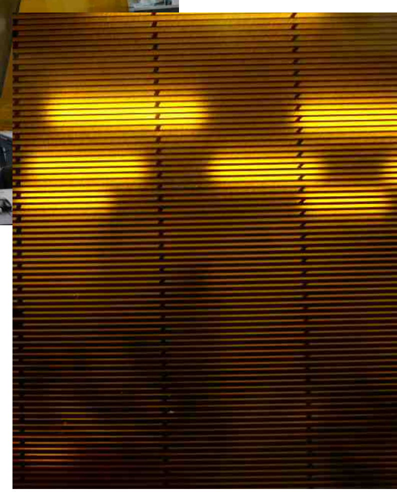
GEM base material

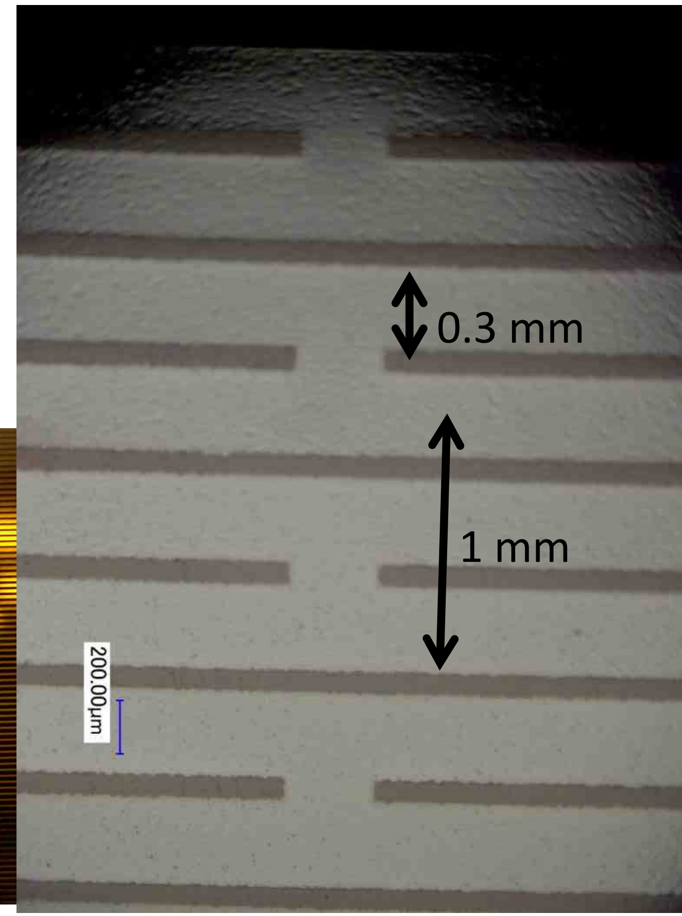


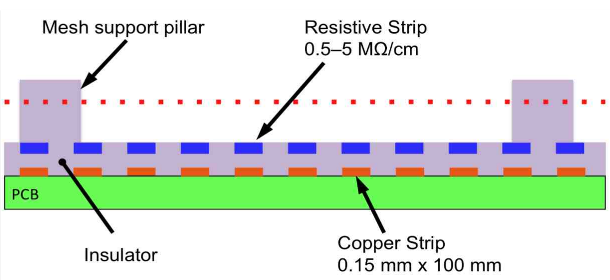
Base material composed of:

-50um Polyimide foil : APICAL NP or AV
-100nm sputtered Chromium
-0.2um sputtered Copper
-5um electrolytic copper

Vacuum deposited DLC (diamond like coating) for Micromegas resistive protection



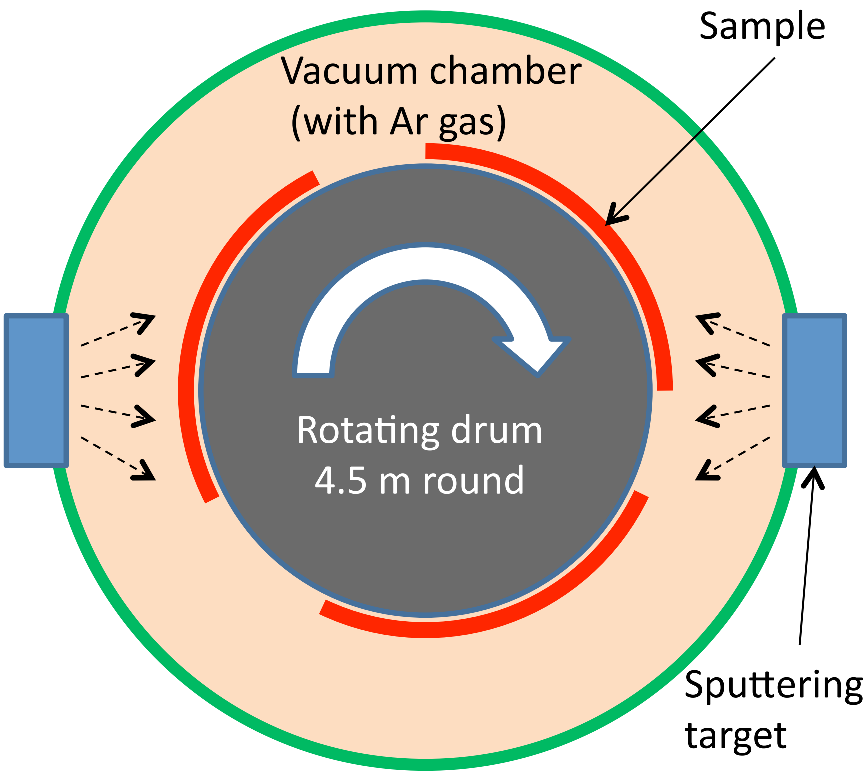




made in Japan (courtesy OCHI Atsuhiko KOBE university)

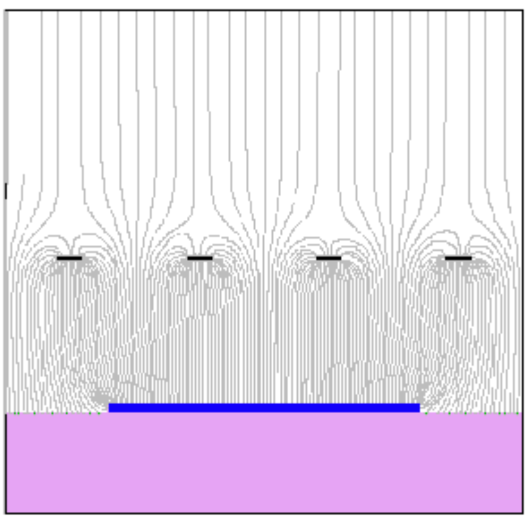
Sputtering facilities

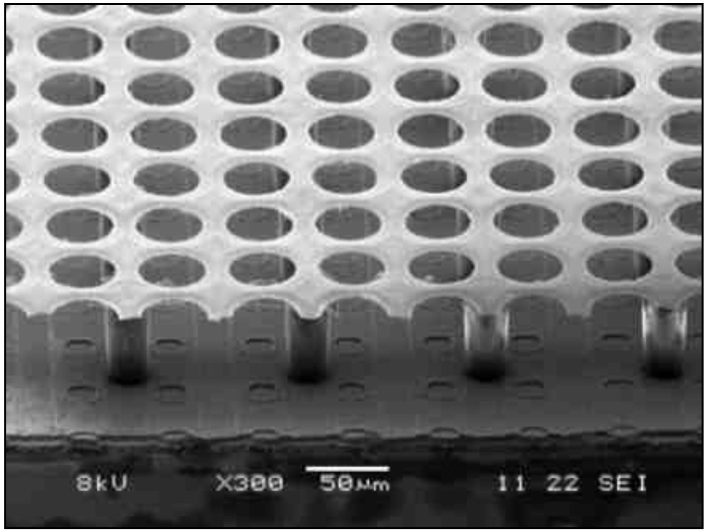
- **Large size sputtering is available**
  - **4.5m x 1m for flexible film**



Gossip: high granularity Micromegas

<u>Gossip is composed by:</u>
-High granularity read-out silicon pixel chip (50um x 50um pixel)
-8um sputtered resistive layer on chip for spark protection
-SU8 photoimageable material to create pillars
-Few um sputtered and patterned Aluminum layer to create the mesh



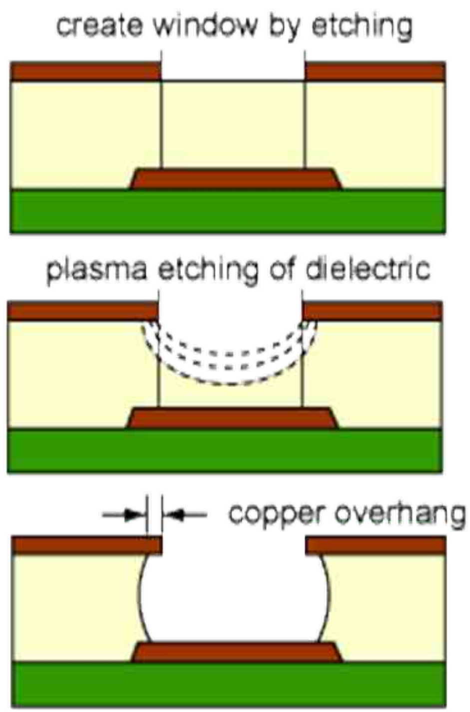


Harry van der Graaf, Nikhef

outline

- **MPGD structures introduction**
- **Mechanics**
- **Chemistry /electro chemistry /photolithography**
- **Screen printing**
- **Laser**
- **Vacuum deposition**
- ***Plasma***
- **Ink jet printing**

Plasmas



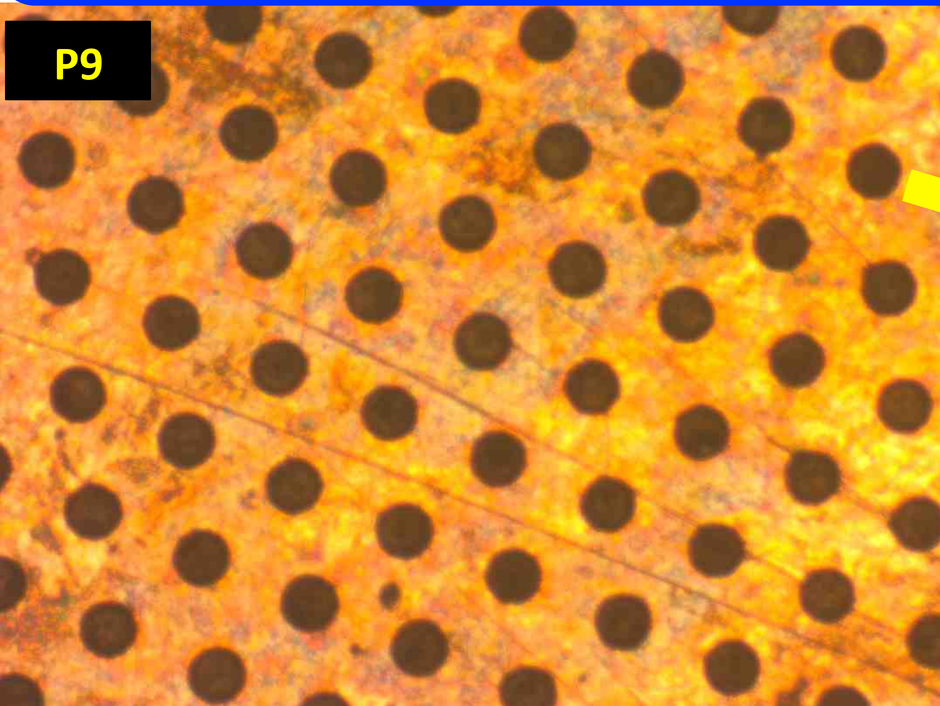
RF : for dielectric materails
DC : for conductive materials
RIE : with chemical assistance
DRIE : with field and chemical assistance

Problems:
-Non uniformity on large size
-Etching time versus shape
- Maximum possible size

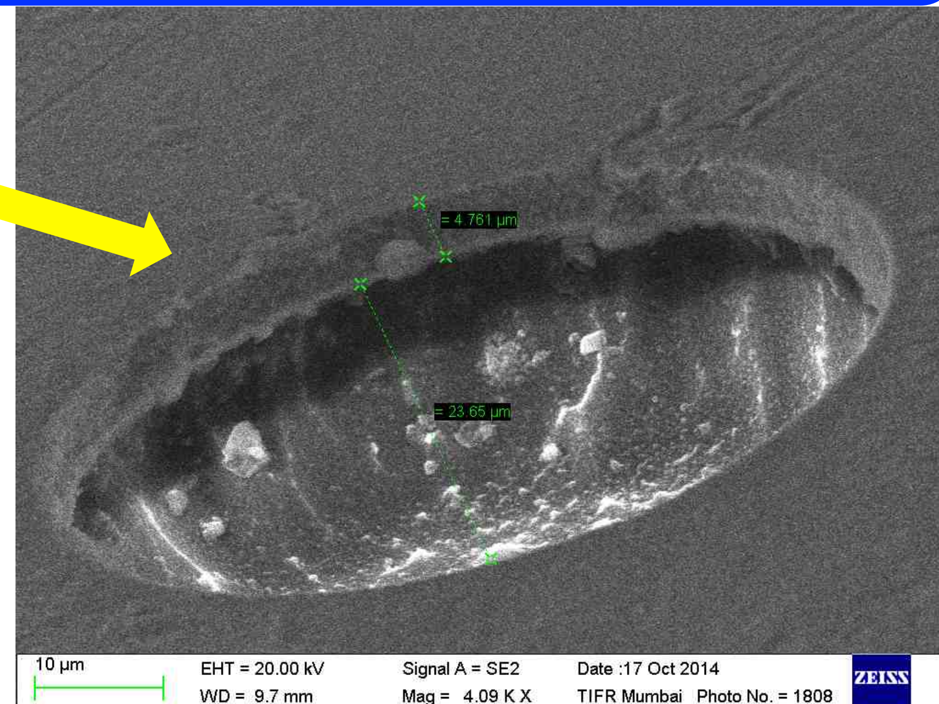
Advantages:
-Able to produce smaller patterns than chemistry (with DRIE Plasma)
-Good candidate for future structures

~ 24 μm deep trench in Polyimide in 60 minutes under SF_6 (20%) + O_2

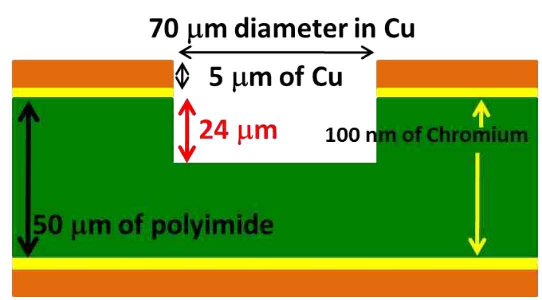
Note , there is no undercutting



Courtesy : Shuvendu, ASD-BARC
And Alpha Pneumatics india
A joshi



SEM view



outline

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- **Plasma**
- ***Ink jet printing***

Inkjet printing

- **Minimum structures scale of 1um**
- **3D structures**
- **Resistors , conductors and dielectrics**
- **Relative large size 50cm x 50cm**
- **Low cost**
- **Fast prototyping**
- **Not yet explored**

Who we are?

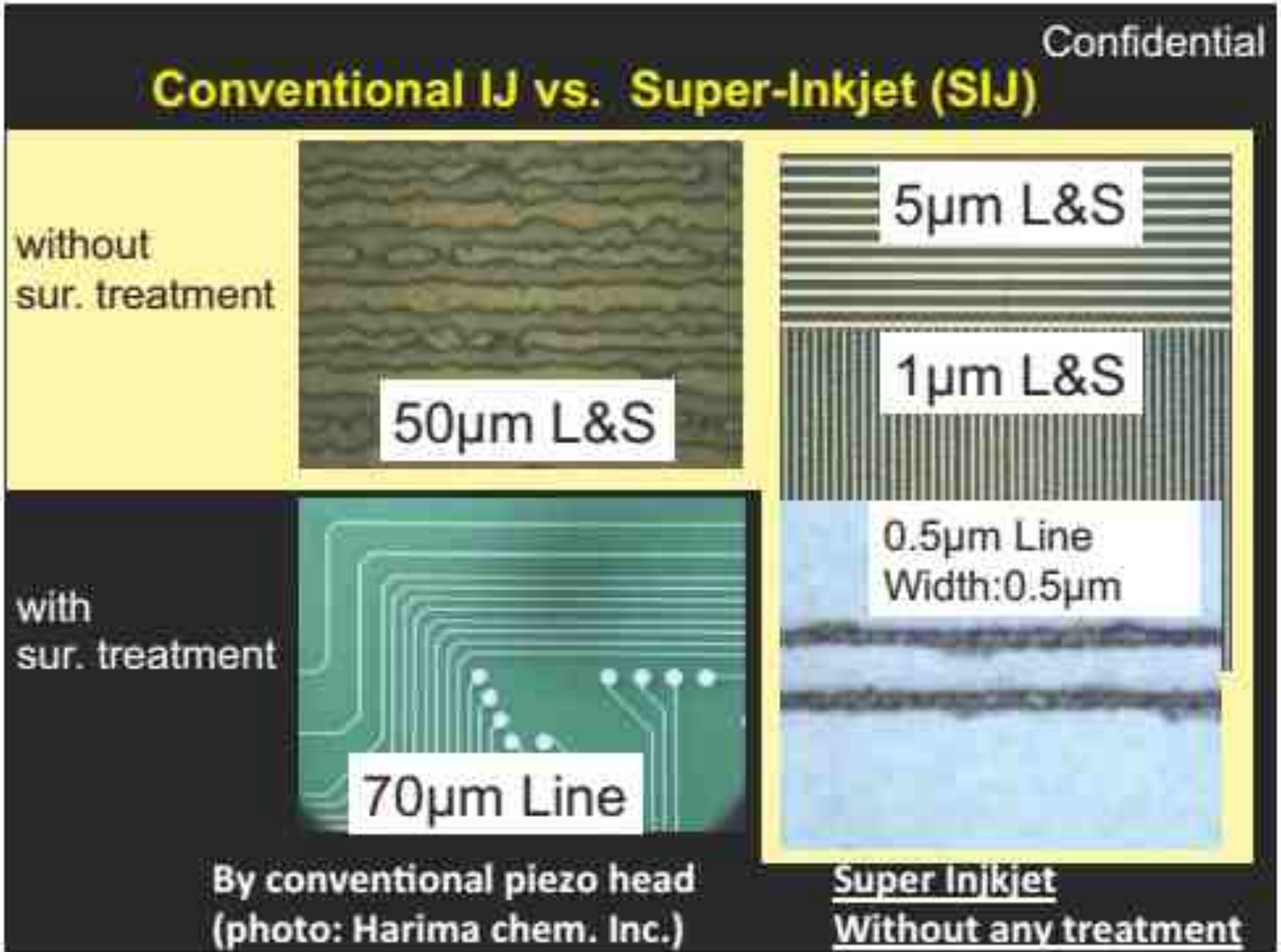
Confidential

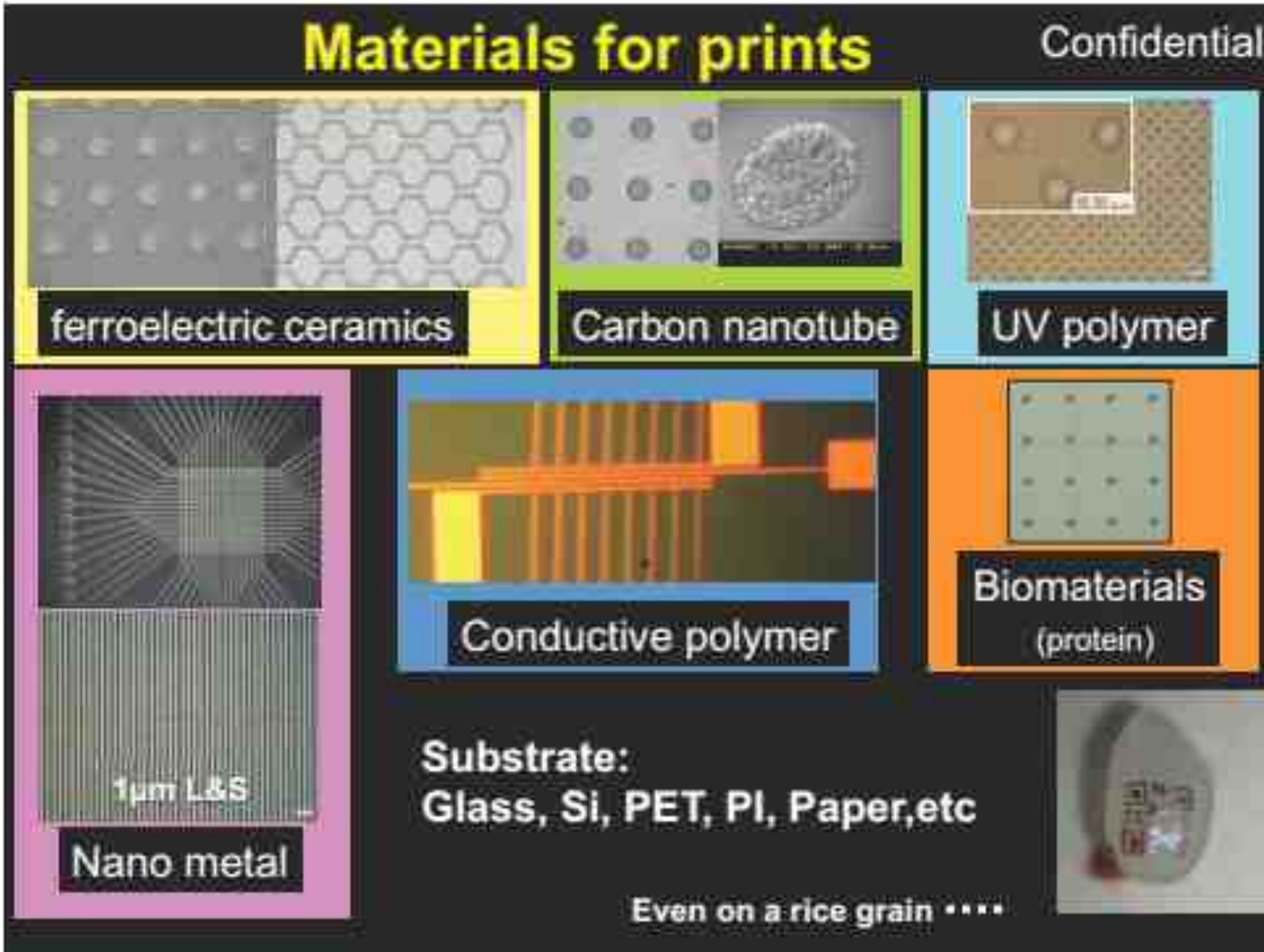
SIJTechnology, Inc. is
an AIST (National Institute of Advanced Industrial Science & Technology) high-tech. start ups .

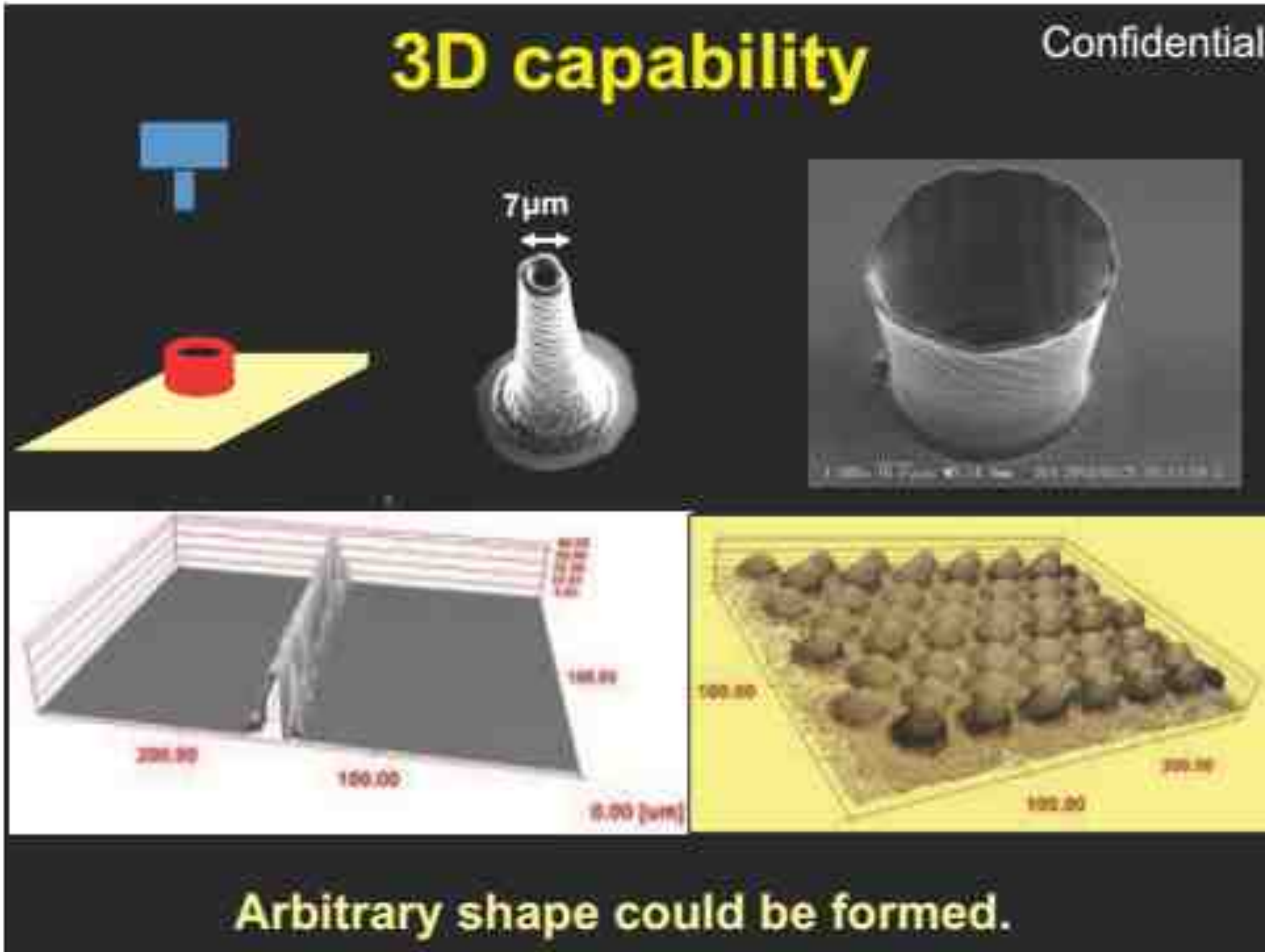
Founded in 2005
CEO&CSO, Co-founder Dr. Kazuhiro Murata
Chairman, CFO, Co-founder Dr. Kazuyuki Masuda

Our mission
To realize the "minimal manufacturing" process by using our special technology, "Super ink jet technology".

Huge process & factory vs. Desk top compact system


Confidential
Conventional IJ vs. Super-Inkjet (SIJ)
without
sur. treatment
50µm L&S
with
sur. treatment
70µm Line
5µm L&S
1µm L&S
0.5µm Line
Width:0.5µm
By conventional piezo head
(photo: Harima chem. Inc.)
Super Injkjet
Without any treatment


Materials for prints
Confidential
ferroelectric ceramics
Carbon nanotube
UV polymer
Nano metal
1μm L&S
Conductive polymer
Biomaterials
(protein)
Substrate:
Glass, Si, PET, PI, Paper,etc
Even on a rice grain ････


3D capability
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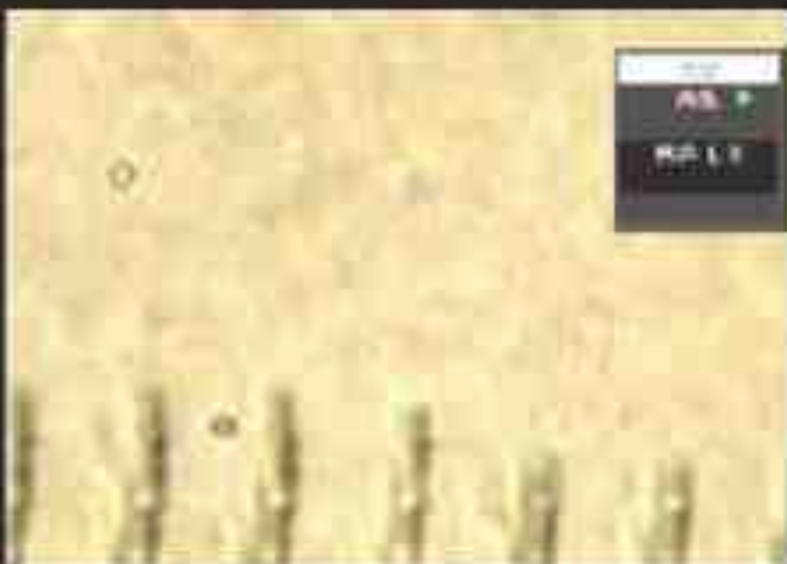
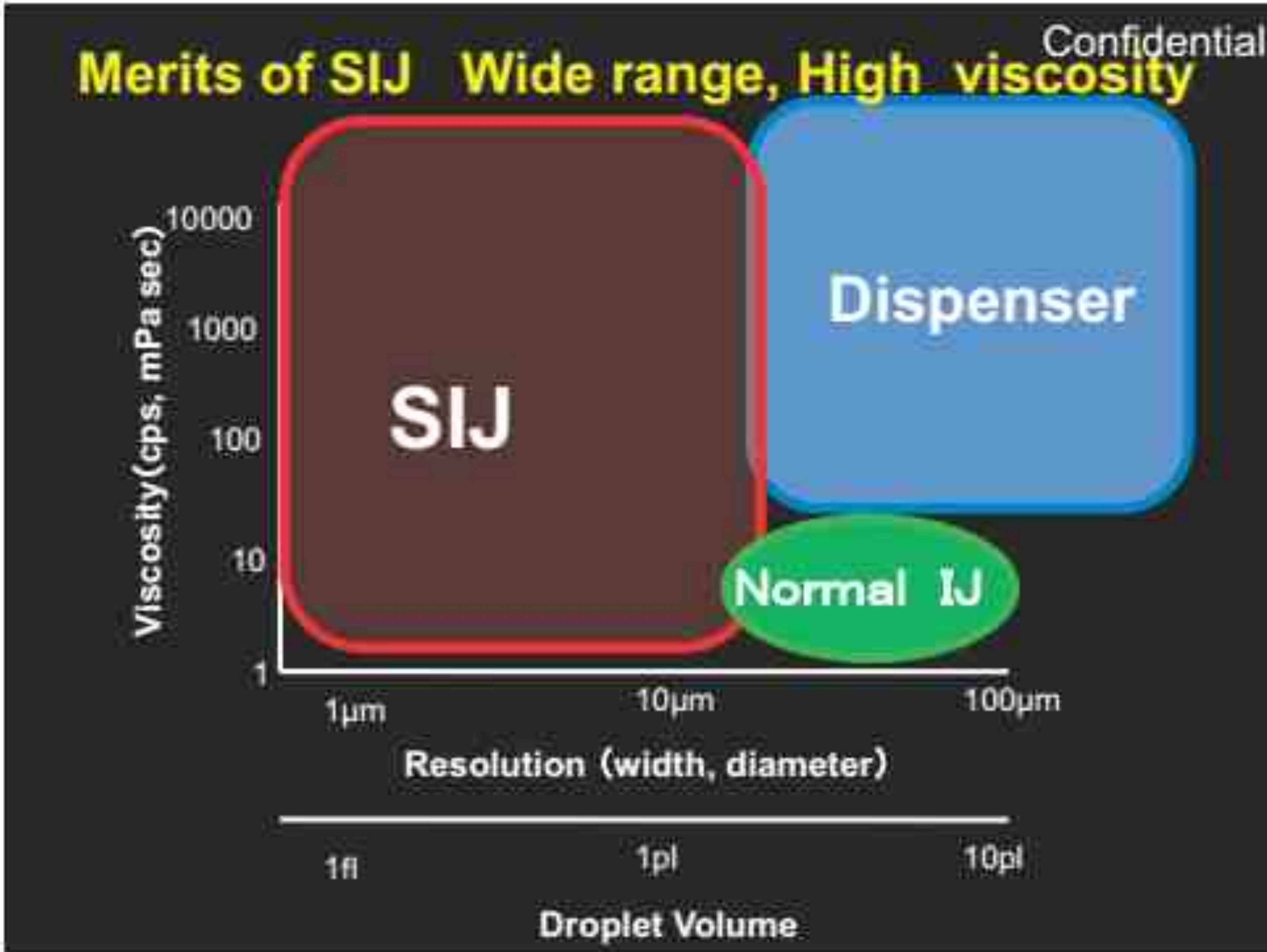
7μm
Arbitrary shape could be formed.

Bump structures formation by using super inkjet



Real time video

In air atmosphere, (no chamber)
At room temperature



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Merits of SIJ Wide range, High viscosity
Viscosity(cps, mPa sec)
10000
1000
100
10
1
SIJ
Dispenser
Normal IJ
1µm
10µm
100µm
Resolution (width, diameter)
1fl
1pl
10pl
Droplet Volume

Conclusion

- **Many techniques are existing to build MPGDs**
  - **Mechanical (1mm scale structures)**
  - **Chemical (100um scale structures)**
  - **Screen printing**
  - **Laser**
  - **Vacuum deposition**
- **Plasma and ink jet printing are good candidates to produce 3 D 10um to 1um scale structures in the future.**
- **Single board or foil detector are nearly ready**