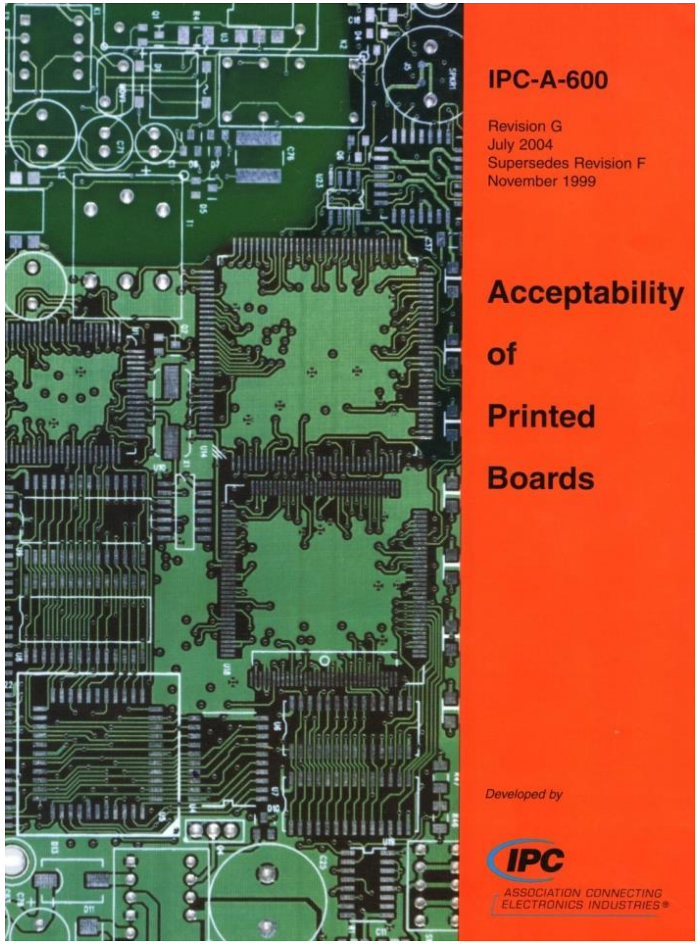
Manufacturing techniques:
Photolithography
Chemical etching
Plating techniques
Gluing techniques
Drilling techniques

Tuesday 28 November 11h30

Building 40 - Salle Curie 40/S2-C01

Production rules



IPC-A-600

Revision G
July 2004
Supersedes Revision F
November 1999

Acceptability
of
Printed
Boards

Developed by

IPC
ASSOCIATION CONNECTING ELECTRONICS INDUSTRIES®

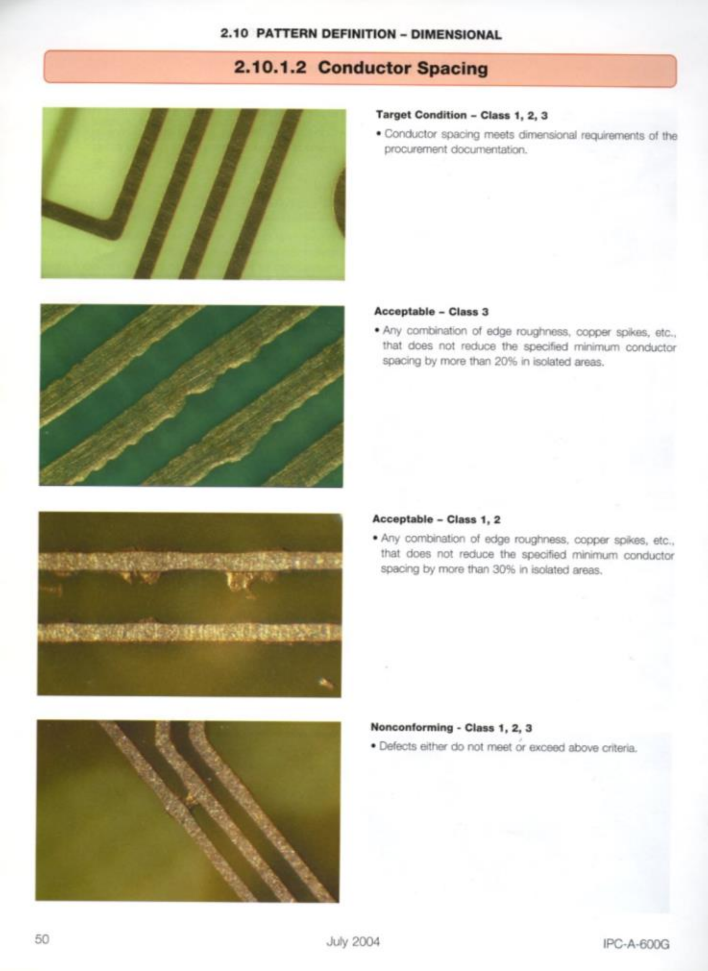
IPC standard define the parameters to check and set 3 levels of quality

Class 1: Worse level but the PCB works → general electronic Products.

Class 2: Industrial products for which uninterrupted service is desired but not critical.

Class 3: High reliability electronics products.
No possibility to exchange boards during its full life

Ex: lines quality



2.10 PATTERN DEFINITION – DIMENSIONAL

2.10.1.2 Conductor Spacing

Target Condition – Class 1, 2, 3
- Conductor spacing meets dimensional requirements of the procurement documentation.

Acceptable – Class 3
- Any combination of edge roughness, copper spikes, etc., that does not reduce the specified minimum conductor spacing by more than 20% in isolated areas.

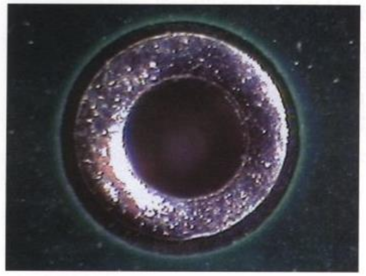
Acceptable – Class 1, 2
- Any combination of edge roughness, copper spikes, etc., that does not reduce the specified minimum conductor spacing by more than 30% in isolated areas.

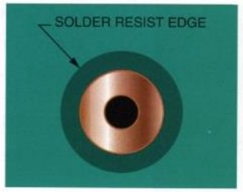
Nonconforming - Class 1, 2, 3
- Defects either do not meet or exceed above criteria.

50 July 2004 IPC-A-600G

2.9 SOLDER RESIST (Solder Mask)

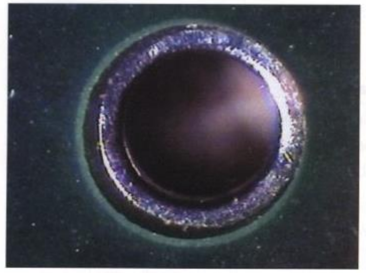
2.9.2 Registration to Holes (All Finishes)

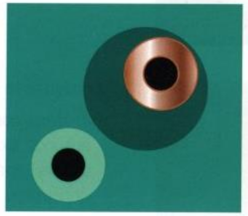




Target Condition – Class 1, 2, 3

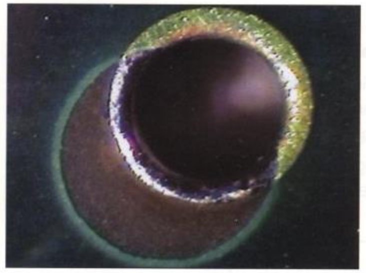
- No solder resist misregistration. The solder resist is centered around the lands within the nominal registration spacings.

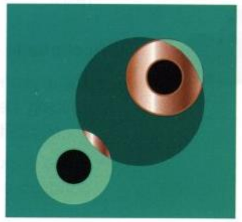




Acceptable – Class 1, 2, 3

- Misregistration of the resist to the land patterns but the resist does not violate minimum annular ring requirements.
- No solder resist in plated-through holes, except those not intended for soldering.
- Adjacent, electrically isolated lands or conductors are not exposed.



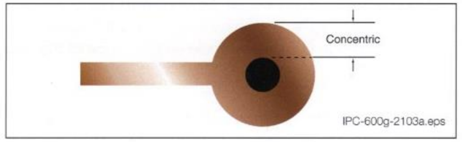


Nonconforming – Class 1, 2, 3

- Defects either do not meet or exceed above criteria.

2.10 PATTERN DEFINITION – DIMENSIONAL

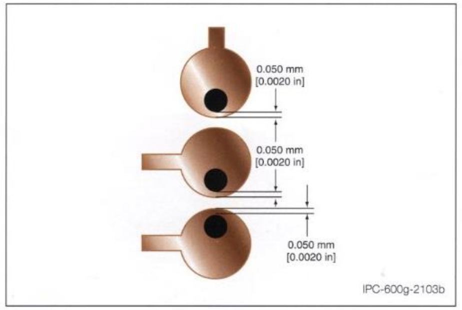
2.10.3 External Annular Ring - Supported Holes



IPC-600g-2103a.eps

Target Condition – Class 1, 2, 3

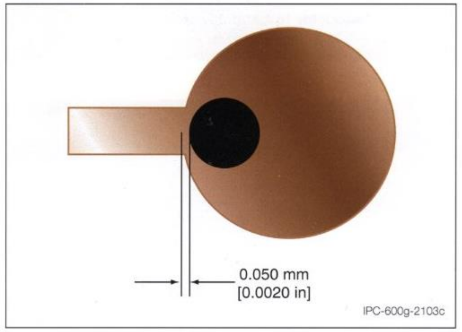
- Holes are centered in the lands.



IPC-600g-2103b

Acceptable – Class 3

- Holes are not centered in the lands, but the annular ring measures 0.050 mm [0.0020 in] or more.
- The minimum external annular ring may have 20% reduction of the minimum annular ring at the measurement area due to defects such as pits, dents, nicks, pinholes, or splay.



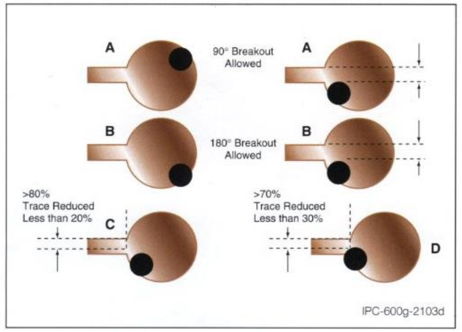
IPC-600g-2103c

Acceptable – Class 2

- 90° breakout or less. (A)
- If breakout occurs at the conductor to land junction area, the conductor is not reduced by more than 20% of the minimum conductor width specified on the engineering drawing or the production master nominal. The conductor junction should never be less than 0.050 mm [0.0020 in] or the minimum line width, whichever is smaller. (C)
- Minimum lateral spacing between conductors is maintained.

Acceptable – Class 1

- 180° breakout or less. (B)
- If breakout occurs at the conductor to land junction area, the conductor is not reduced by more than 30% of the minimum conductor width specified on the production master nominal. (D)
- Form, fit and function are not affected.
- Minimum lateral spacing between conductors is maintained.

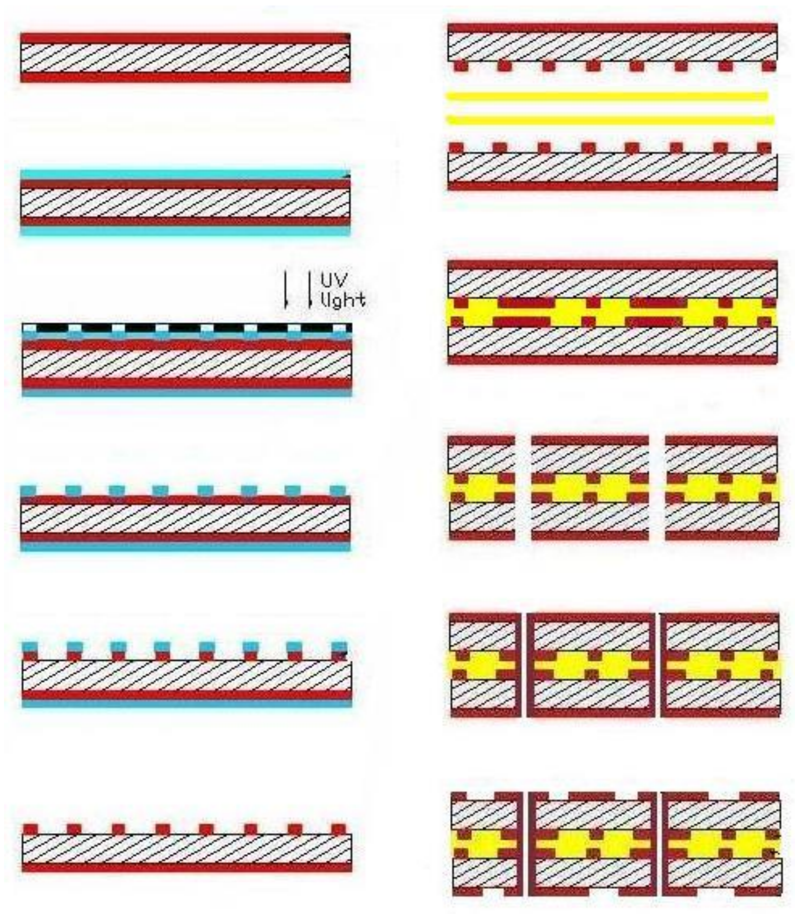


IPC-600g-2103d

Nonconforming - Class 1, 2, 3

- Defects either do not meet or exceed above criteria.

Talk outline → 4 Layer PCB production steps



Base material

Photolithography

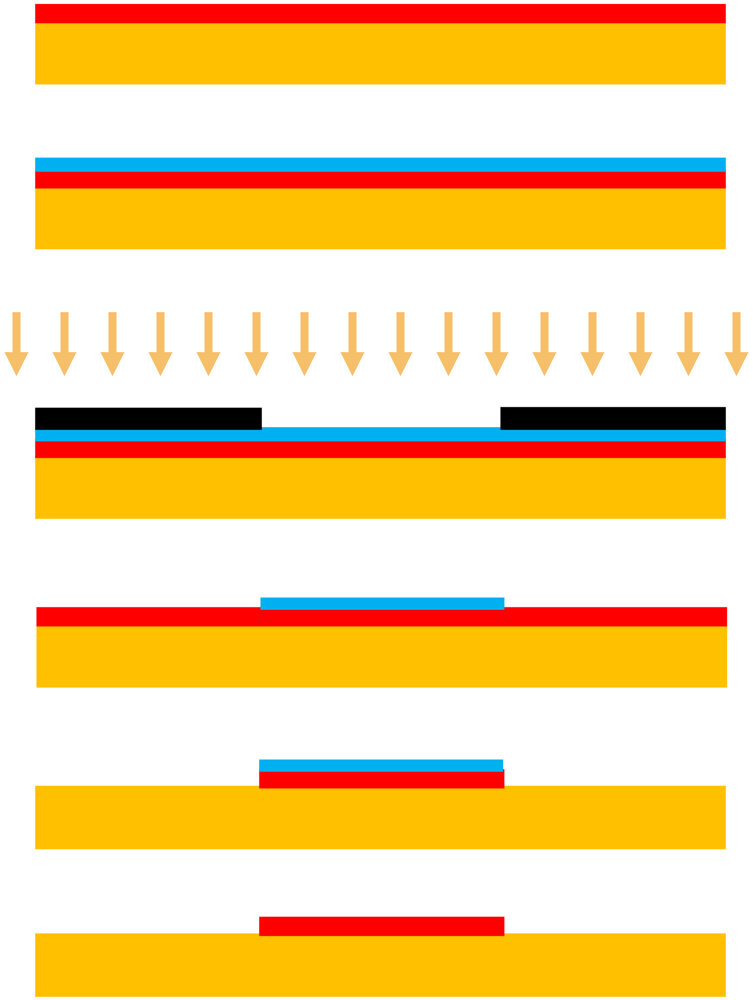
Gluing

Drilling

Plating

External layers patterning

Photolithography basics



Base material with copper

Photoresist deposition

UV exposure through a mask

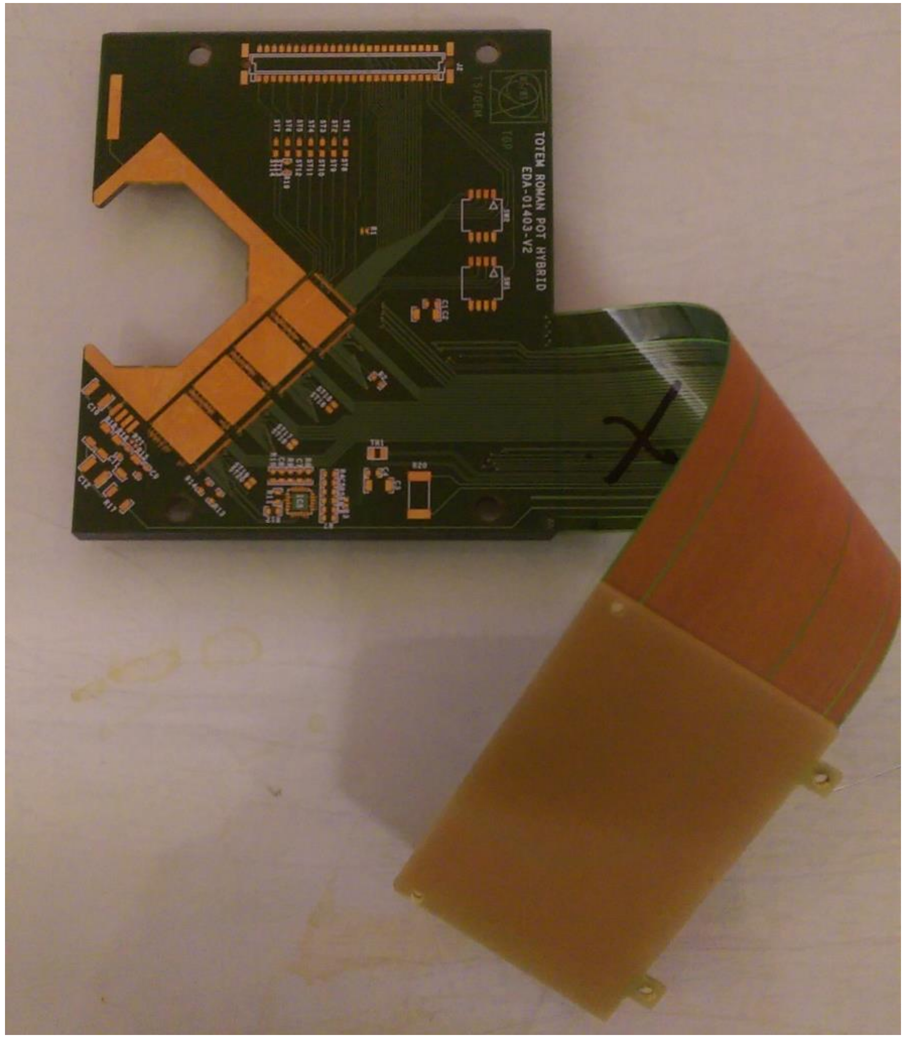
Resist development

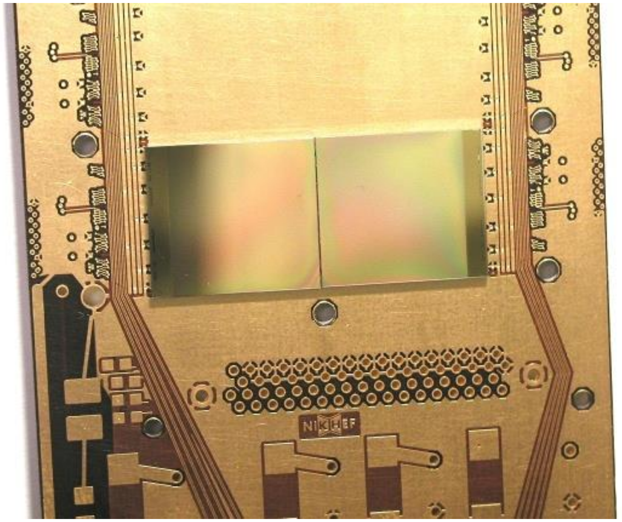
Copper Etching

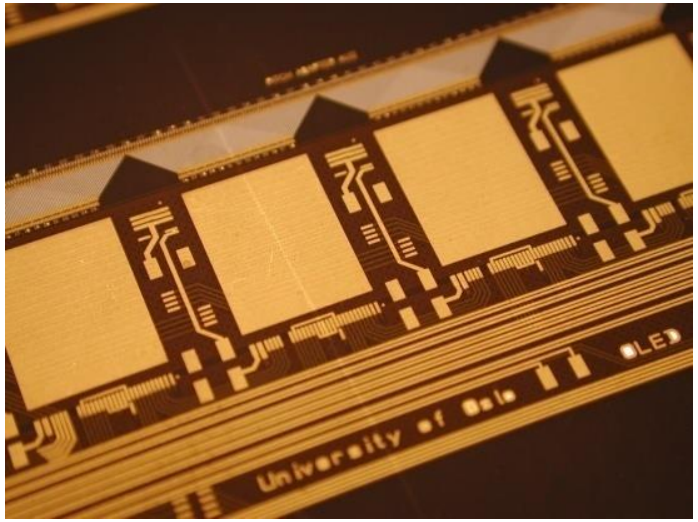
Resist Stripping

Used for Printed Circuit Boards production

- Creation of all the conductive tracks
- Protective layers : soldermask & coverlay
- Legend ink
- Micro via patterning





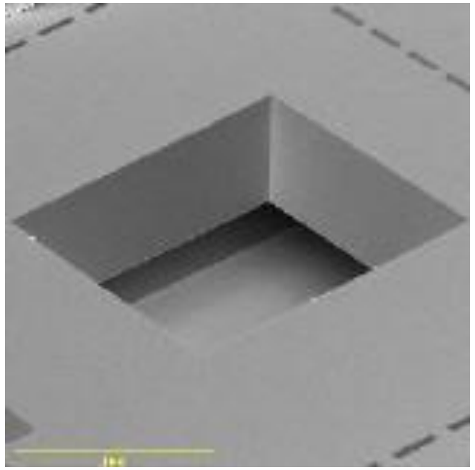


Chemical milling and electroforming

- Wave guides
- Meshes
- Heat sinks
- Ink jet nozzles
- Optical parts
- Fuel cell parts
- Lead frames
- Encoder discs
- Flow sensors

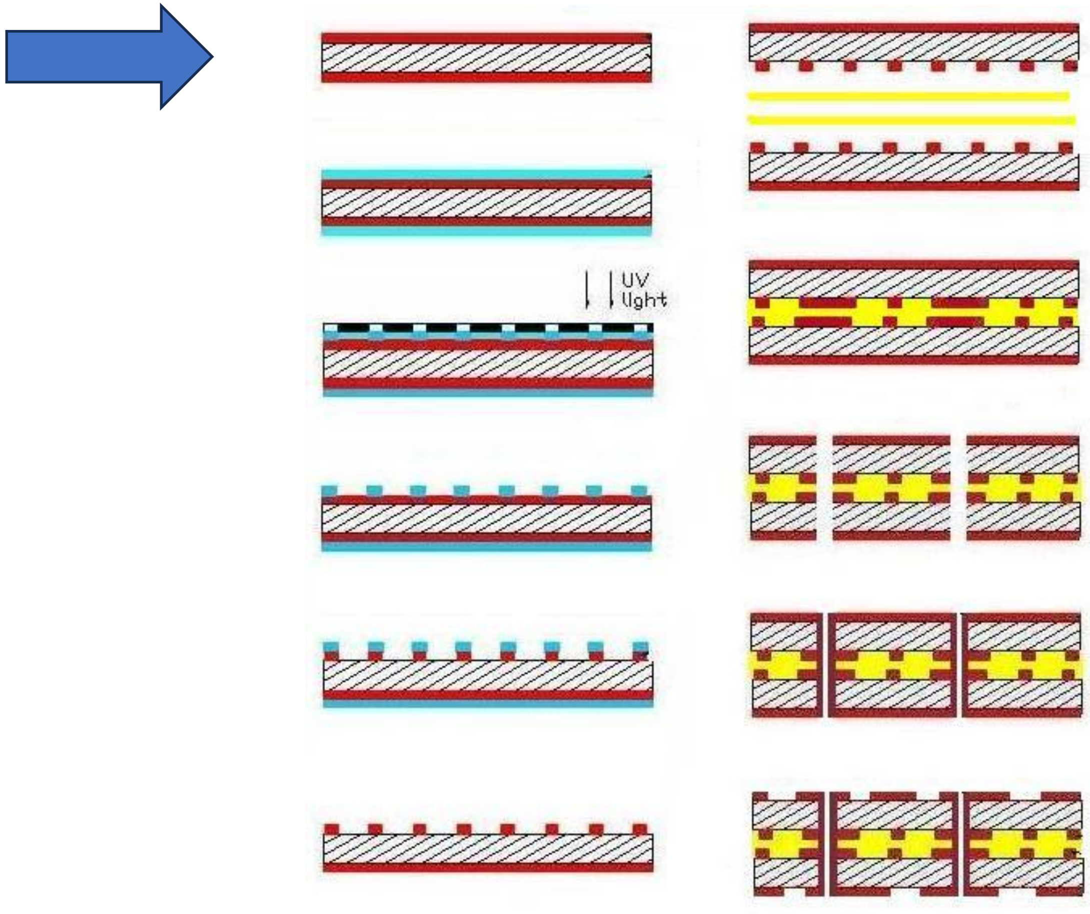
Semiconductor industry

- Creation of metal lines for interconnection
- Define areas for selective doping
- Patterning of protective layers
- Micromachining of silicon
    - Ink jet printer heads
    - Pressure sensors
    - Accelerometers
    - Magnetic sensors
    - Actuators by electroforming magnetic materials



4 Layer PCB

Base material



Substrates

- Glass epoxy
  - G10 , FR4, High TG, Low loss , low Dk , anti CAF , low CTE etc..
- Aramid Epoxy
  - Low CTE
- Glass polyimide
  - G30 ,High temperature , high reliability
- Glass Teflon , ceramic Teflon
  - High frequencies
  - not good for high radiation dose.
- Polyimide
  - General flex application
- Peek
  - High reliability flex application
  - low moisture absorption
  - High frequencies
- Bakelite
  - Low cost

Example of data sheet

Elite Material Co., Ltd.

http://www.emctw.com

Lead-free , Halogen-free Material

EM-370(5) / EM-37B(5)

- Superior thermal resistance for lead-free process
- Halogen, antimony and red phosphorus free
- For LCD, memory module and mobile device application

Basic Laminate Property

Item		IPC-TM-650	Test condition	Unit	Typical Value
Glass transition temp.		2.4.25	DSC	℃	155
CTE, X-, Y-axis		2.4.24	Pre-Tg, TMA	ppm/℃	12/15
CTE, Z-axis		2.4.24	Alpha 1, TMA	ppm/℃	40
			Alpha 2, TMA	ppm/℃	190
Z-axis Expansion		2.4.24	50~260℃, TMA	%	2.60
Decomposition temp.		2.4.24.26	TGA	℃	385
Thermal stress 10sec 288℃		2.4.13.1	Clad	—	Pass Visual
			Etched	—	Pass Visual
Water absorption		2.6.2.1	E-1/105+D-24/23	%	0.11
Peel strength	0.5 oz	2.4.8	as received	lb/in	7.4
			after thermal stress	lb/in	7.4
	1.0 oz	2.4.8	as received	lb/in	8.6
			after thermal stress	lb/in	8.4
Permittivity (RC 50%)	1 MHz	2.5.5.9	C-24/23/50	—	4.8
	1 GHz			—	4.3
Loss tangent (RC 50%)	1 MHz	2.5.5.9	C-24/23/50	—	0.009
	1 GHz			—	0.013
Volume resistivity		2.5.17.1	C-96/35/90	MΩ-cm	$>10^{10}$
Surface resistivity		2.5.17.1	C-96/35/90	MΩ	$>10^{8}$
Flexural strength	Warp	2.4.4	as received	MPa	560~600
	Fill		as received	MPa	470~510
Flame resistance		UL-94	A&E-24/125	—	V-0

Specification Sheet : IPC-4101C / 127 · 128

4 Layer PCB

Resist deposition

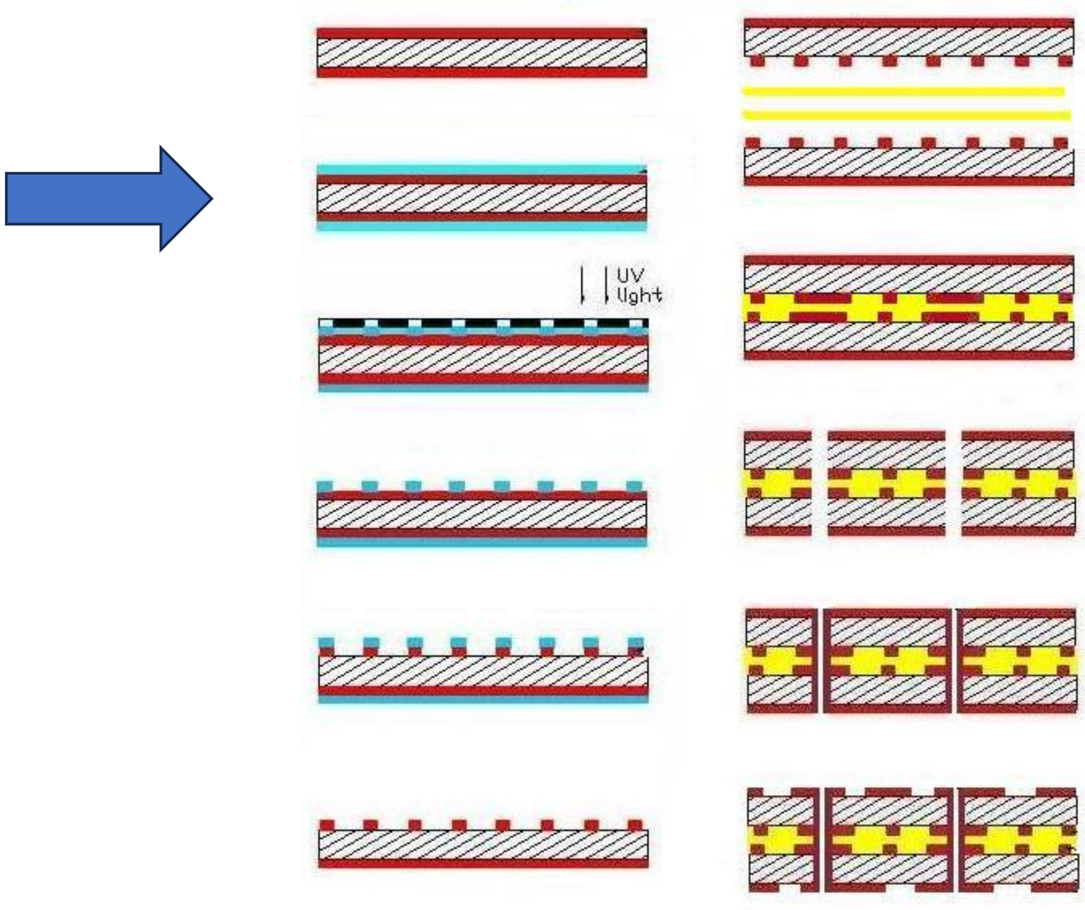
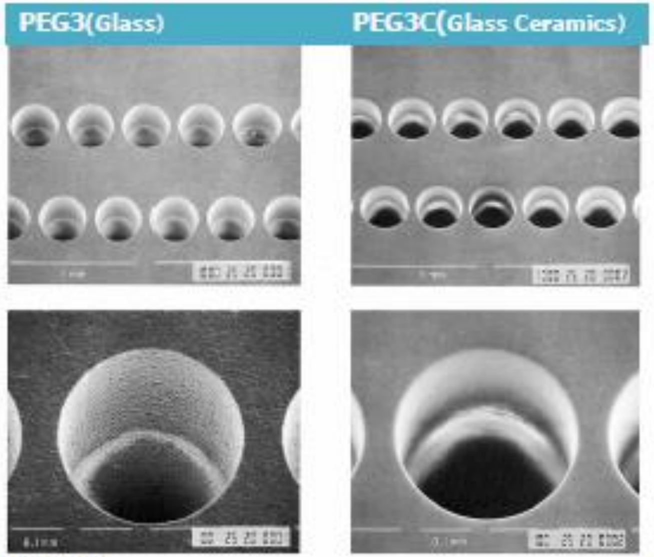


Photo-imageable materials

- Liquid resist
  - Thicknesses ranging from 1um up to 5um
  - Spin , spray ,deep , screen-printing coatings
  - Aqueous or solvent development
  - Fine lines , sub micron capabilities
- Solid resist
  - Thicknesses ranging from 15um up to 100um
  - laminated
  - Aqueous development
  - Minimum line 20um
- Solder-mask (not sacrificial)
  - Protect external lines on rigid boards
  - Solid or liquid
  - Typical thickness 30um
  - Many colors available
- Photo-imageable Cover-layer (not sacrificial)
  - Protect lines on flexible boards
  - Solid or liquid
  - Typical thickness 30um
  - Aqueous development
- Legend inks (not sacrificial)
  - Most of the time liquid
  - Typical Thickness 20um
  - Many colors
- Polyimide (usually not sacrificial)
  - Make 3D shapes , protect Chips
  - liquid
  - Thickness ranging from 1 to 30um
- Epoxy (usually not sacrificial)
  - Make 3D shapes
  - SU8 , used in many MEMs
  - Thickness ranging from 1 to 100um

HOYA corporation
Innovative Glass Material Developer in Japan

Photo Etchable Glass 3 : PEG3

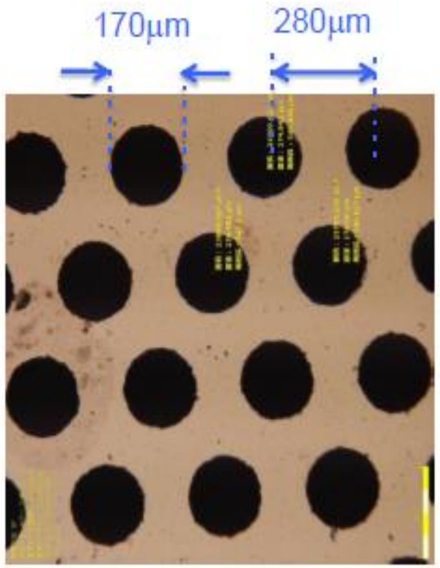


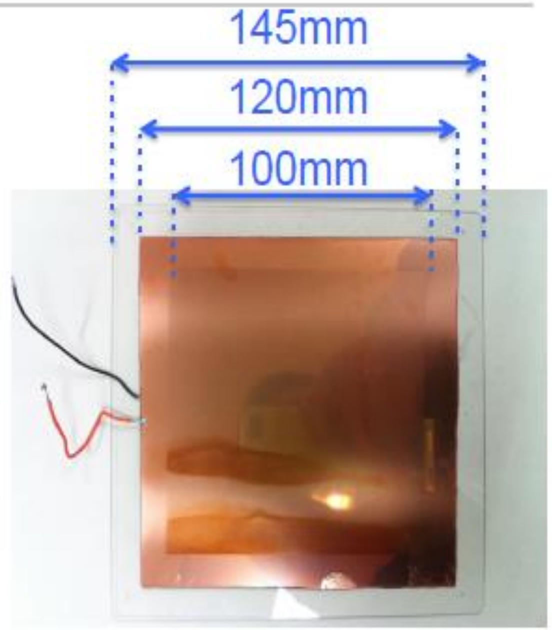
Features

- Via-Hole and Trench Structure
- High Aspect Ratio
- Small Diameter
- 3-Dimensional Fabrication Process
- Transmits Light (PEG3)
- Smooth and Flat Surface

Glass GEM

東京大学
THE UNIVERSITY OF TOKYO





- Substrate: 145 mm x 145 mm
- Effective area: 100 mm x 100mm
- Thickness: 680µm (410~800µm)
- Electrode: Cu + Cr
- Hole pitch: 280µm
- Hole dia.: 120~190µm

Resist deposition

-Spinning - semiconductor production
Thin layers, Highest resolution

-Dip coating - fine lines for PCBs or 3D objects
Fine lines, large sizes

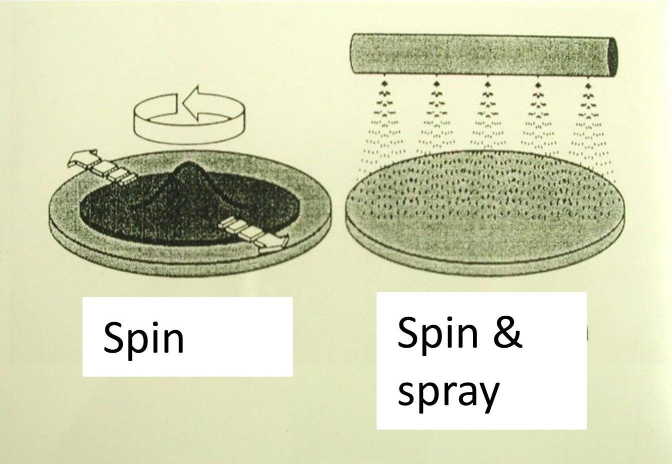
-Curtain coating - solder mask deposition
Fast, not accurate, cheap

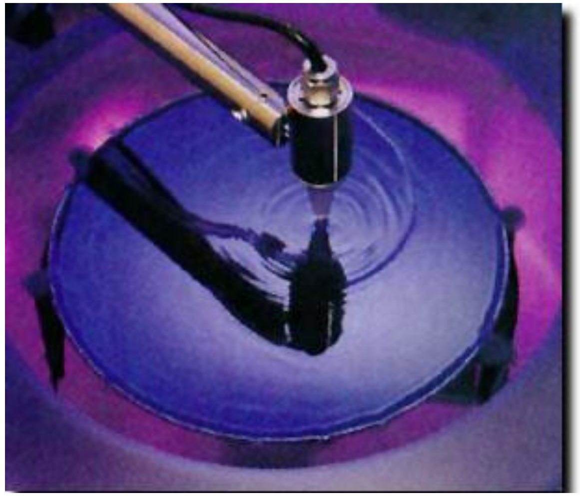
-Spray - liquid resist, solder mask deposition
3D best coverage, best quality for solder mask

-Screen printing - solder mask deposition
Ultra-fast but medium quality

-Dry film lamination- PCB production
Fast, good resolution

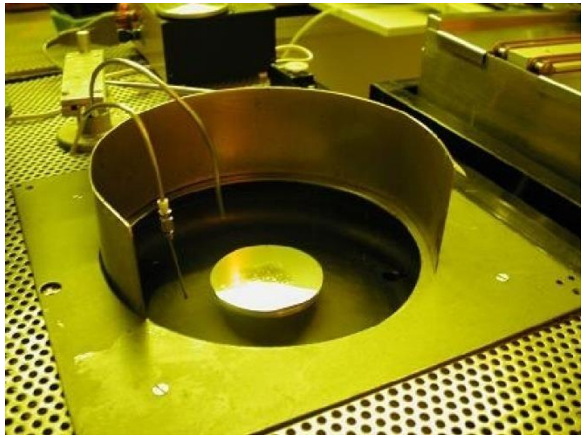
Spin Coating



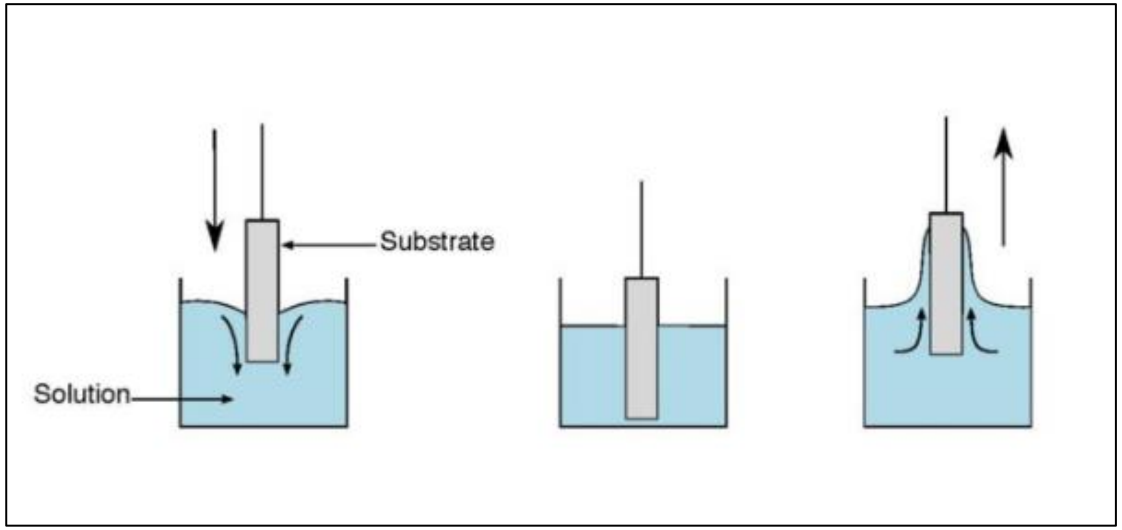


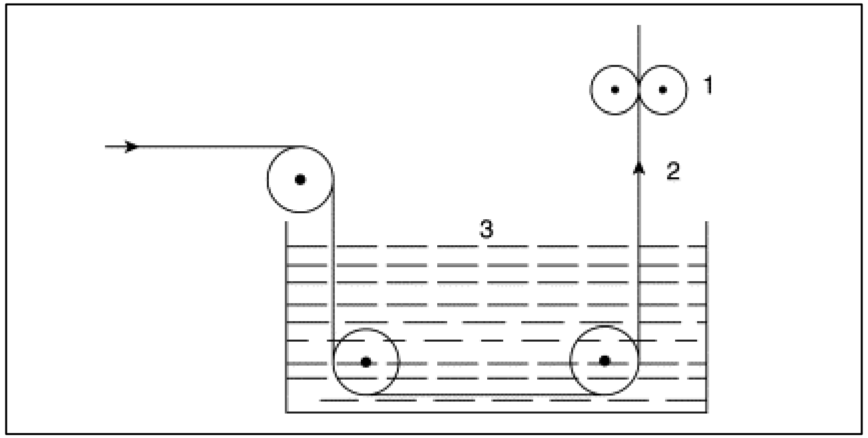
Best deposition !

- Deposition by centrifugation
- Uniform thickness
- Ultra-thin :down to 1 µm
- Excellent repeatability
- Clean room mandatory



Dip Coating





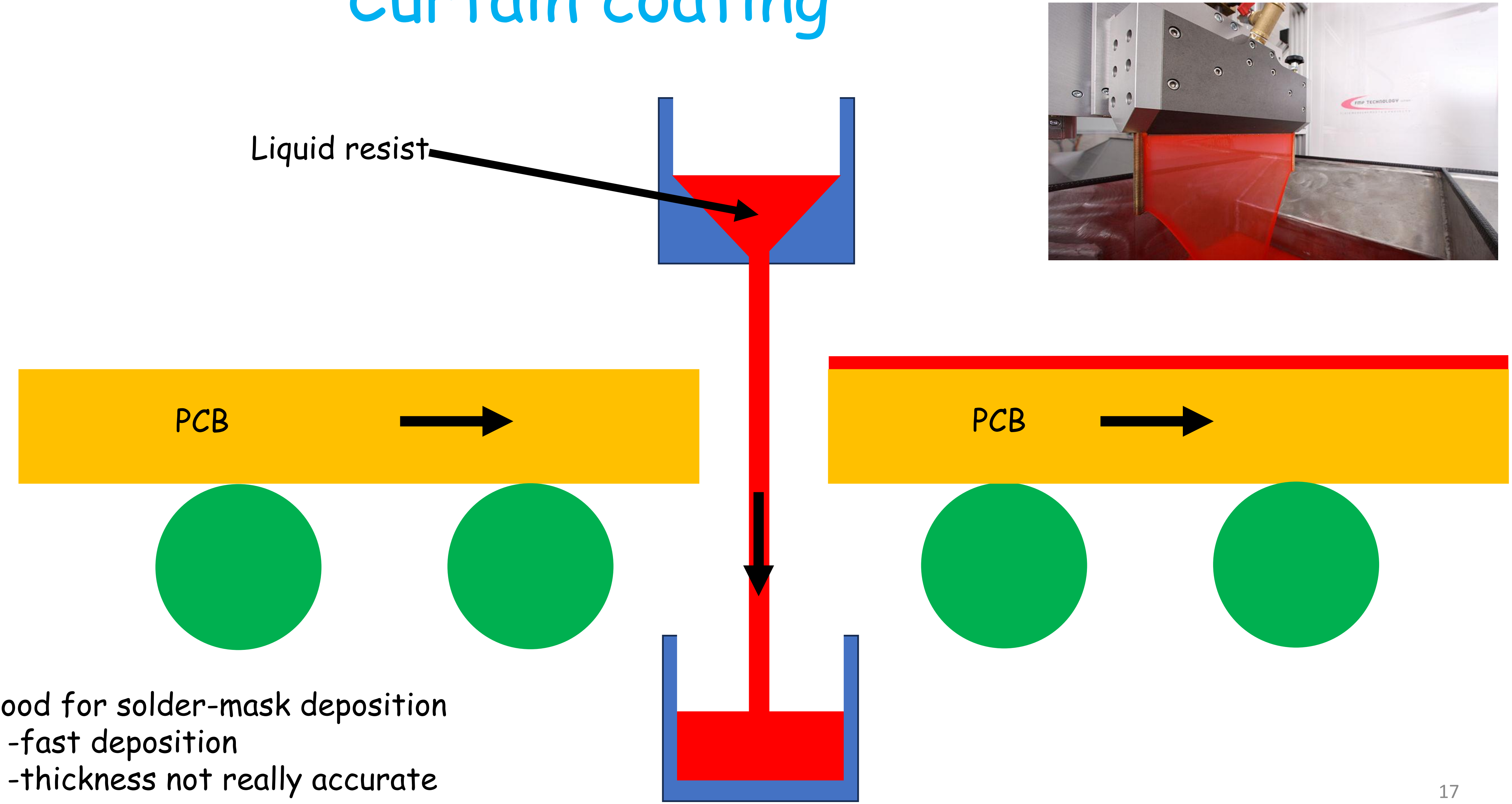
Really simple principle but difficult to tune with small productions

Thin depositions
Fine patterns

Good for continuous mass production lines

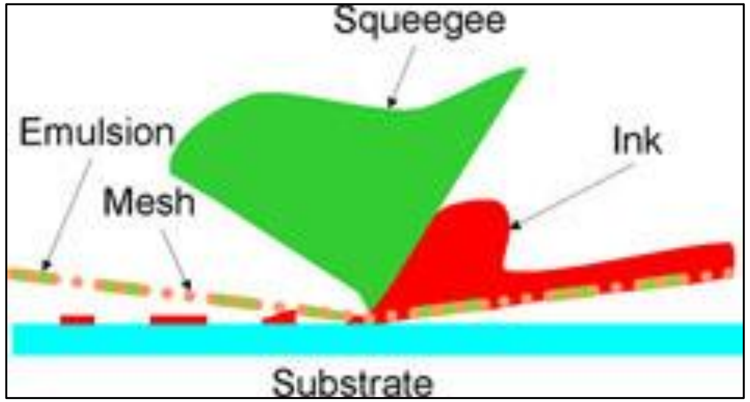
1/vertical dryer
2/base material
3/tank with liquid resist

Curtain coating



Good for solder-mask deposition
-fast deposition
-thickness not really accurate

Screen printing

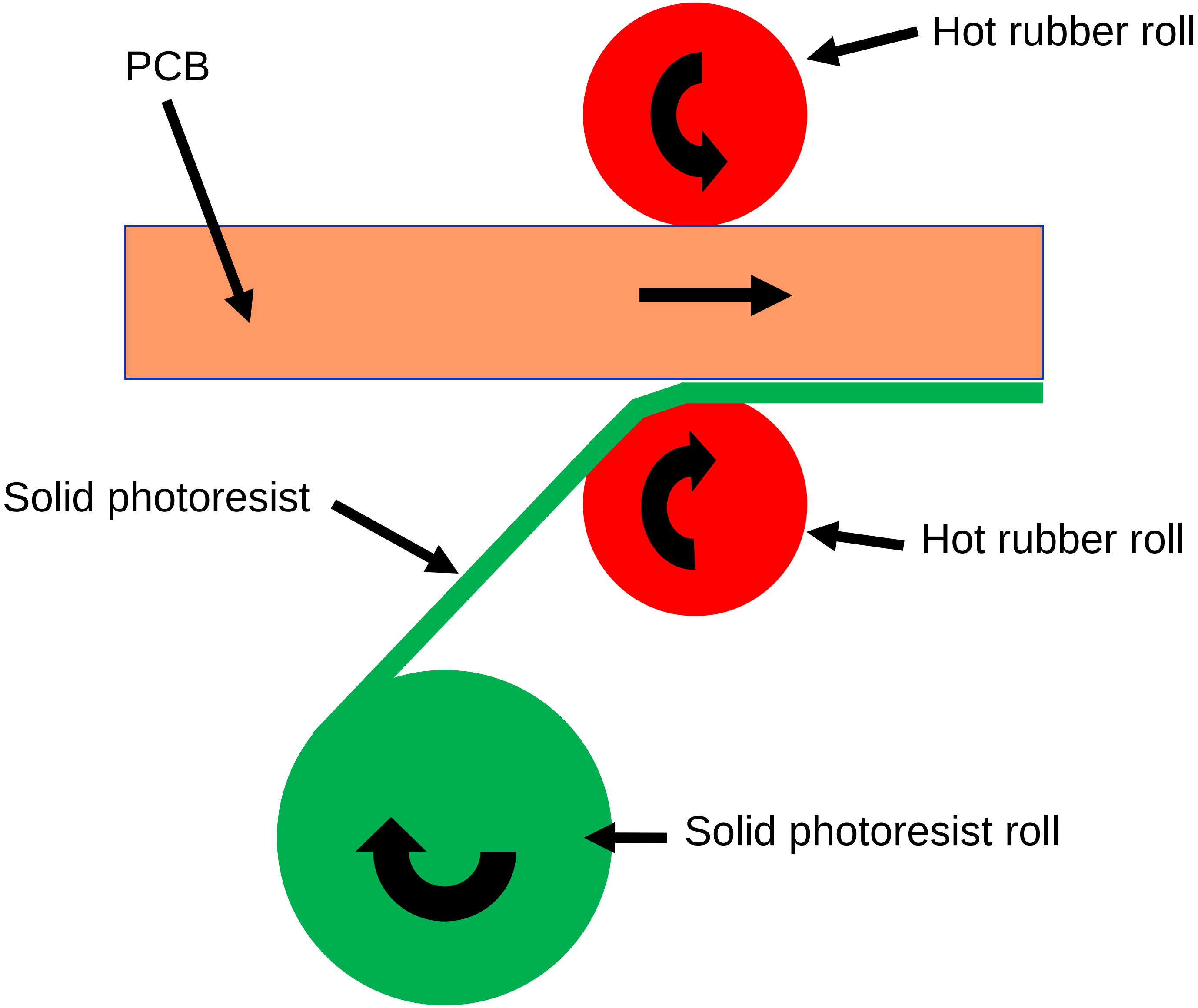


Good for solder-mask deposition
- fast deposition
- thickness not really accurate

CERN precise machine
20cm x20cm deposition

CERN Semi automatic machine 1.5m x 2m
General purpose

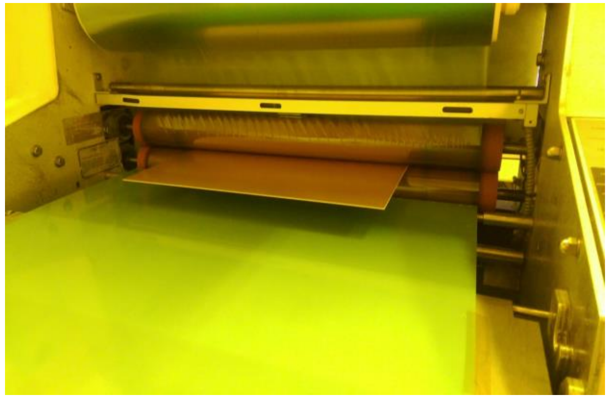
Hot roll lamination



Best speed Vs quality compromise !
- Dry process
- Medium class clean room
- Large size
- Precise thickness
- Easy to process
- Resolution 30µm line/space
- Not compatible with 3D shapes

Hot roll lamination deposition

Cu/Glass-Epoxy/Cu plate
Or flex



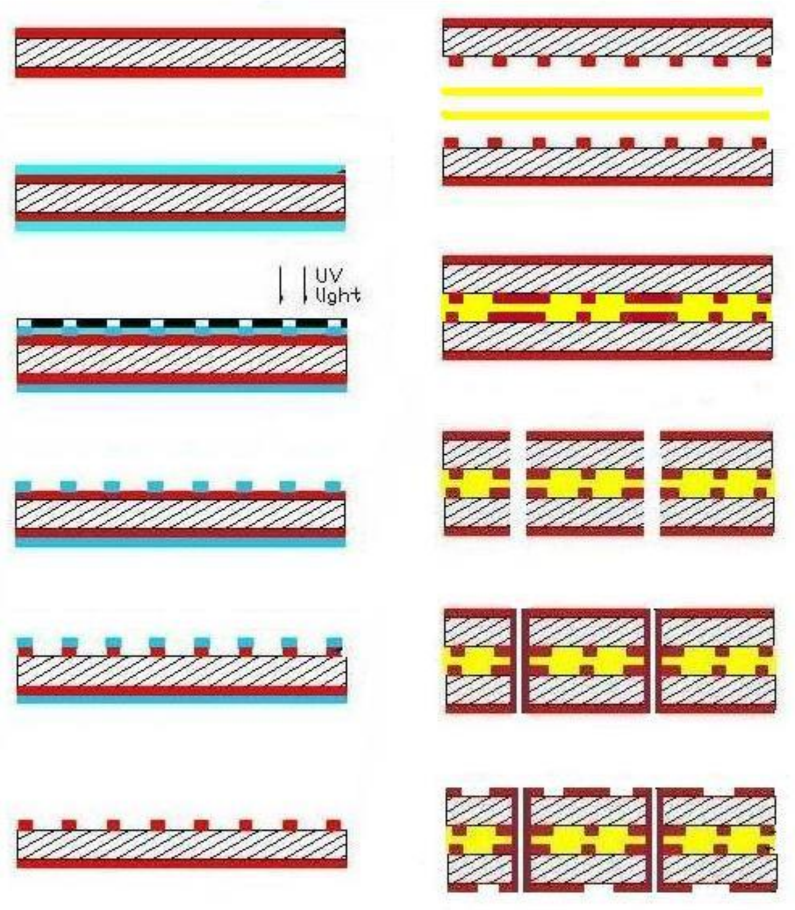
Resist deposition by Lamination

Plate + Photoresist

4 Layer PCB

UV exposure

Resist development



Masks

Glass mask : Glass or Quartz
- Cr on thick soda lime glass
- Direct laser ablation of thin vacuum deposited Chromium
- Sub-micron resolution possible
- up to 1m x 0.6m

Polyester mask : 100um thick
- Minimum line and width around 20um
- up to 2m x 1.5m
- Laser exposure of a photosensitive layer on a polyester film

Laser direct imaging : no mask
- Minimum 15um strips
- up to 80cm x 60cm
- resist direct Laser exposure

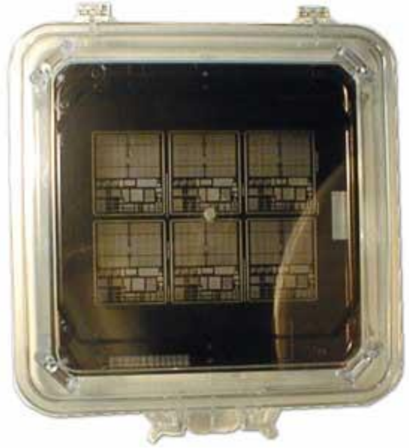
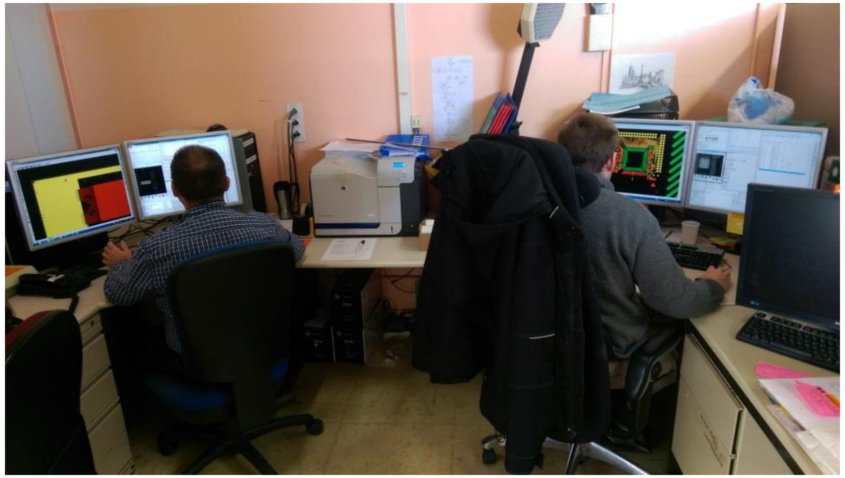


Figure 2 e 3 – The Paragon-8000 Laser Direct Imaging system (above) and 25 µm features exposed using this system (below)

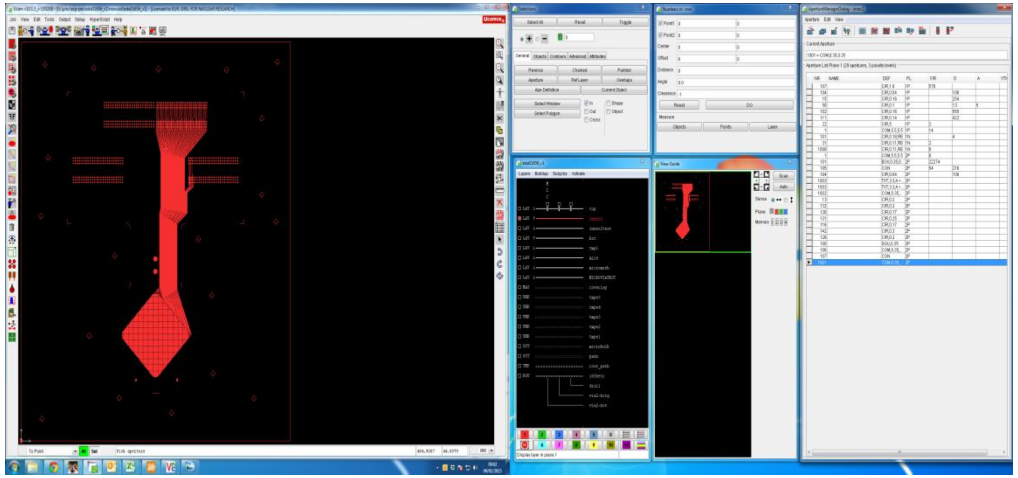
Polyester Mask production

start with GERBER file
Or DXF files



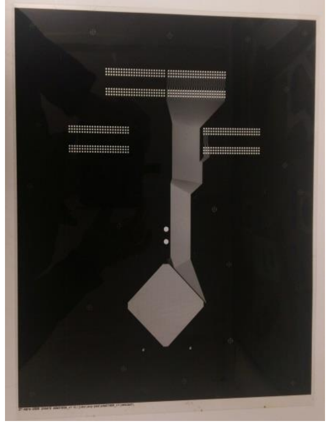
UCAM software (GERBER → DPF)

-Corrections for over etch
-DRC
-conversion to Plotter Format : DPF to raster file



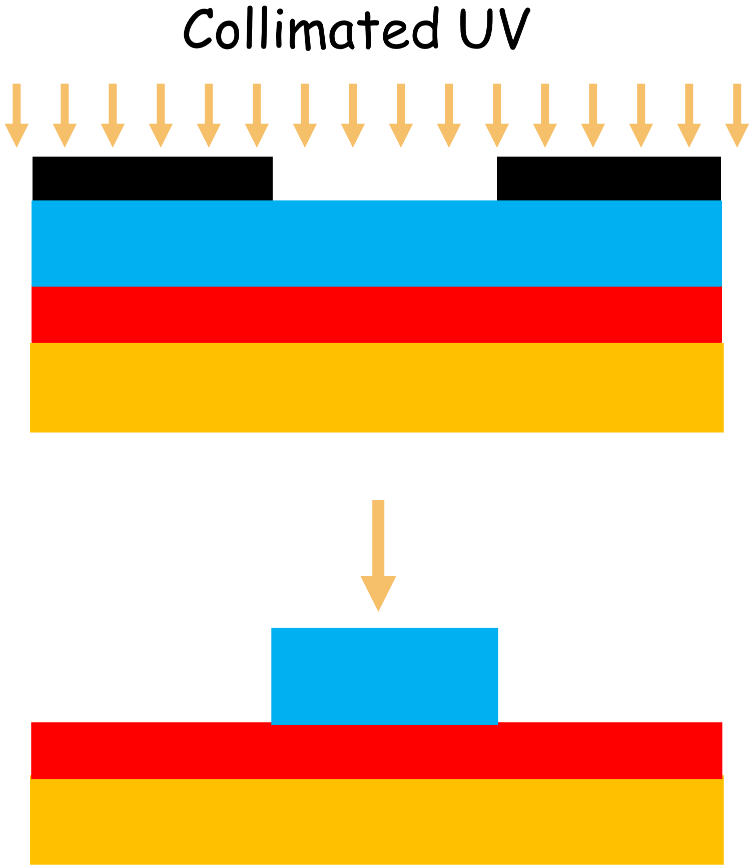
Laser photo plotter

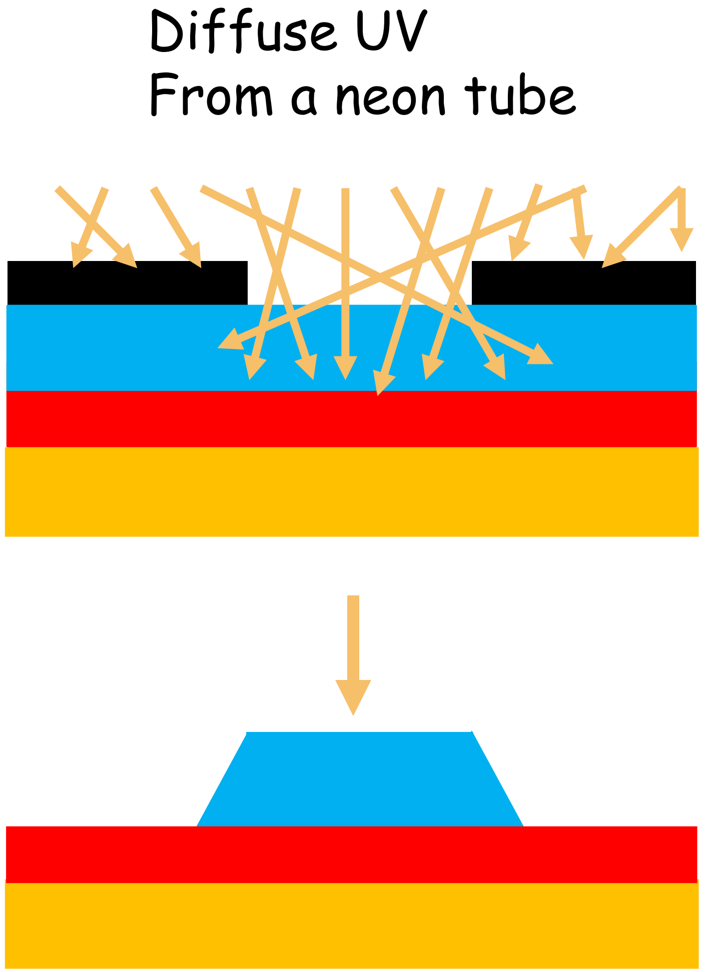
Chemical Mask development



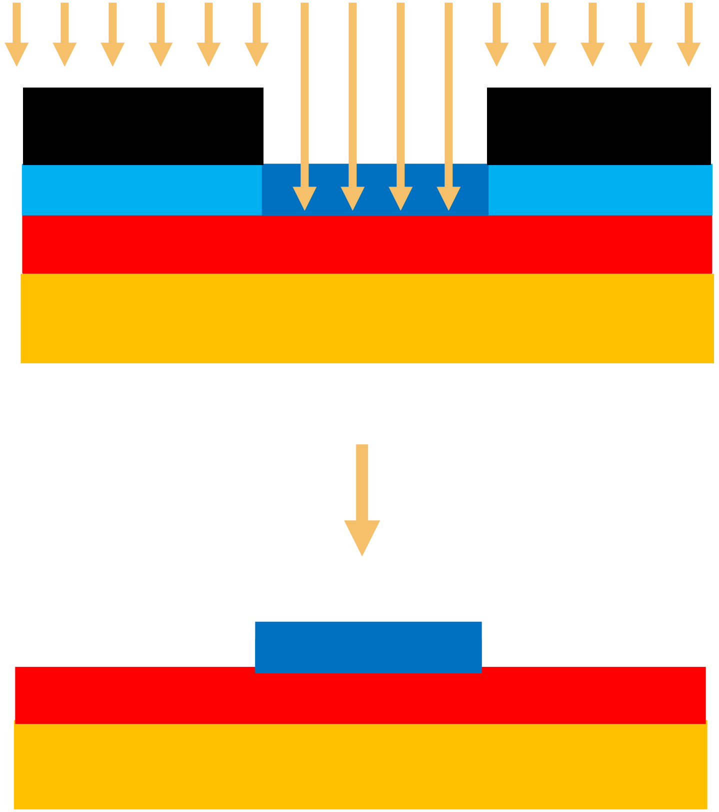
Mask

light diffusion problem

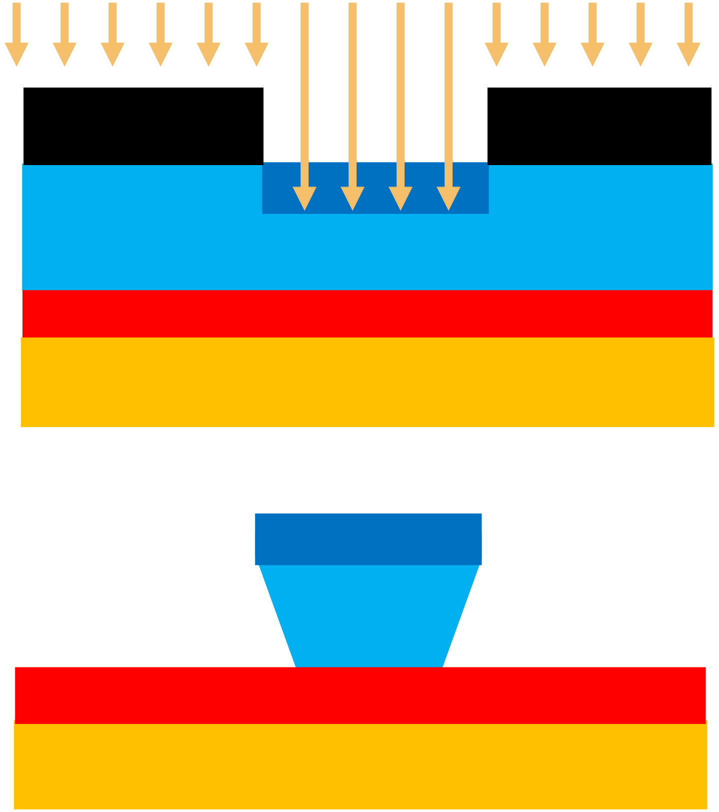




light absorption problem

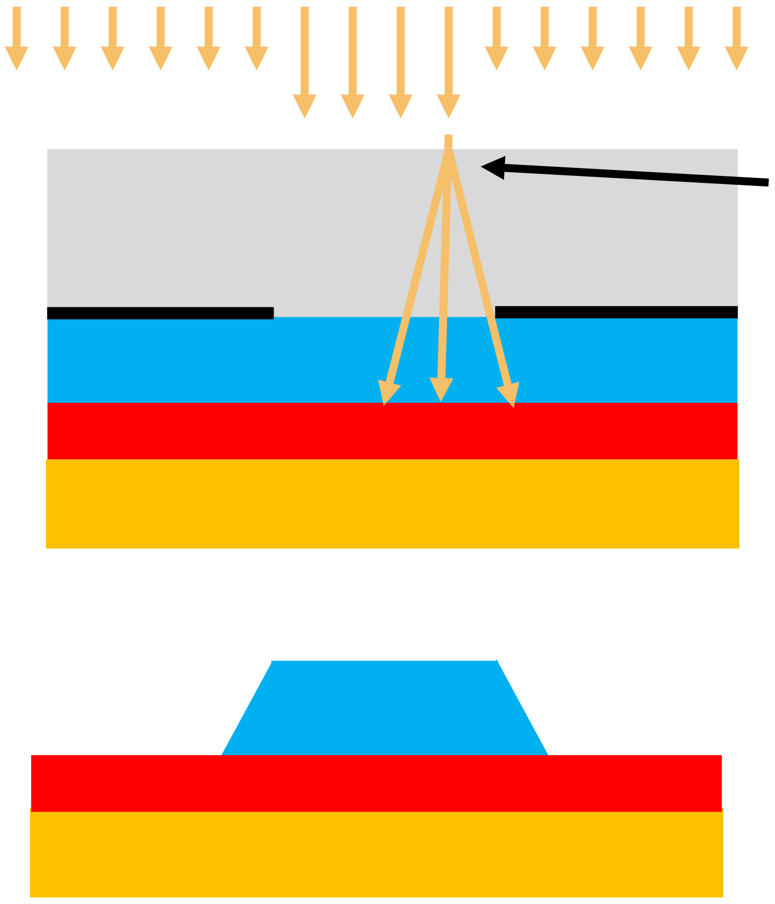


Thin layers ok



Problem with thick layers

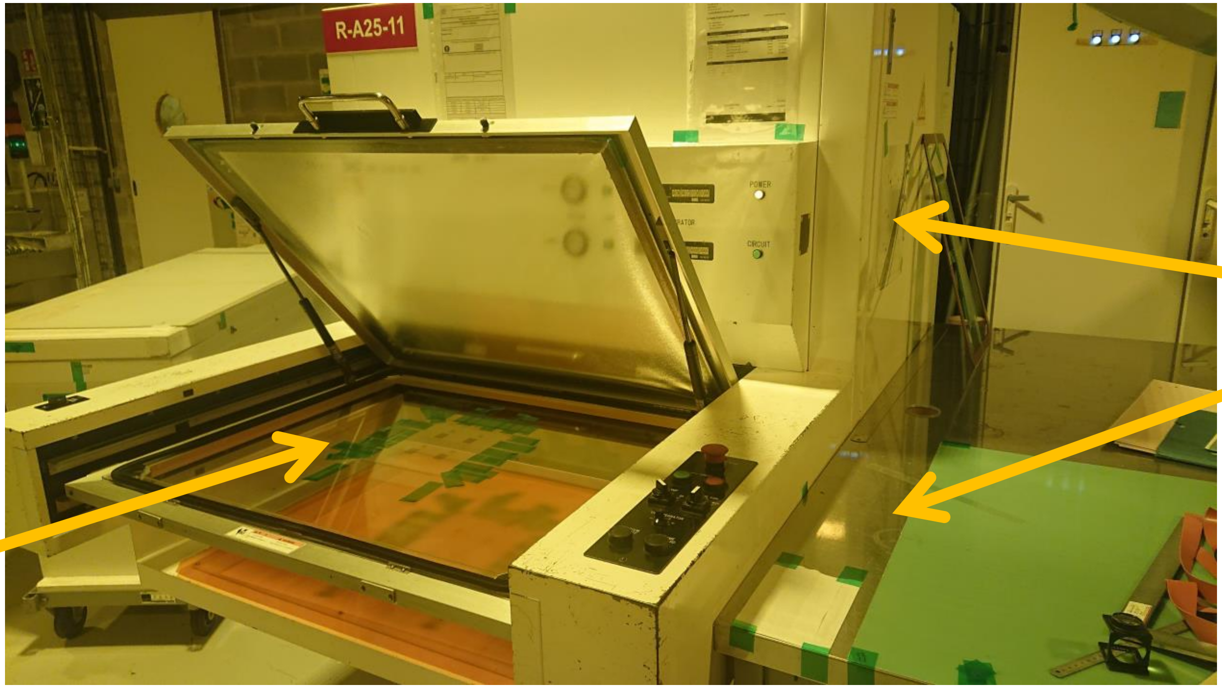
light diffraction problem

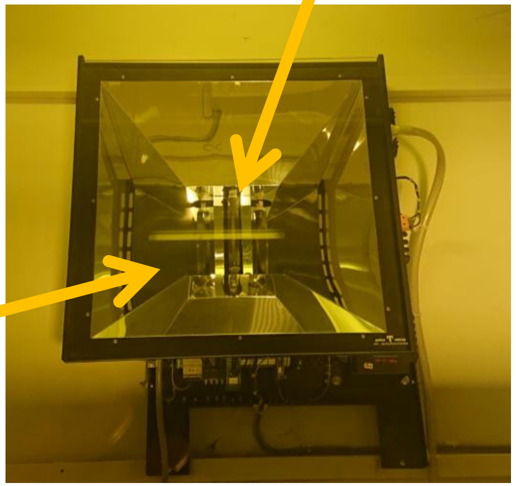


Diffraction in glass or polyester
Less with quartz

Ultra thin patterns
Micrometric range

STD UV exposure





Two UV bulbs

Vacuum Drawer (open)
Sliding in the machine.

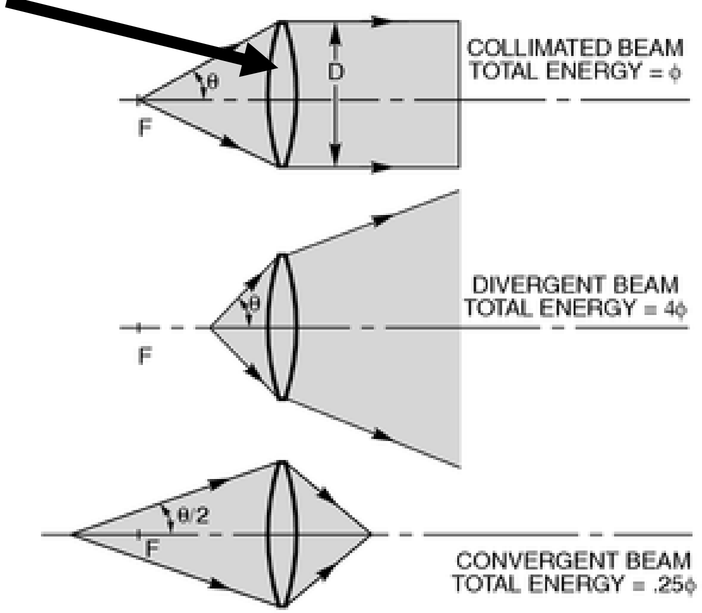
Stack up:
- -Polyester foil
- -Mask → manual alignment
- -PCB with resist to pattern
- -Glass plate

Deflectors to
Improve collimation

Collimated UV lamps avoid diffuse light

Precise large size lens up to 12 inches

The lens quality is the base of this system



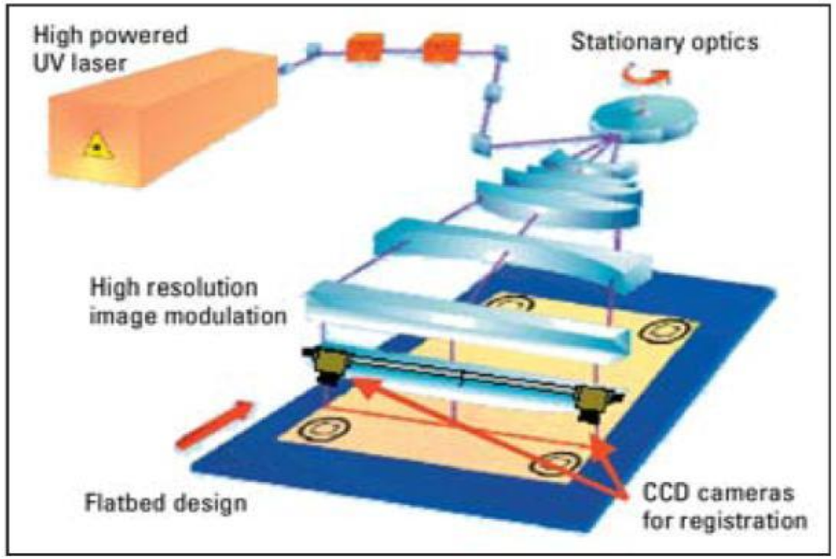
UV Source alone for multipurpose application
or
Combined with a high precision mechanical system for alignment: “Mask aligner”

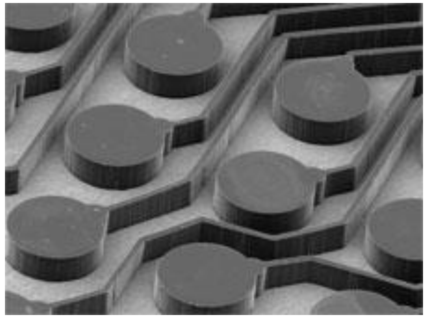
LDI: laser Direct Imaging

Increasing local energy can beat the 3 problems

But with thick resist the absorption remains .

Precision: 0.5 µm to 2 µm (depending on laser type)

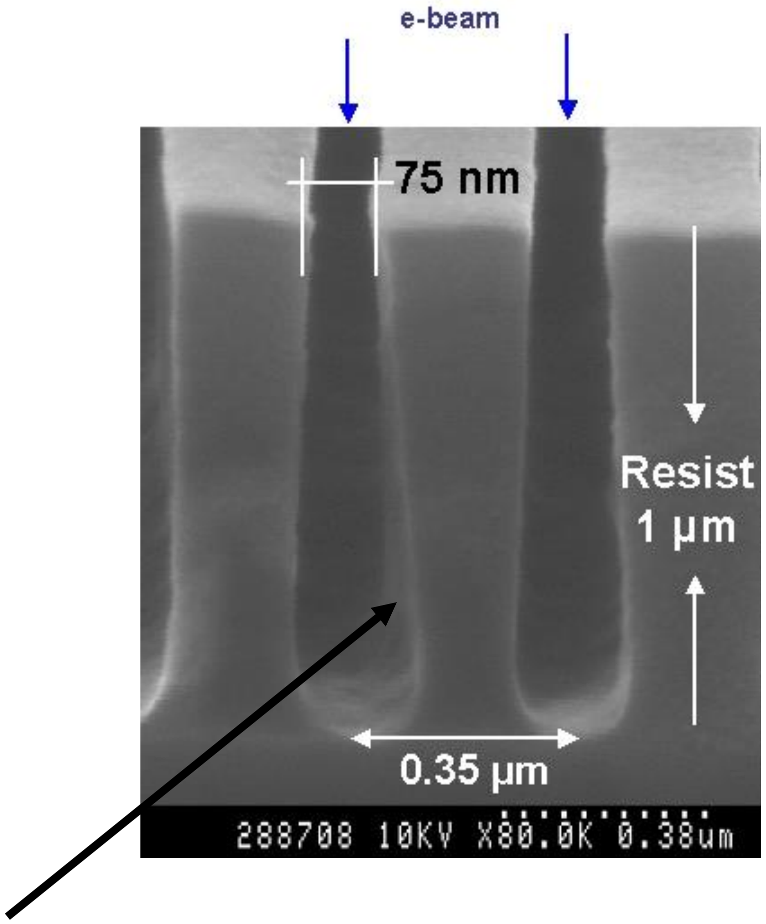




Electron beam exposure beats all the problems

Current dedicated systems have produced line widths of 10 nm or smaller

The primary advantage of electron beam lithography is that it is one way to beat the diffraction limit and make features in the nanometer regime



Angle due to Electron scattering in resist

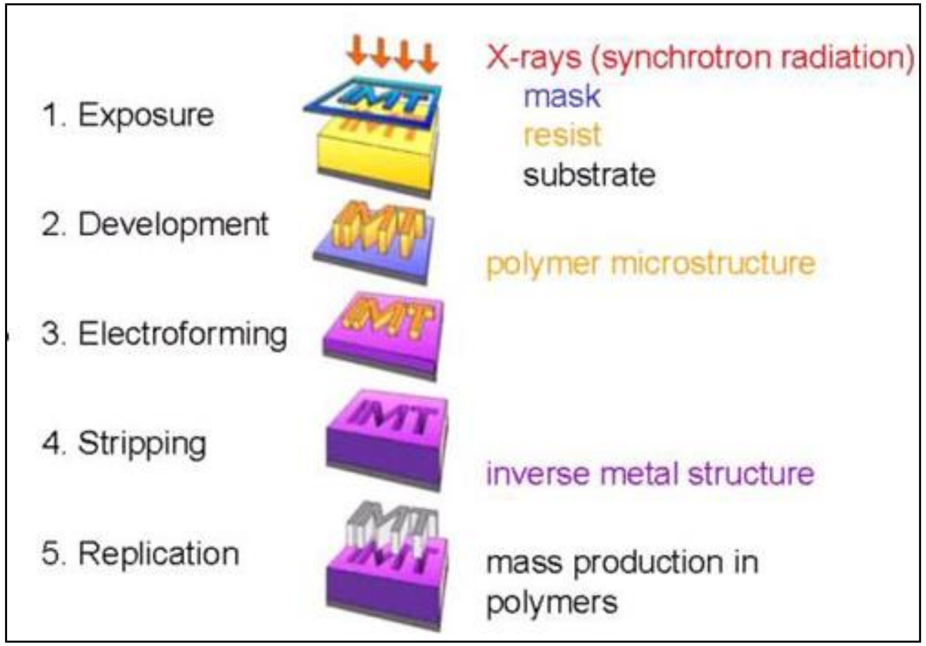
Advanced image transfer with X-ray exposure

LIGA technology uses X-ray lithography to obtain polymer structures with extremely high aspect ratios (lateral precision bellow 1µm in a 0.1 to 2mm thick polymer).

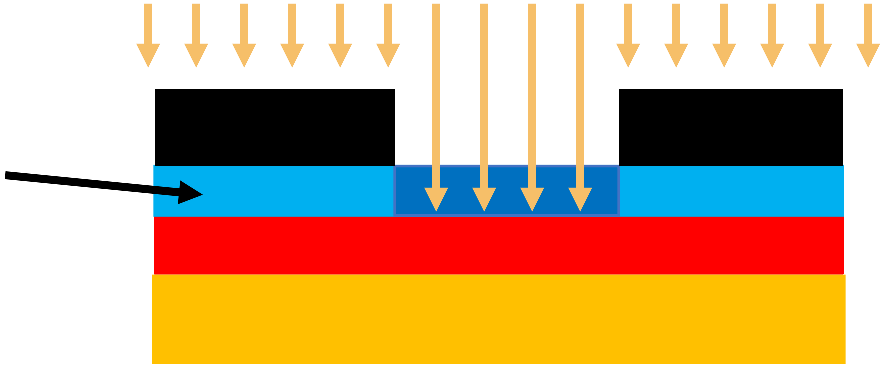
LIGA is a German acronym →in English Lithography, Electroplating, and Molding.

Because of the high collimation of X-rays needed, the source must be synchrotron light.

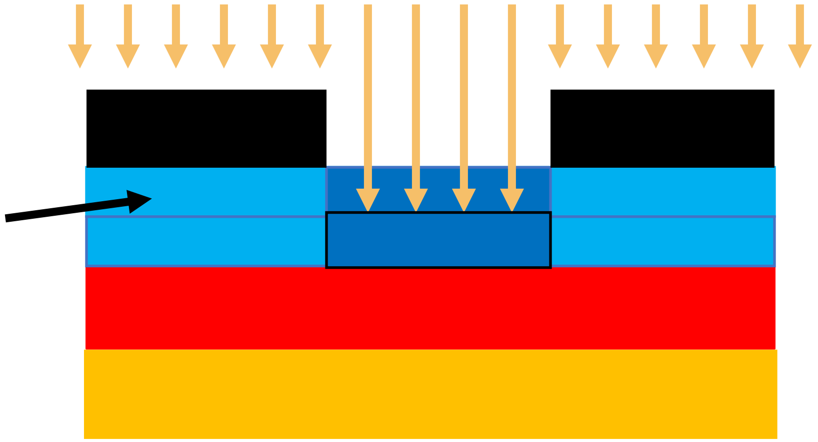
This technology is the base for many MEMS, It beats the limitation of light absorption in the photoresist.



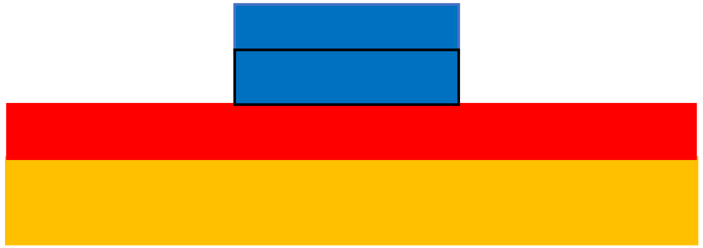
Cheaper way to avoid light absorption problem



Resist lamination
+ UV exposure



Second Resist lamination
+ second UV exposure



After development

That's how we produce
Thick pillars for Micromegas

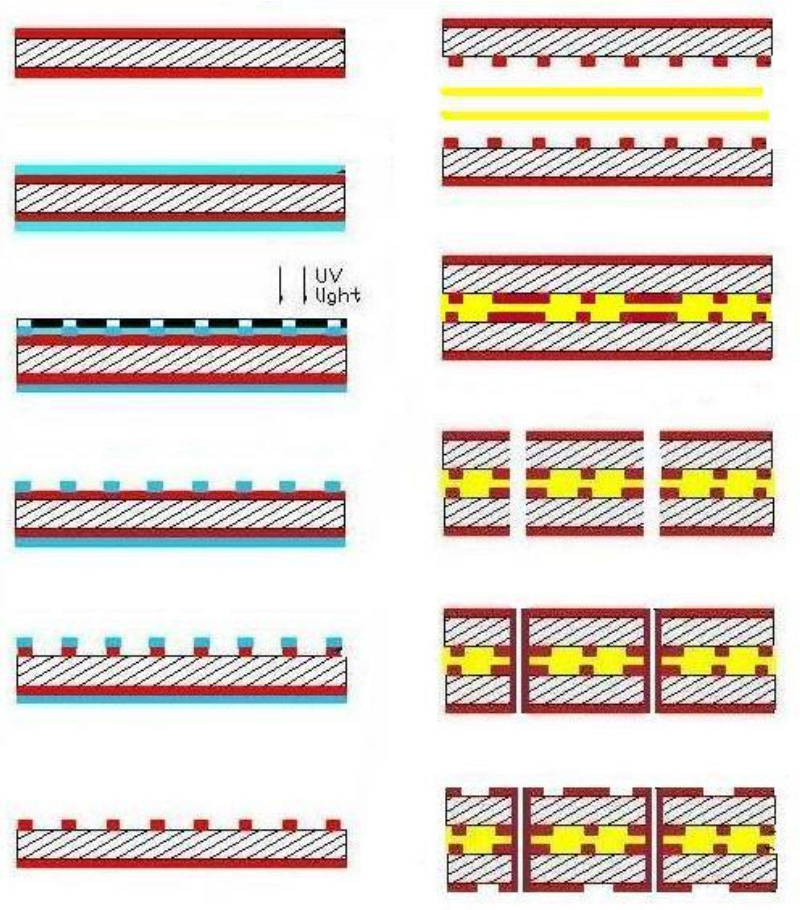
After exposure →Wet development

After Exposure

Development with NA2CO3

After Development

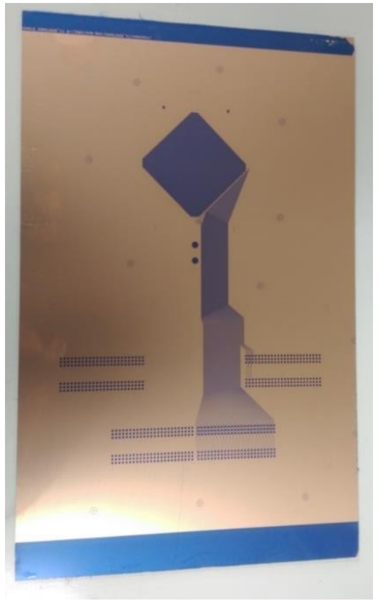
4 Layer PCB



Etching

Resist stripping

Wet spray Etching



Resist Image

Wet spray horizontal etching

Some examples of chemistries:

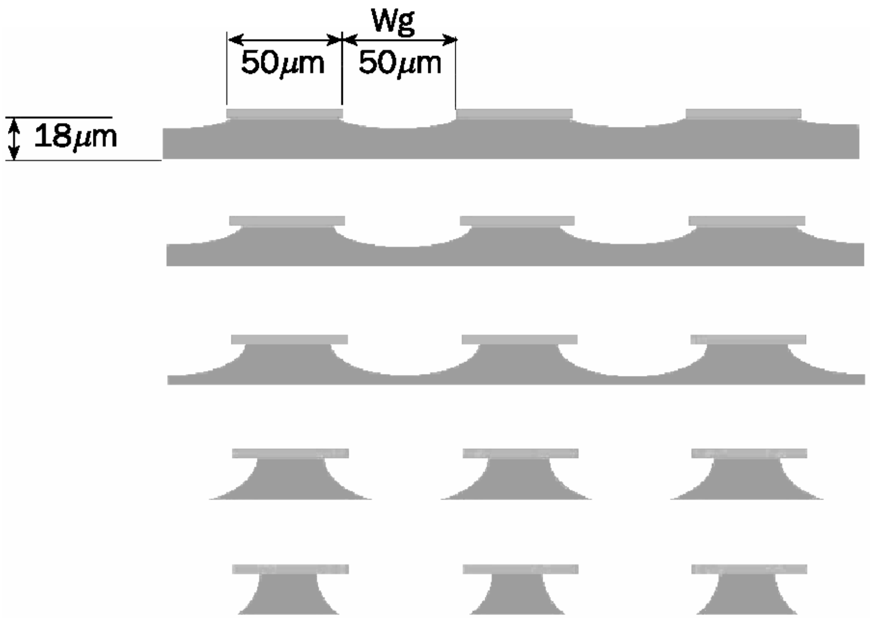
- -Ferric Perchloride for Copper/SS/Aluminium
- -Phosphoric/sulphuric/Fluoridric acid for Niobium
- -Fluoridric acid for Titanium
- -Potassium Ferrocyanide for Tungsten
- -Iode/Iodine for Gold
- -Iron nitrate for Silver etc.. etc..

After Etching

Anisotropic , Isotropic wet etching

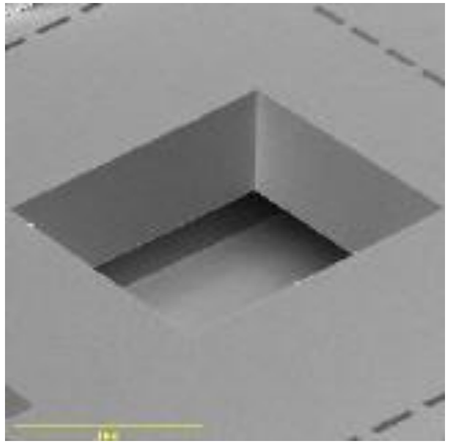
- Most metals can be wet etched
- The etching is isotropic for nearly all of them
- Most of the dielectrics are difficult to wet etch

- Some exceptions
  - Silicon etching is anisotropic due to its crystalline structure
  - Polyimide etching can also be anisotropic

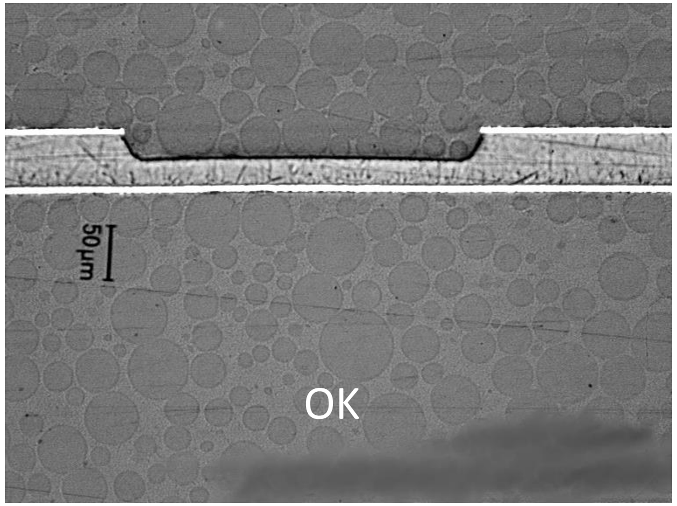


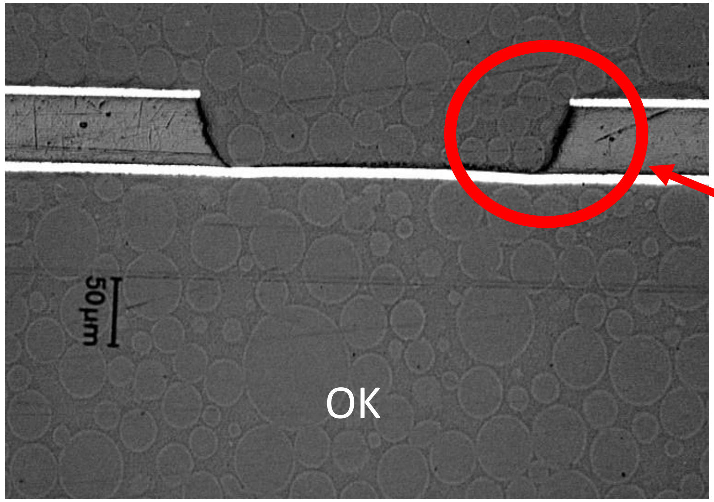
Big limitation with thick layers
Minimum opening 3 to 4 time the thickness

Anisotropic etching

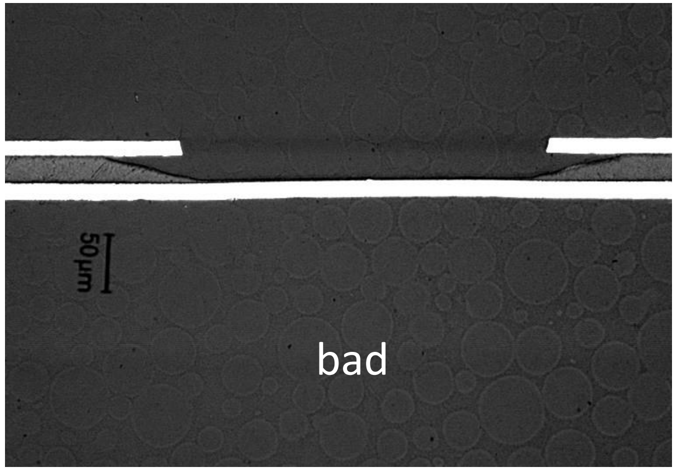


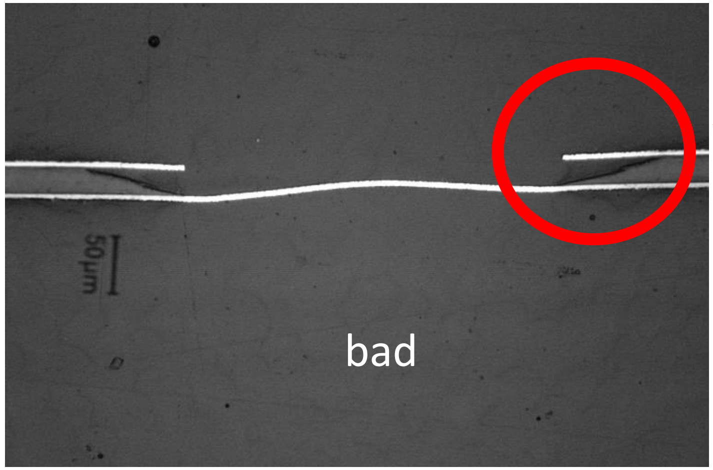
Polyimide wet etching , isotropic and anisotropic





First type of polyimide:
Perfect anisotropic etching
No under etch
Perfect to make small holes





Second type of polyimide:
Fully isotropic etching
Not satisfactory

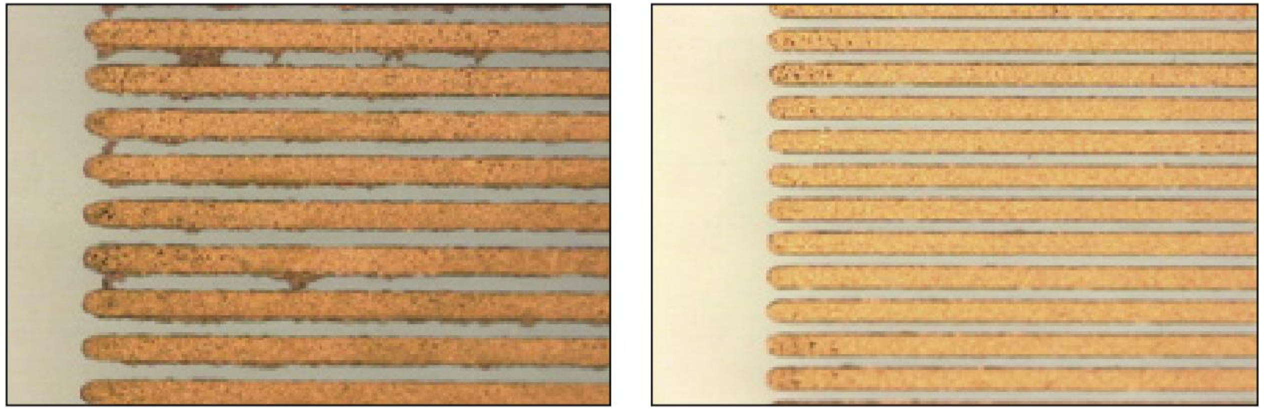
Les than 10% of PIs available on the market are OK

Laser etching

-Laser direct metal patterning is not yet used to make lines in PCBs.

-With thick layers (above a few um), the speed /quality ratio is much worse than chemical etching.
    -Powerful and fast laser ablation produces poor quality lines
    -And to get good quality lines the throughput is too slow

-But laser is nice for repairs .



Full of shorts   Cleaned up

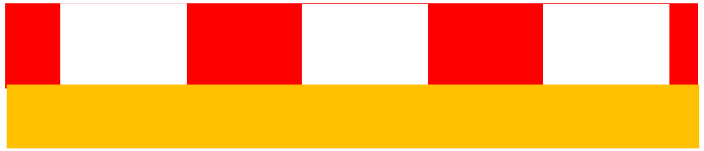
It looks simple but the process is complex

Electroforming to beat wet etching isotropy

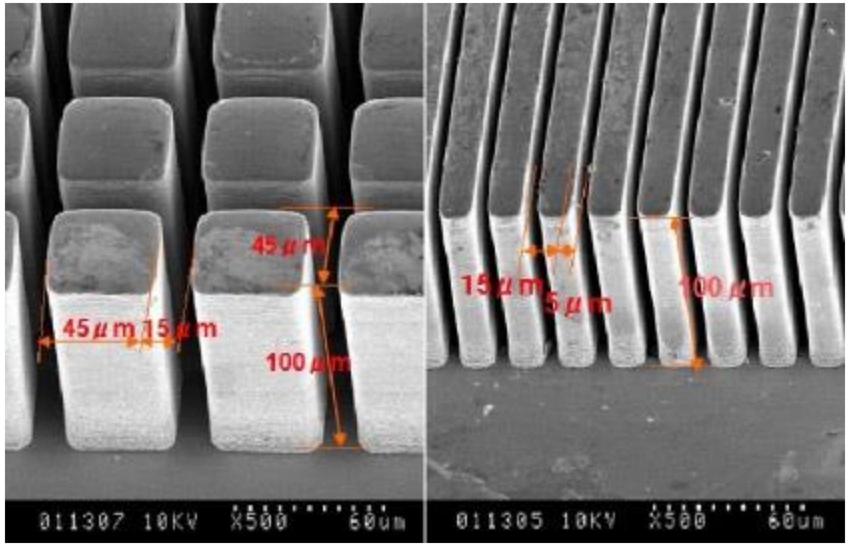
Thick resist

Electro plating

Resist stripping



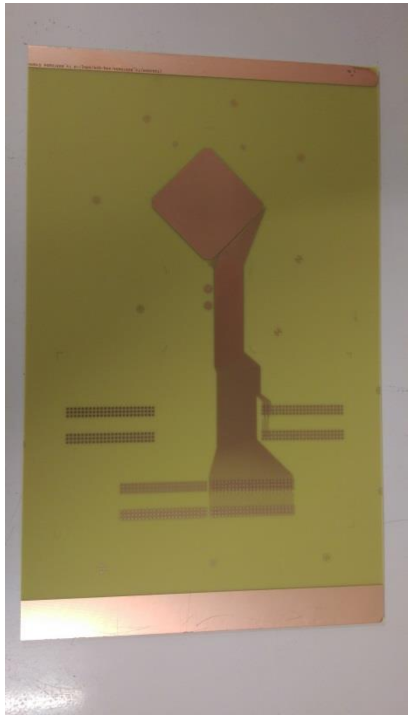
Seed layer removal



After wet etching → resist Stripping

After copper Etching

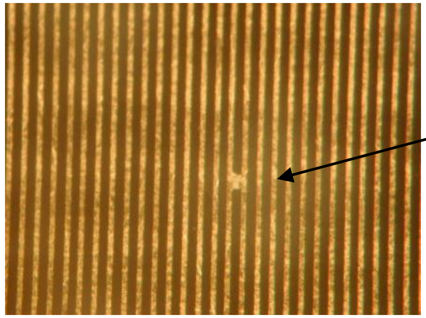
Stripping with:
NAOH
KOH
Solvents



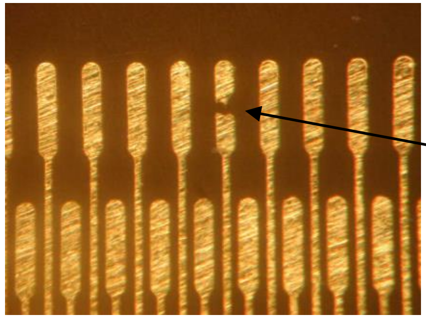
After stripping

After stripping → Automatic Optical inspection (AOI)

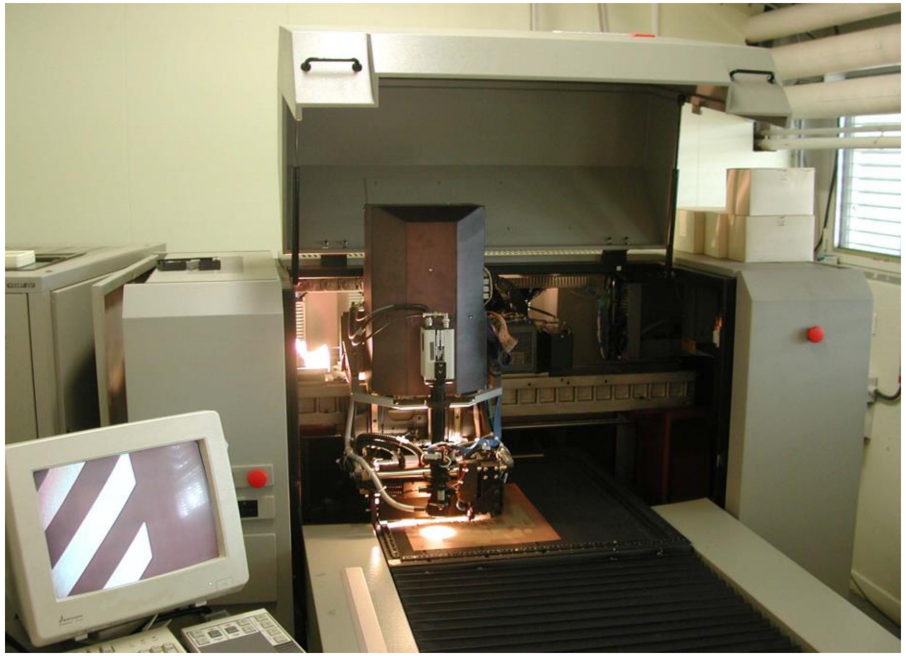
-Compare the scanned image with the design file
-Minimum track or space 20um
-Minimum detectable defect around 5 um (pixel 2.5um)
-Cannot detect hole plating defect



Short circuit

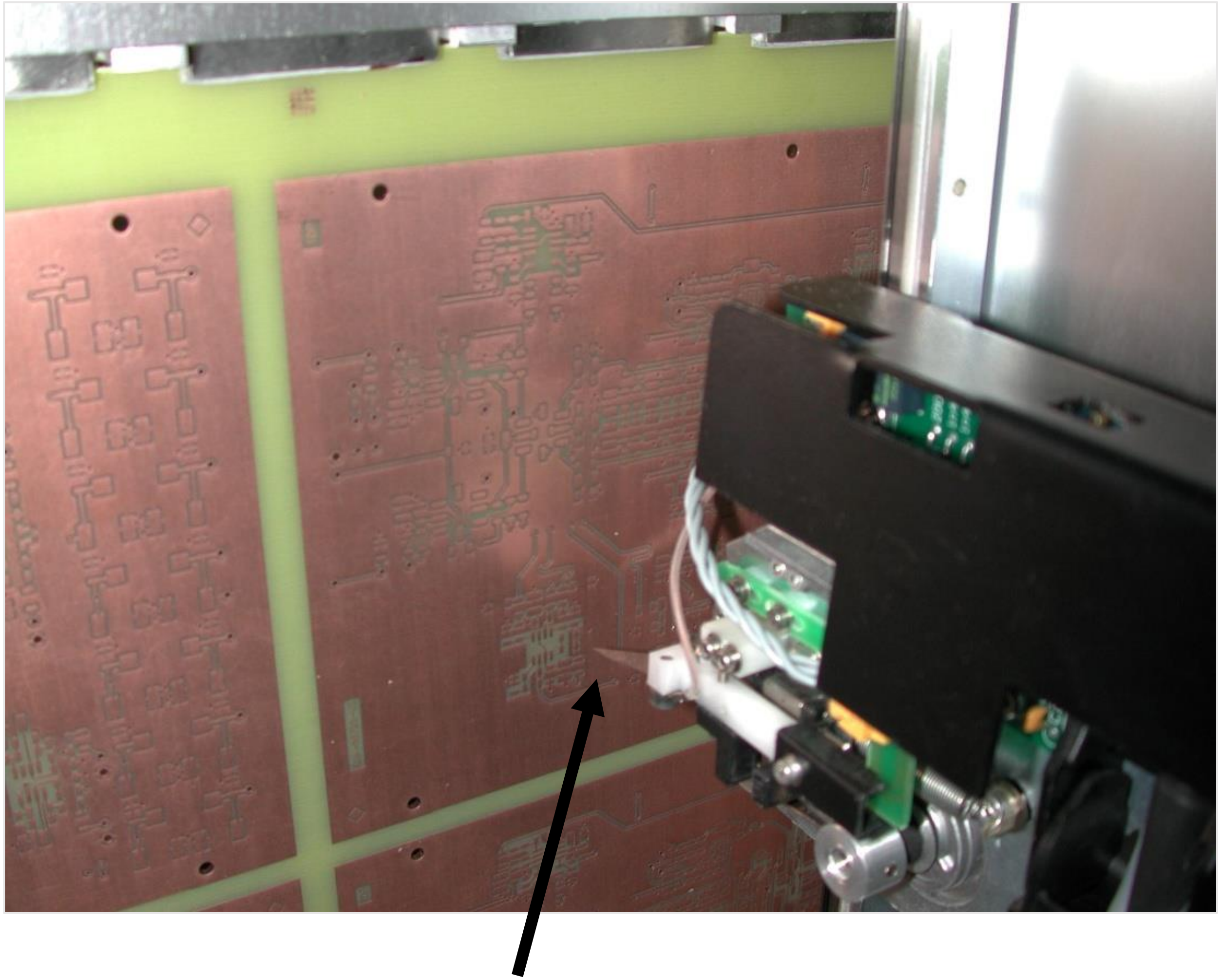


Open
Bonding pad

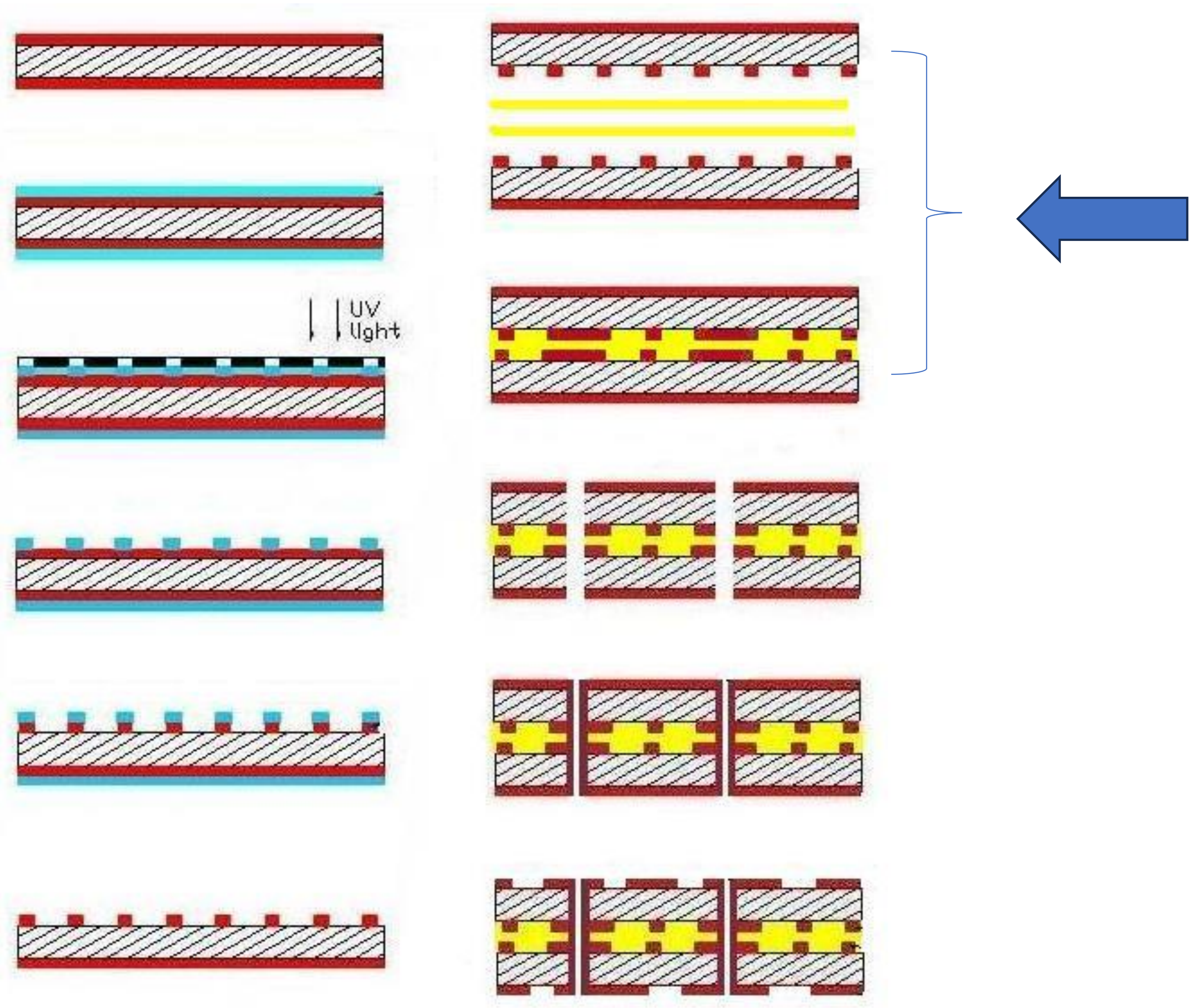


At the end →Electrical test

Control netlist integrity
Including PTH this time



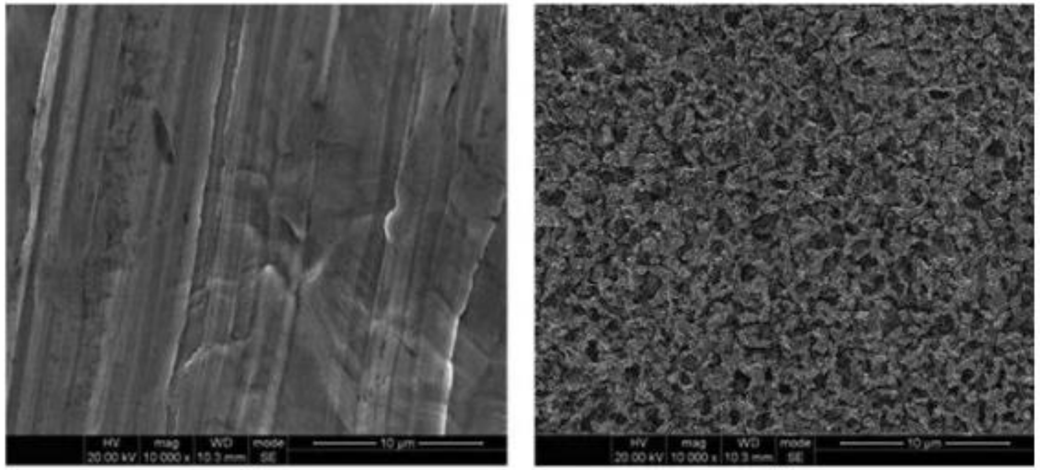
Flying probe
2 in front 2 in bottom



Gluing

First step →prepare the metals

1/Detergent Cleaner
2/Pre-conditioning
3/Micro structurizing Chemistry
4/DI water Rinse
5/Dry



(a) (b)

Some metals can be nearly directly glued:
  - Aluminum , Titanium

Some need to be micro-structurized
  - Copper and alloys

Other need to be chemically treated
  - Ni, stainless steel

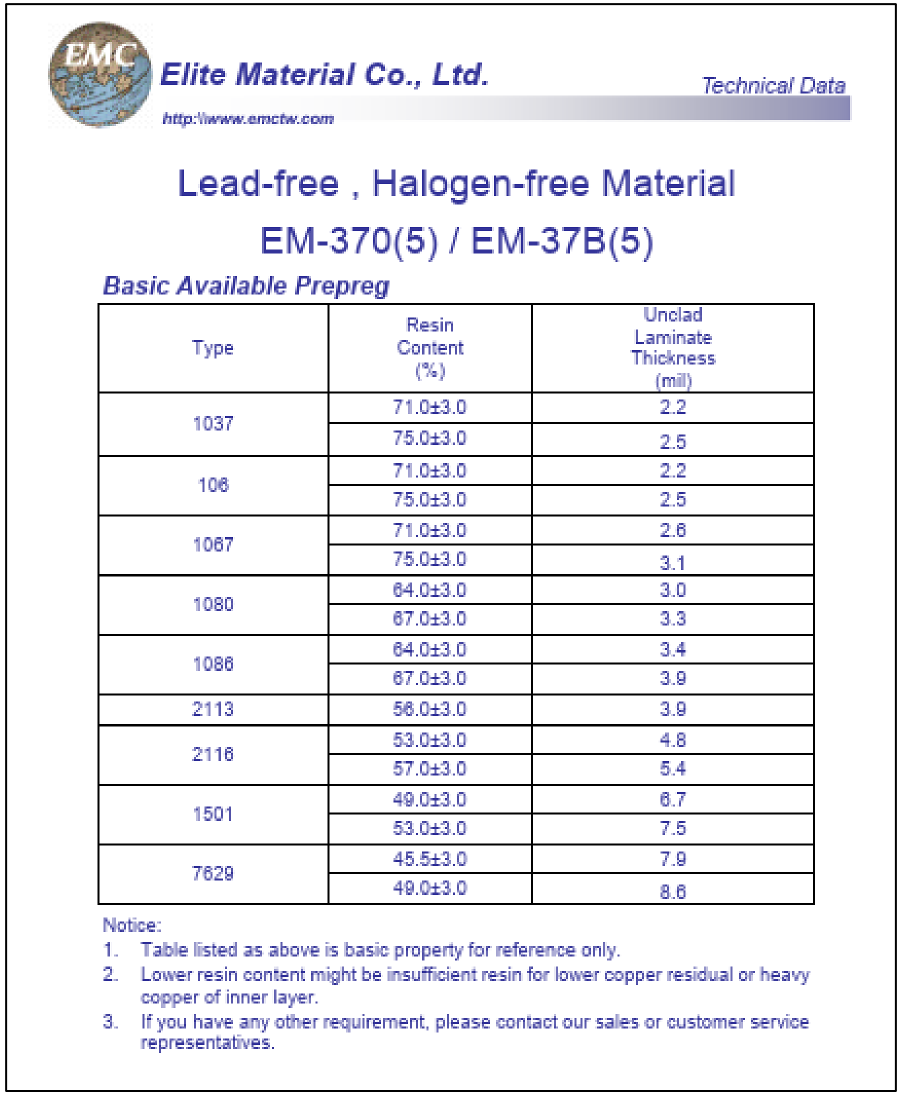
All of them need to be degassed

Gluing Equipment

- Isostatic press
  - Vacuum chamber
  - 5 Heating plates
  - Mechanical Hydraulic pressure (40 Bars)
  - Plate size 600mm x 700mm
  - Presses with plates above 1m is exceptional
  - Short cycles
  - usually only used for flat plates
- Autoclave
  - The parts to glue are in a vacuum bag
  - Pressure coming from compressed air (10 Bars)
  - STD size 2m x 1m
  - Machine with a length of 20m are existing
  - Long cycles
  - 3D objects

Glue

- Liquid
  - Rarely used
  - Difficult to apply , difficult to clean , thicknesses not accurate
- Prepregs
  - Wowen glass impregnated with a bi-stage polymer glue (um precision thickness)
- Cast
  - Thin layer glue (solid) on a carrier (um precision thickness)
- Cover-layer
  - Polyimide layer with a thin layer of glue on one side
- Bond-ply
  - Polyimide foil with glue on both sides
- Pressure sensitive adhesive
  - Thin layer of adhesive on a carrier



Elite Material Co., Ltd.

http://www.emctw.com

Technical Data

Lead-free , Halogen-free Material

EM-370(5) / EM-37B(5)

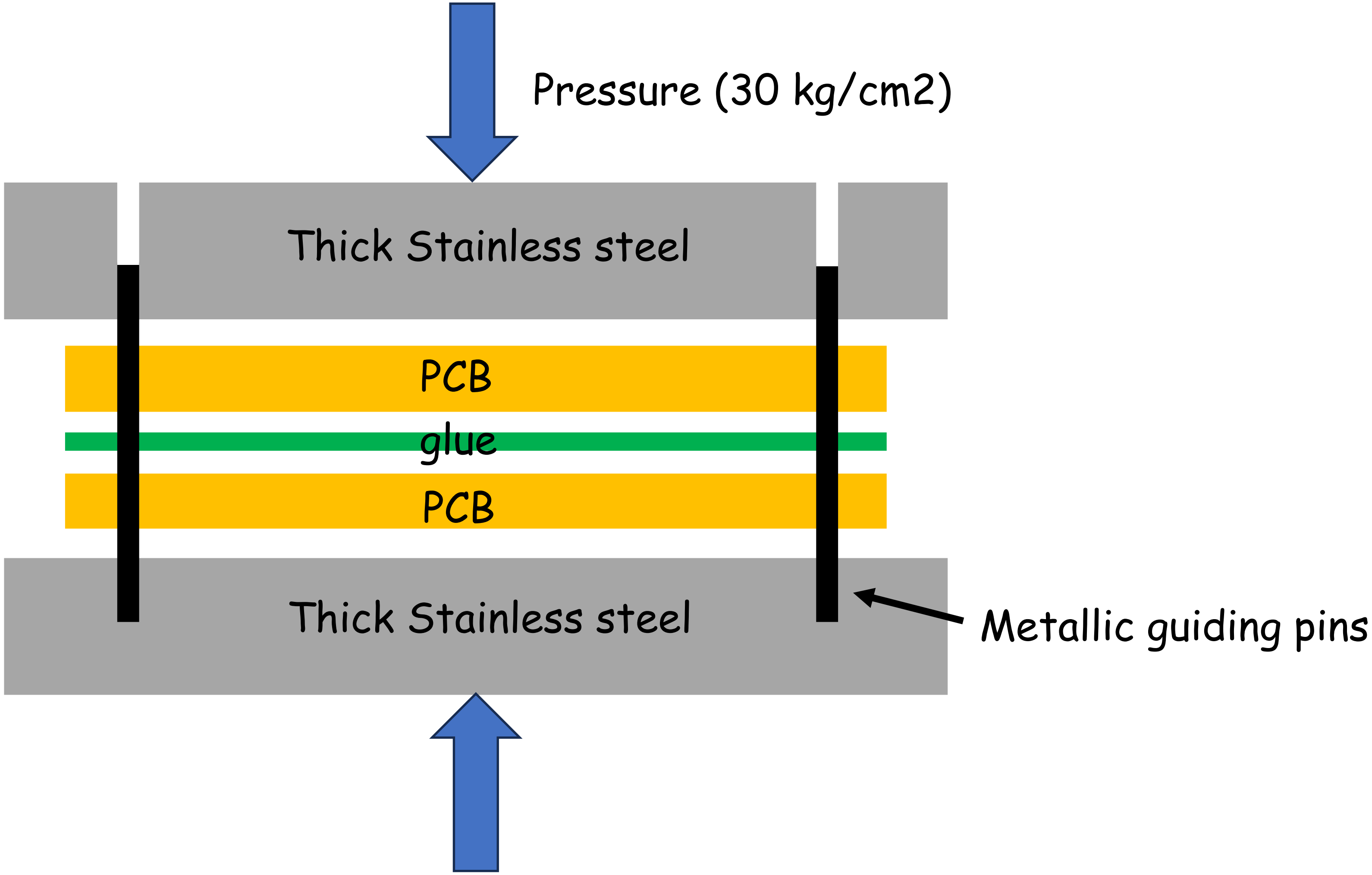
Basic Available Prepreg

Type	Resin Content (%)	Unclad Laminate Thickness (mil)
1037	71.0±3.0	2.2
	75.0±3.0	2.5
106	71.0±3.0	2.2
	75.0±3.0	2.5
1067	71.0±3.0	2.6
	75.0±3.0	3.1
1080	64.0±3.0	3.0
	67.0±3.0	3.3
1086	64.0±3.0	3.4
	67.0±3.0	3.9
2113	56.0±3.0	3.9
2116	53.0±3.0	4.8
	57.0±3.0	5.4
1501	49.0±3.0	6.7
	53.0±3.0	7.5
7629	45.5±3.0	7.9
	49.0±3.0	8.6

Notice:

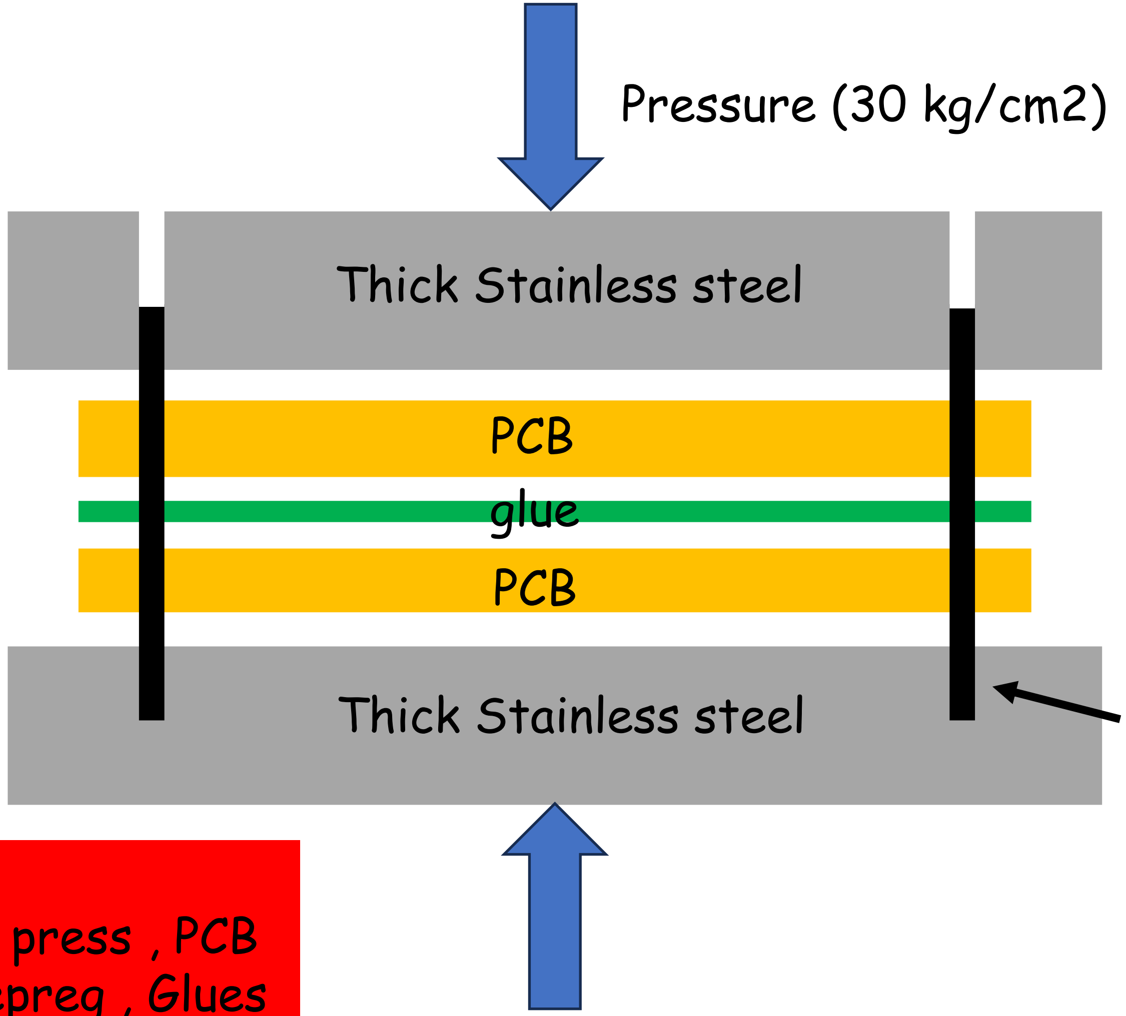
1. Table listed as above is basic property for reference only.
2. Lower resin content might be insufficient resin for lower copper residual or heavy copper of inner layer.
3. If you have any other requirement, please contact our sales or customer service representatives.

Gluing principle



Stack under vacuum
Heat all the stack

Gluing principle

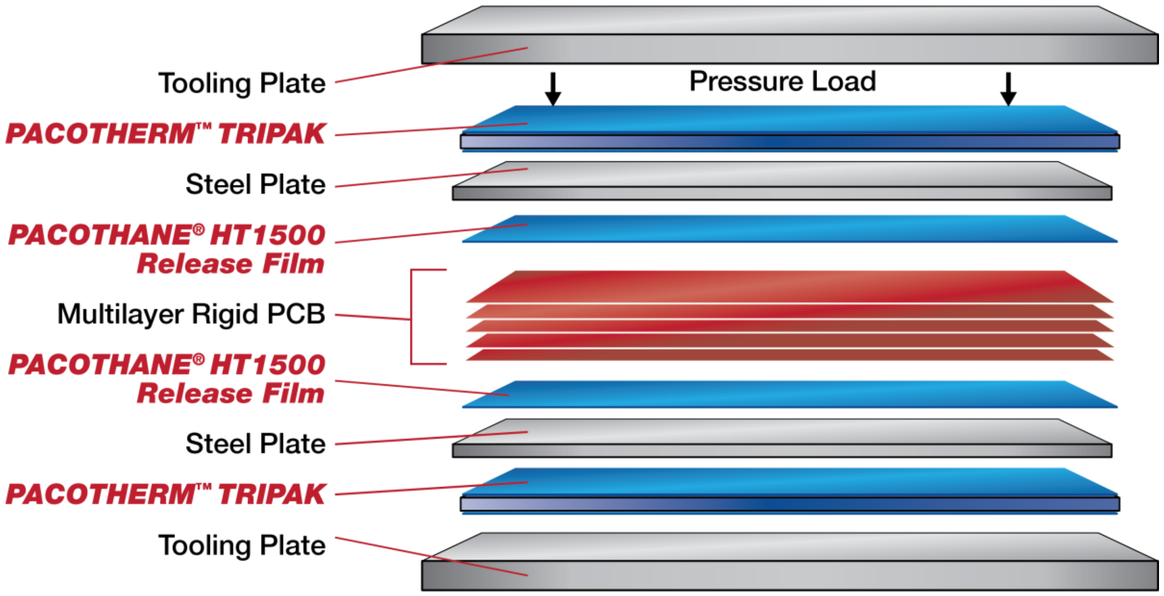


Stack under vacuum
Heat all the stack

Problem :
Flatness of the SS plates , press , PCB
Thickness uniformity of Prepreg , Glues
Thickness variation on a patterned PCB

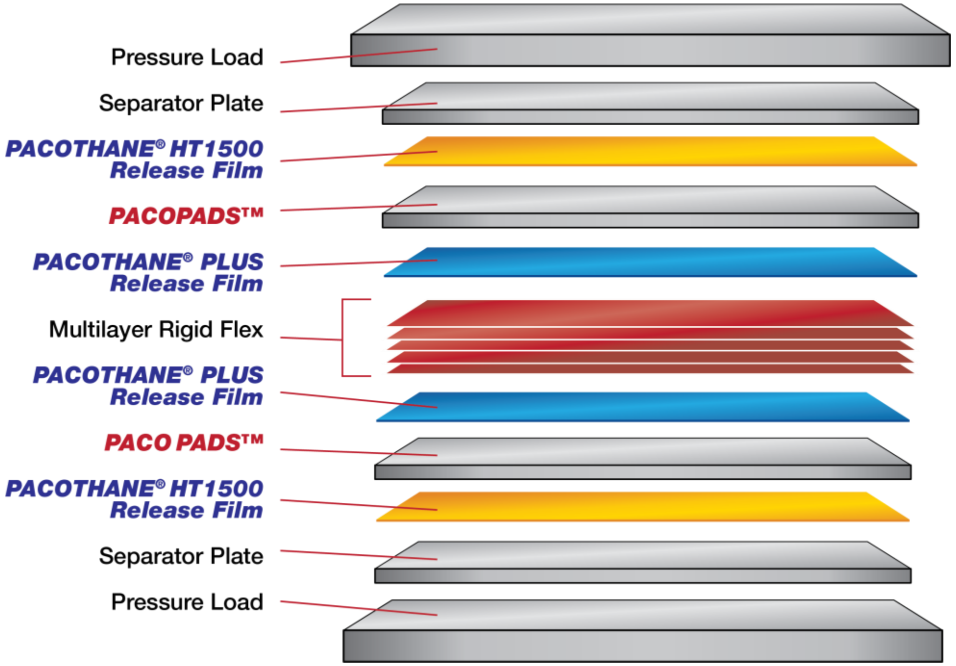
Release and conformal layers

- Pacothane
  - release sheet
- Pacolon
  - High temperature release sheet
- Pacopads
  - Melting with temperature → Planarity corrections up to 200um
- PacoFlex
  - Encapsulate strips , the coverlayer will follow the strips shape
- Pacovia
  - Melting and hermetic →avoid glue coming out from buried holes
- Pacotherm
  - Large Planarity corrections up to 1mm

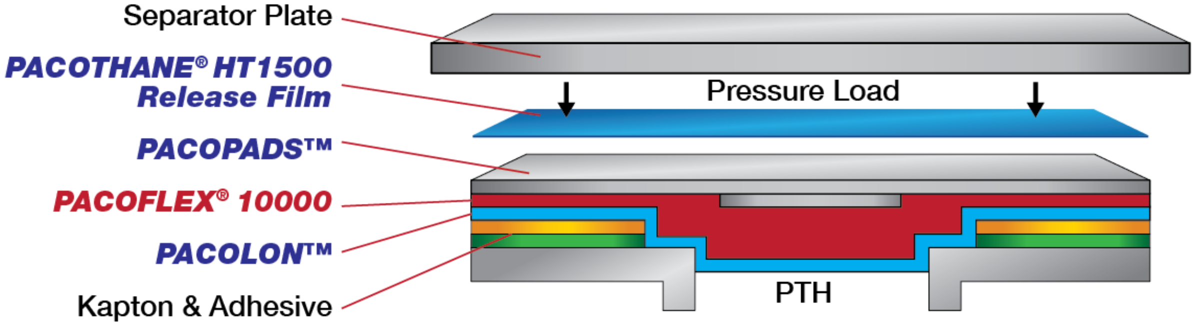


Typical Rigid PCB stack

Others configuration

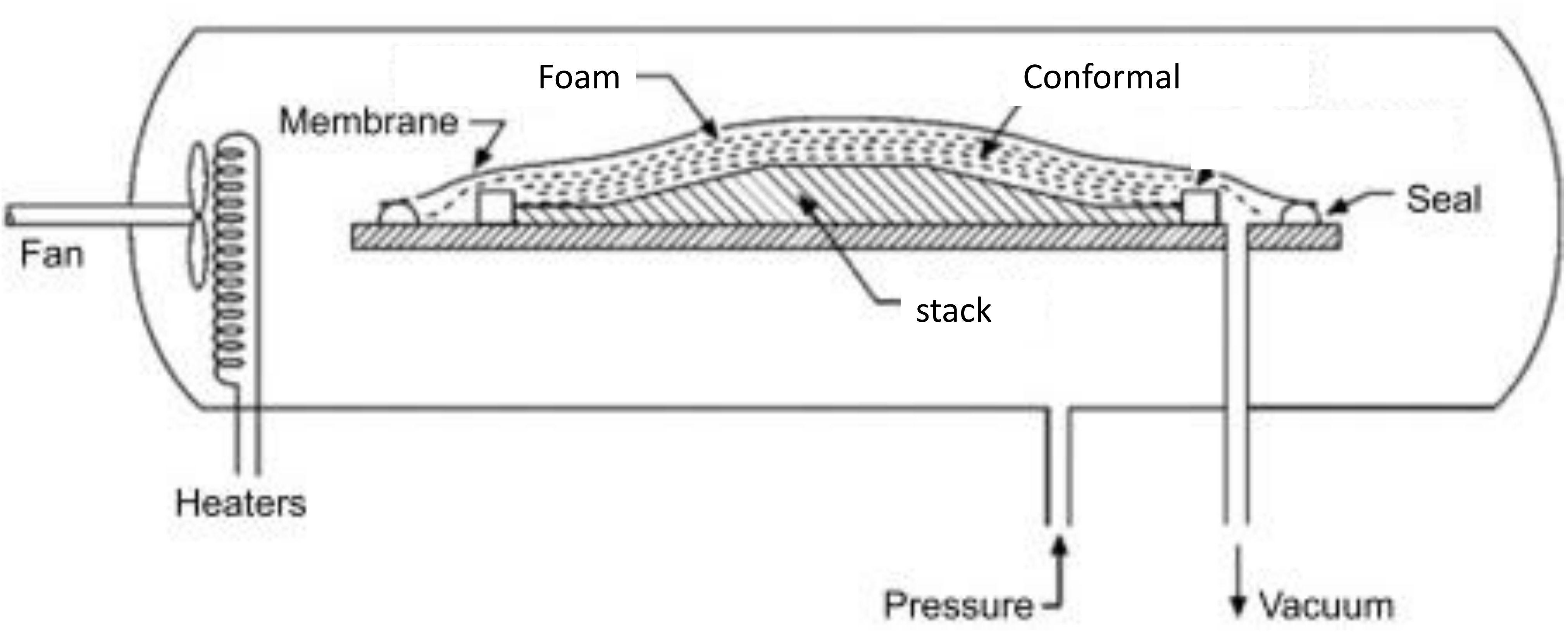


Typical Flex stack



Configuration to avoid glue bleeding

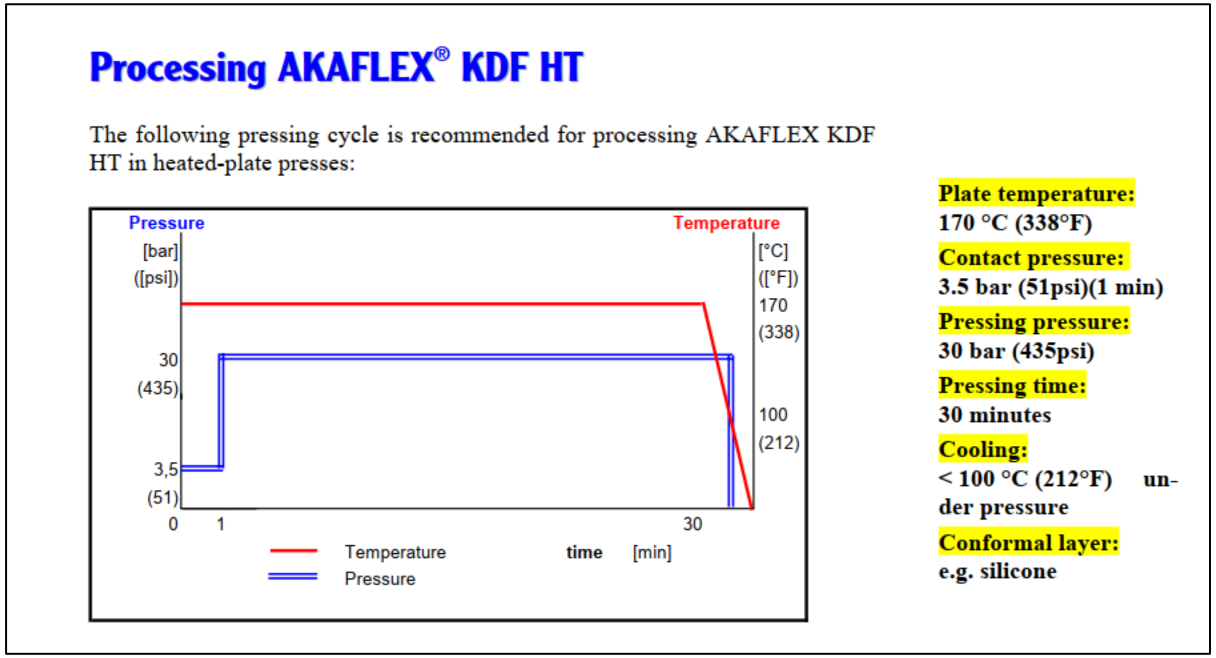
Autoclave configuration



Curing cycle

PrePreg

Cast



Processing AKAFLEX® KDF HT

The following pressing cycle is recommended for processing AKAFLEX KDF HT in heated-plate presses:

Plate temperature:
170 °C (338°F)

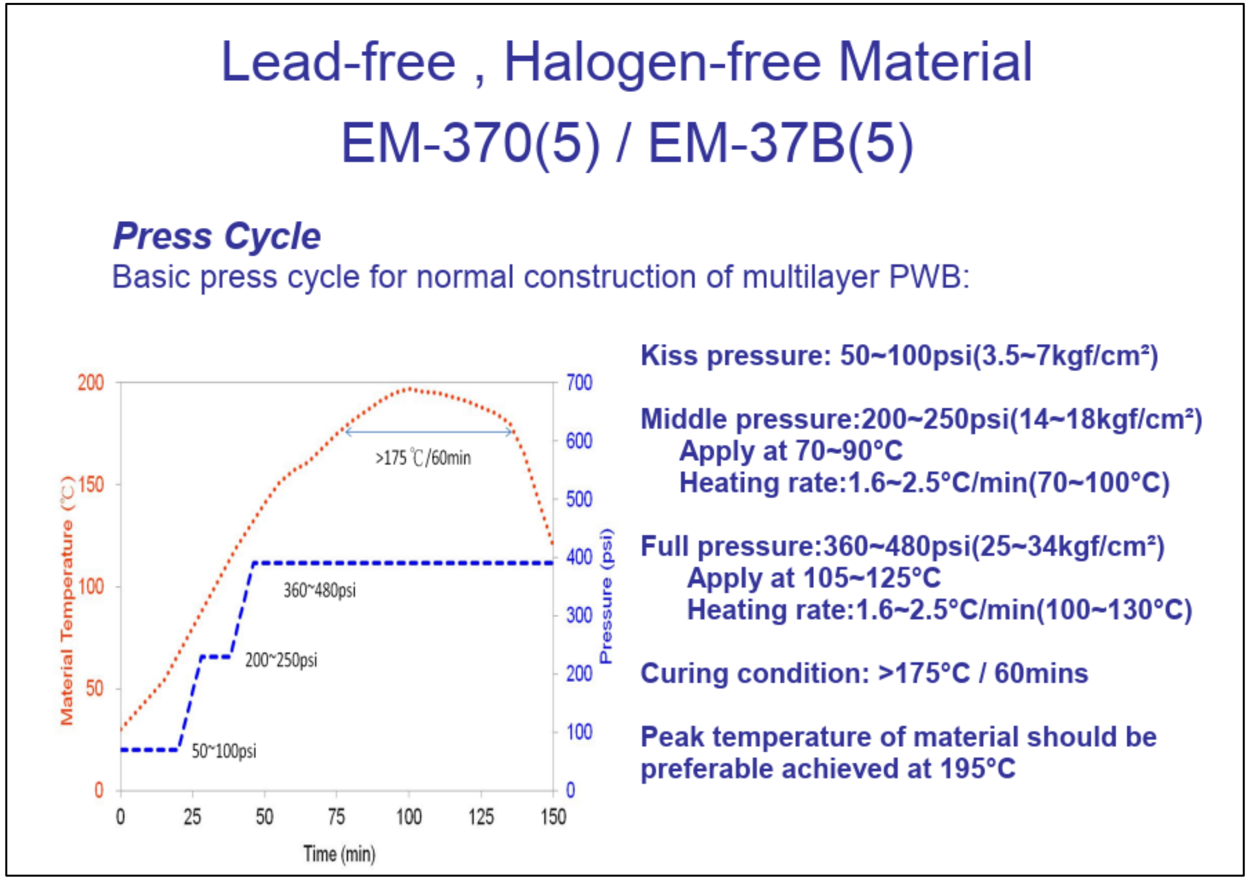
Contact pressure:
3.5 bar (51psi)(1 min)

Pressing pressure:
30 bar (435psi)

Pressing time:
30 minutes

Cooling:
< 100 °C (212°F) under pressure

Conformal layer:
e.g. silicone



Lead-free , Halogen-free Material
EM-370(5) / EM-37B(5)

Press Cycle

Basic press cycle for normal construction of multilayer PWB:

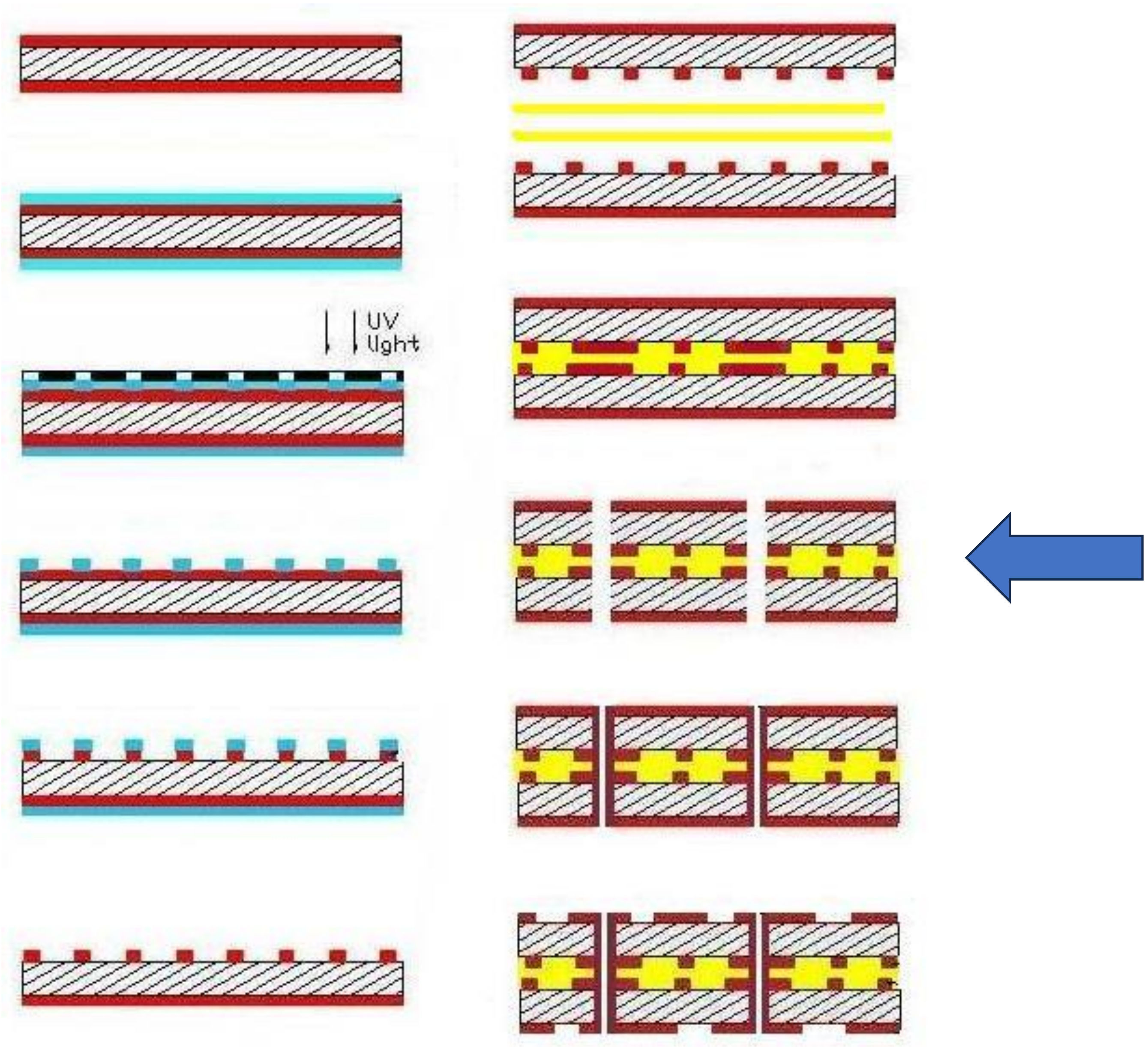
Kiss pressure: 50~100psi(3.5~7kgf/cm^2)

Middle pressure:200~250psi(14~18kgf/cm^2)
Apply at 70~90°C
Heating rate:1.6~2.5°C/min(70~100°C)

Full pressure:360~480psi(25~34kgf/cm^2)
Apply at 105~125°C
Heating rate:1.6~2.5°C/min(100~130°C)

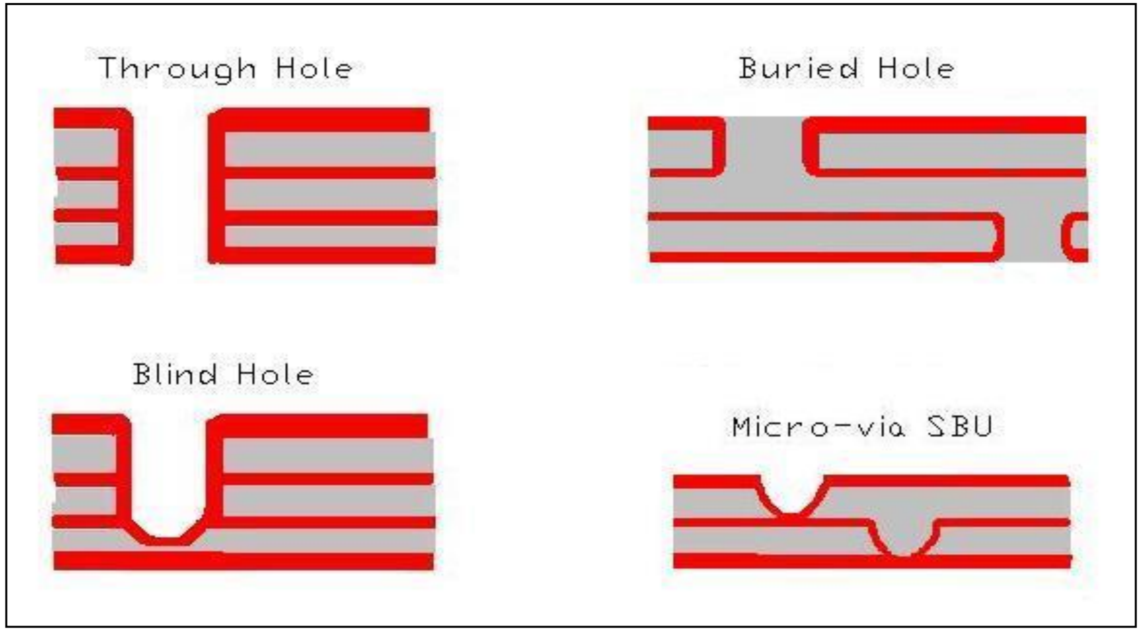
Curing condition: >175°C / 60mins

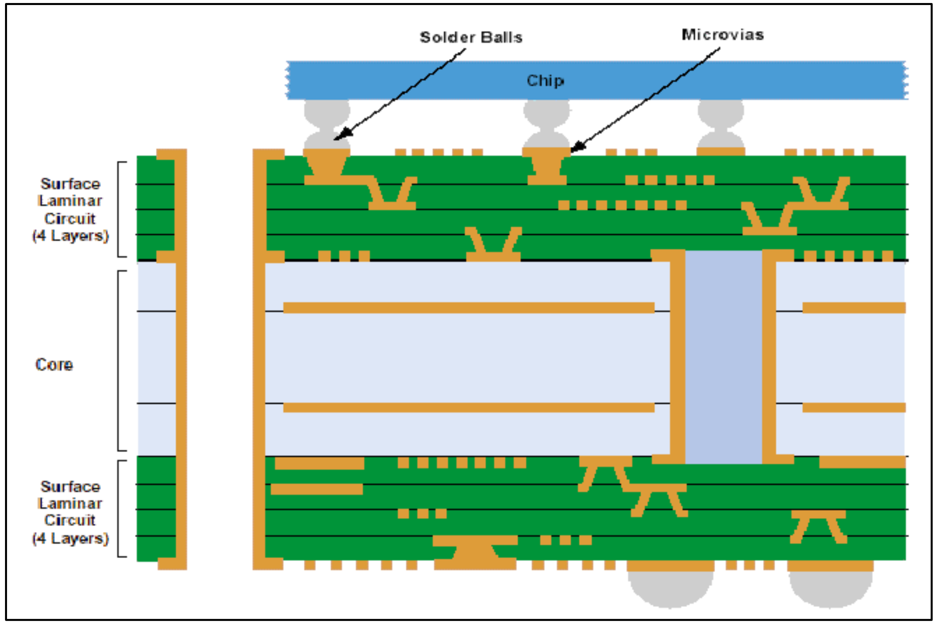
Peak temperature of material should be preferable achieved at 195°C



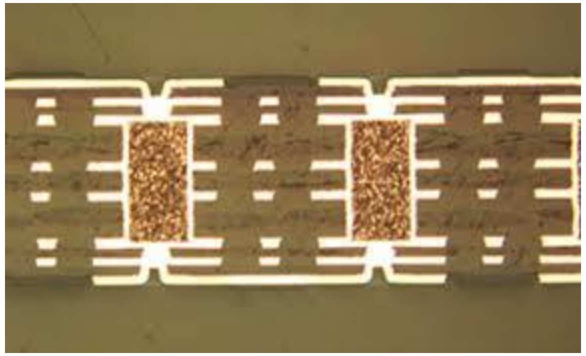
Drilling

Different type of holes





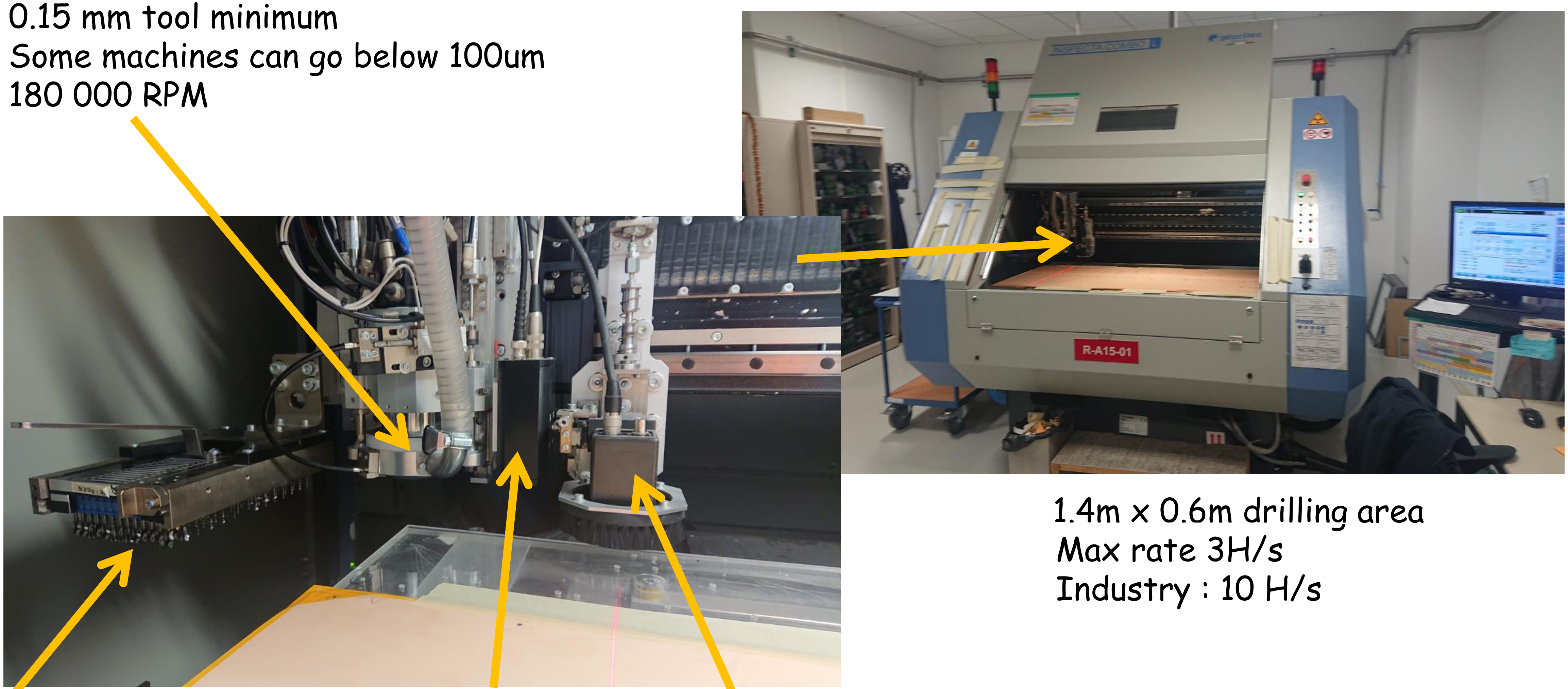
8 layers staggered vias



8 layers stacked vias

Mechanical drilling

Spindle
0.15 mm tool minimum
Some machines can go below 100um
180 000 RPM



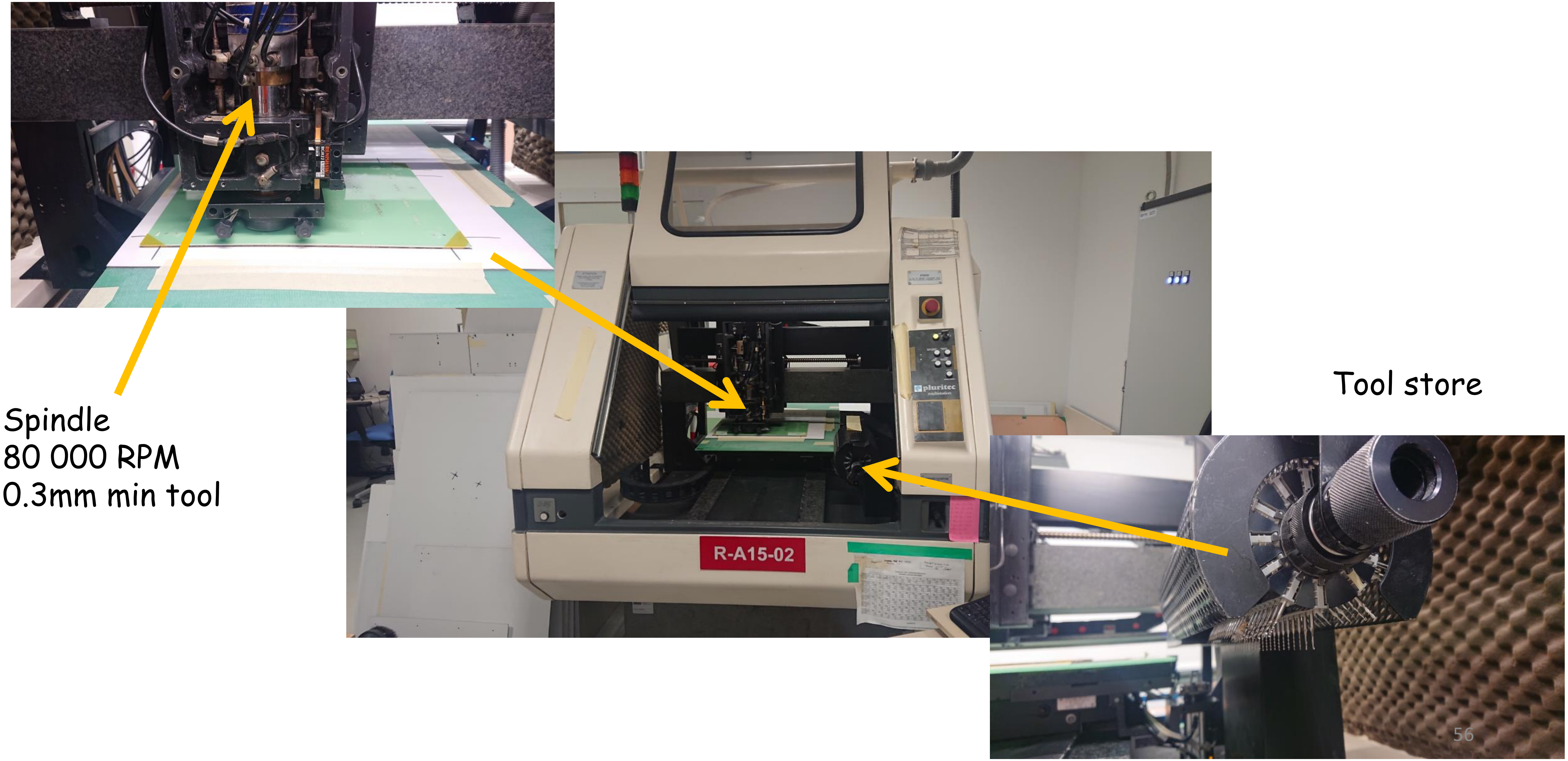
1.4m x 0.6m drilling area
Max rate 3H/s
Industry : 10 H/s

Tool store

Optical camera

Xray Camera

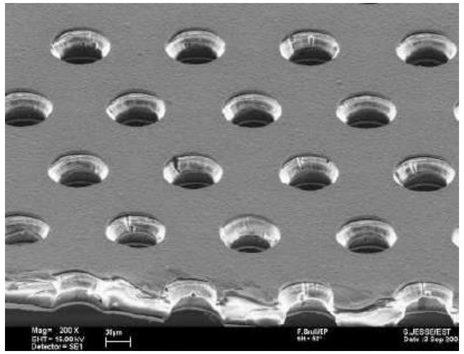
Mechanical Milling



Spindle
80 000 RPM
0.3mm min tool

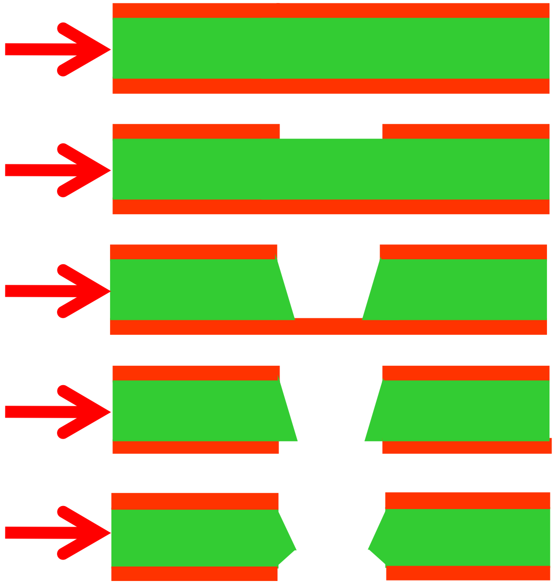
Tool store

Chemical drilling → GEM

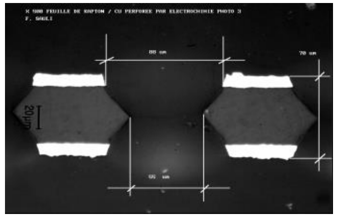


- Base material : Polyimide 50um + 5um on both sides

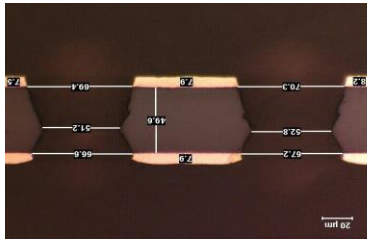
- Double mask
- Single mask



- Same base material
- Hole patterning in Cu
- Polyimide etch
- Bottom electro etch
- Second Polyimide Etch



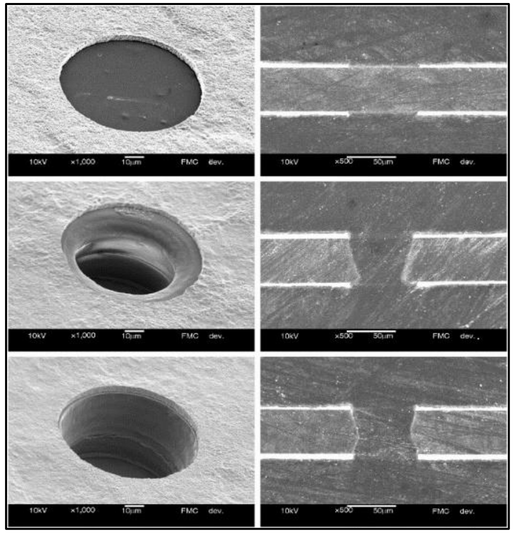
- Limited to 40cm x 40cm due to:
  - The 2 masks alignment precision
  - And Glass mask cost
- 30um hole minimum



- Limited to 2m x 60cm due to:
  - Base material
  - Equipment
- 30um holes minimum

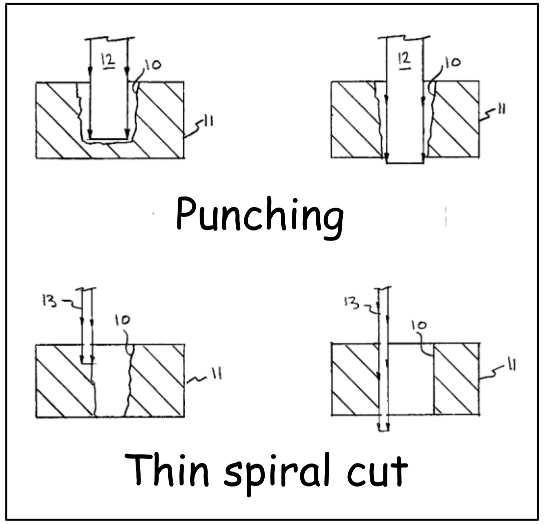
Laser or plasma drilling

CO2 laser



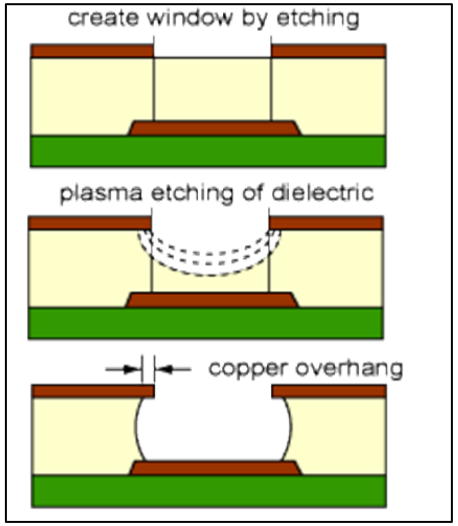
- -Many possible base Materials.
- -Holes perfectly clean.
- -Small patterns
- -30um holes
- -Not competitive with Wet drilling

UV laser



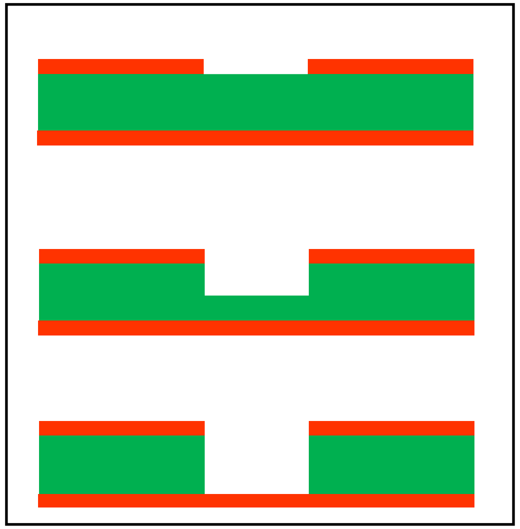
- -Many possible base Materials.
- -Machines can drill both metals and polymers
- -20um holes
- -Not yet competitive with Wet drilling

RIE Plasma



- -Moderate machine cost .
- -Holes perfectly clean
- -50um holes
- -Not uniform on large size.
- -Isotropic Etching

DRIE Plasma

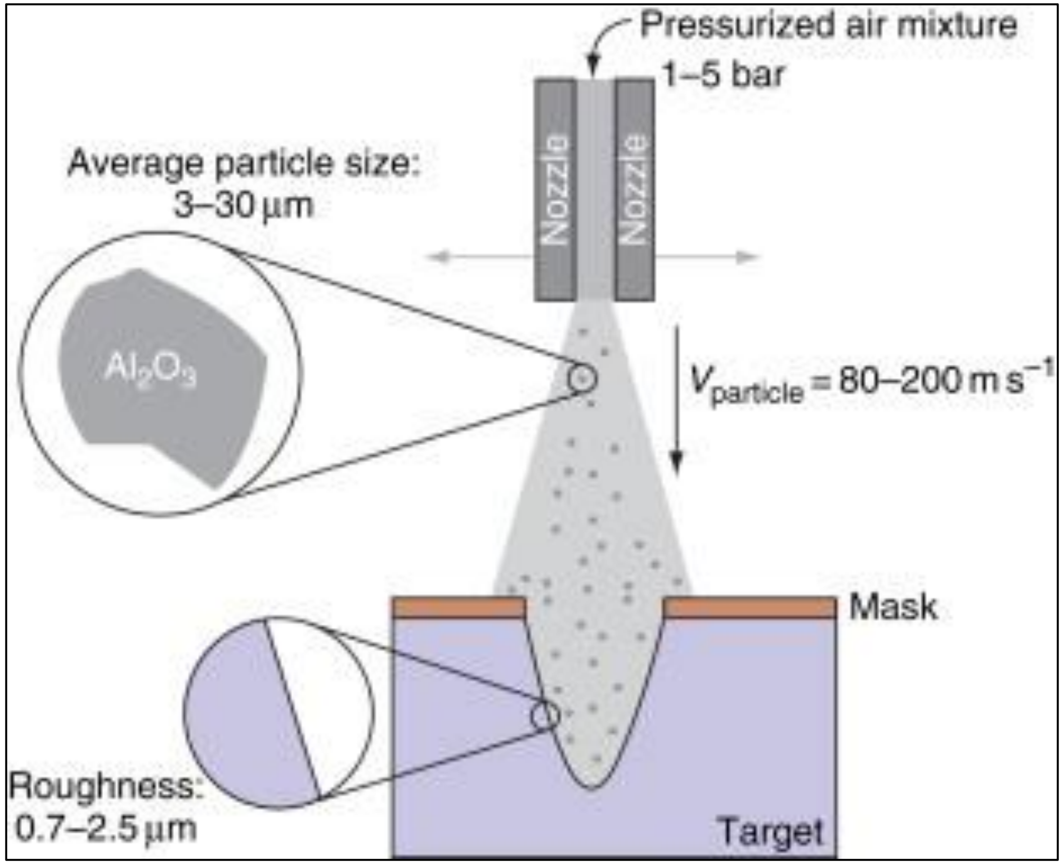


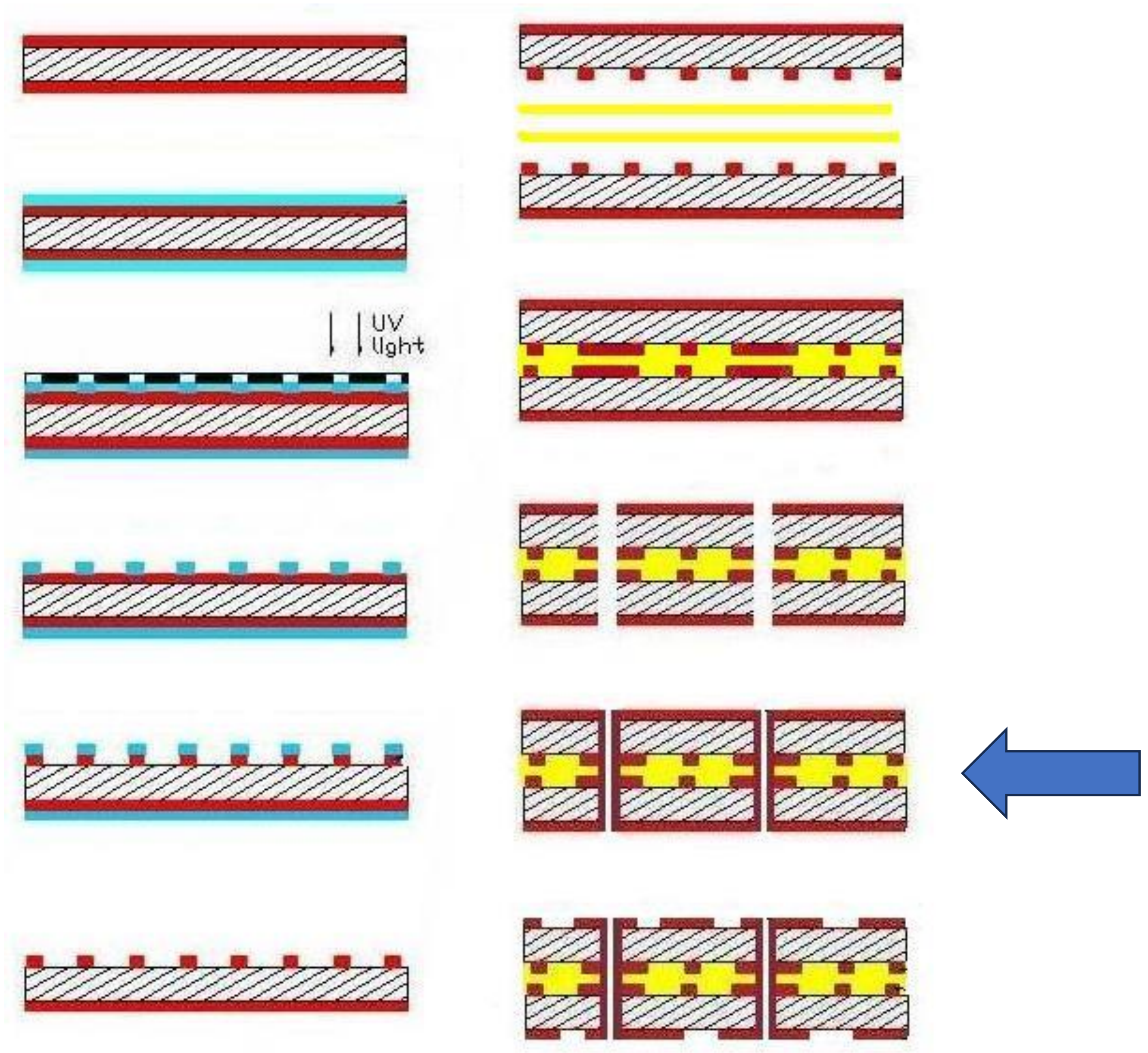
- -Perfect cylindrical holes.
- -Holes perfectly clean
- -Ultra precise patterns
- -20um holes
- -limitation on size : dia 20cm max.

Sand blast drilling

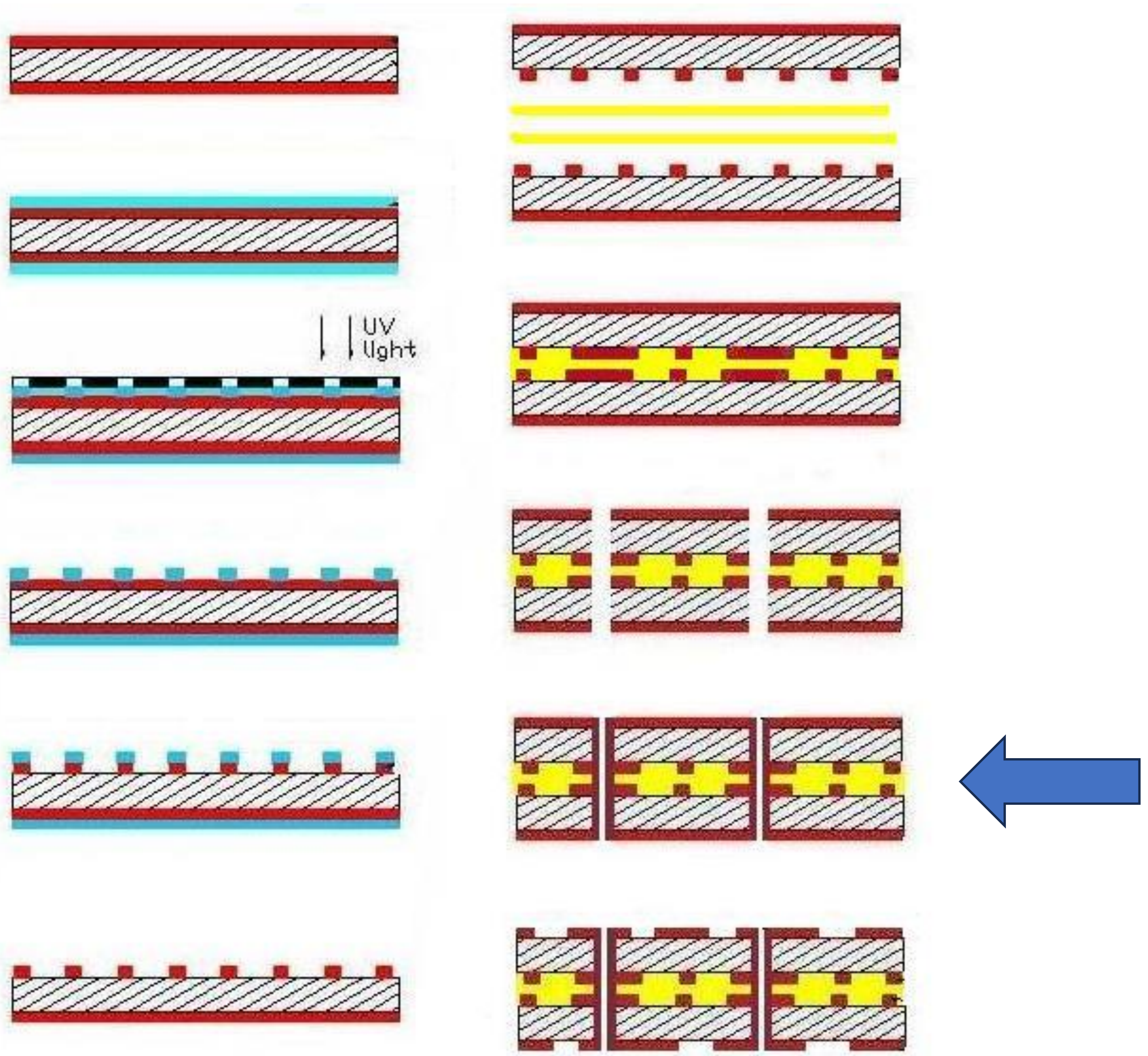
Anisotropic etching
Can treat nearly all materials
Smooth walls

Millimetric scale patterns





Plating



Plating
Electro-plating
Electroless plating
Vacuum plating
Screen printing

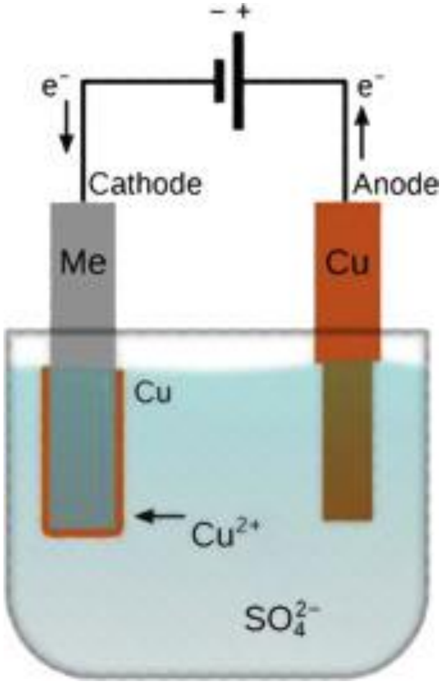
Dielectric treatment before Electro-plating

Deasmear line:
Sweller
+ Potassium permanganate

Carbon line:
Detergent
Carbon full covering
Micro-etch to remove Carbon on Copper

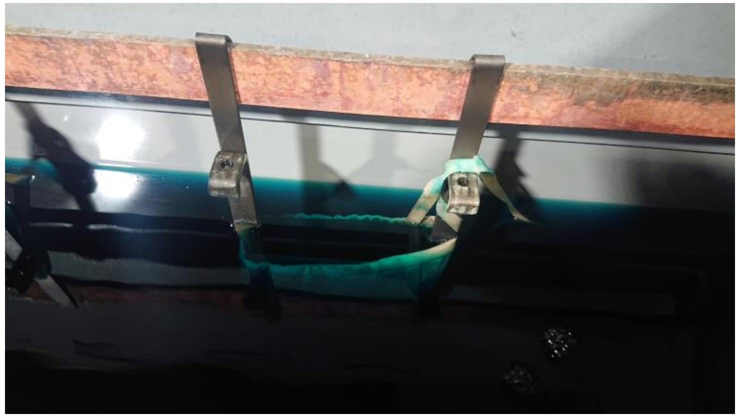
- 1/Deasmear
  - Remove the dust in holes
  - Remove material burnt by drilling
  - Come back to fresh dielectric
- 2/Deposit conductive material on dielectric:
  - Nano Carbon deposition
  - Or organic Palladium

Electro plating

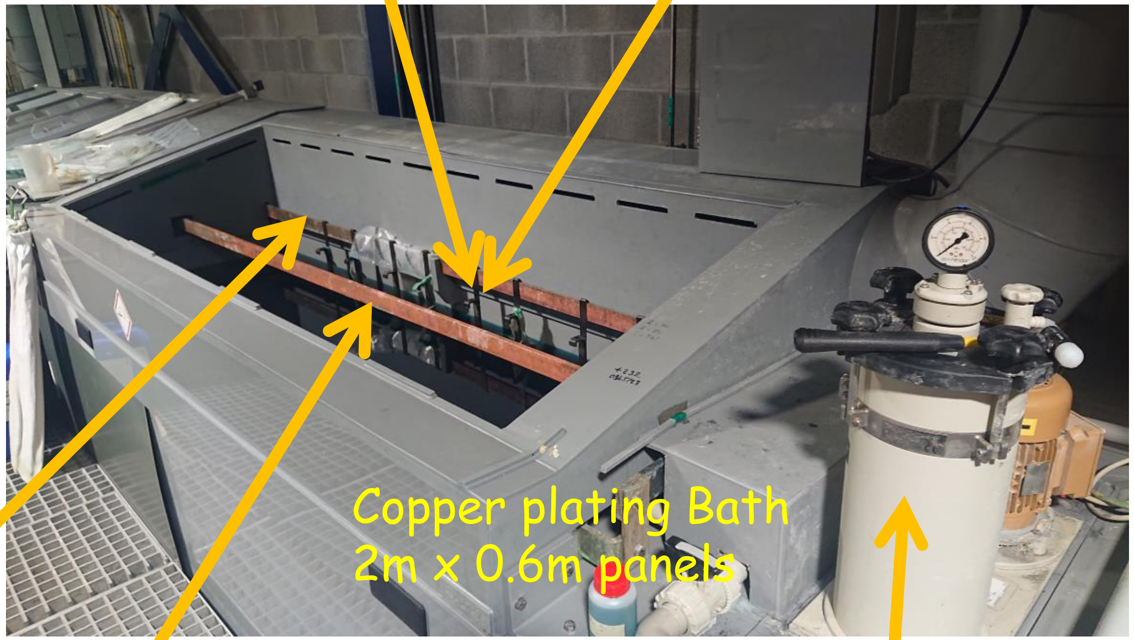


- CU
- NI
- Au

Solid piece



Basket with copper balls



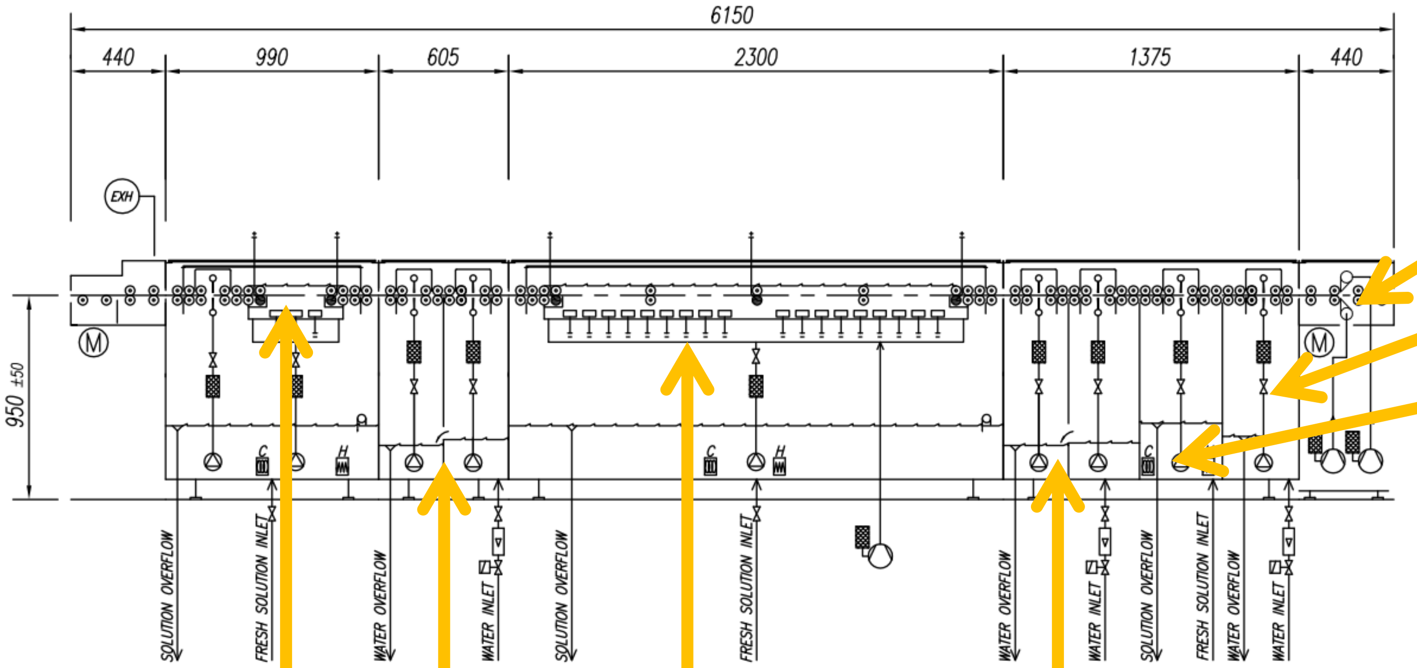
Copper plating Bath
2m x 0.6m panels

Anode

Cathode

Filter/pump

Horizontal Ni or Cu or Ni/Cu line continuous deposition



Dry → Blower

Rince → Spray

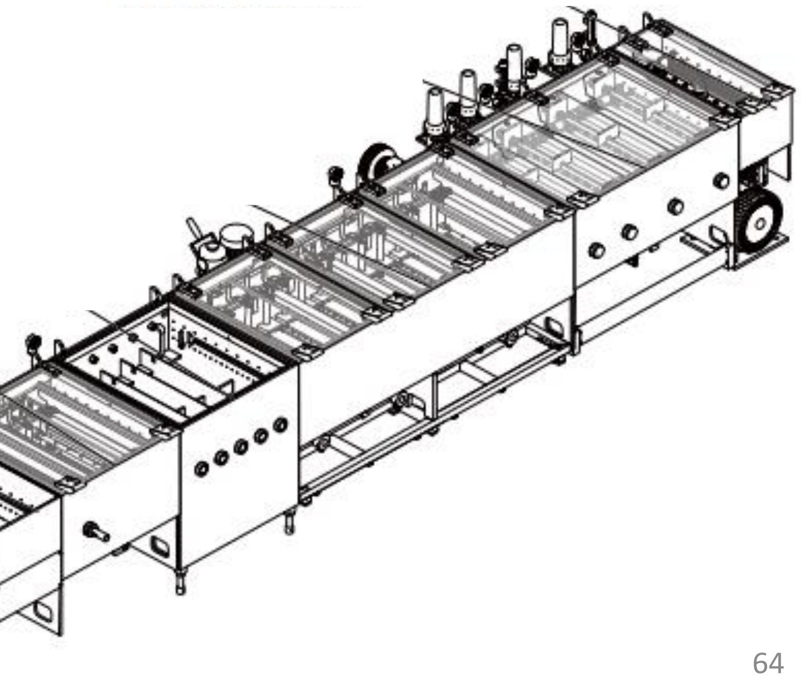
Passivation → Spray

Ni Bath horizontal

Cascade Rince spray

Cu Bath Horizontal

Cascade Rince spray



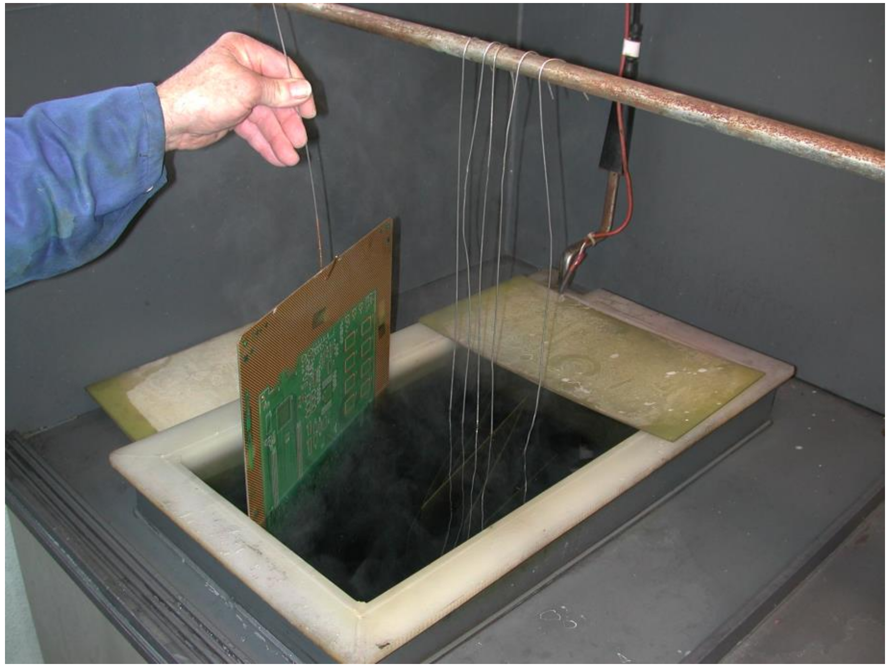
Electro-less plating

- Protect copper from oxidation
- Guaranty an easy soldering
- Allow Aluminum or Gold wire Bonding

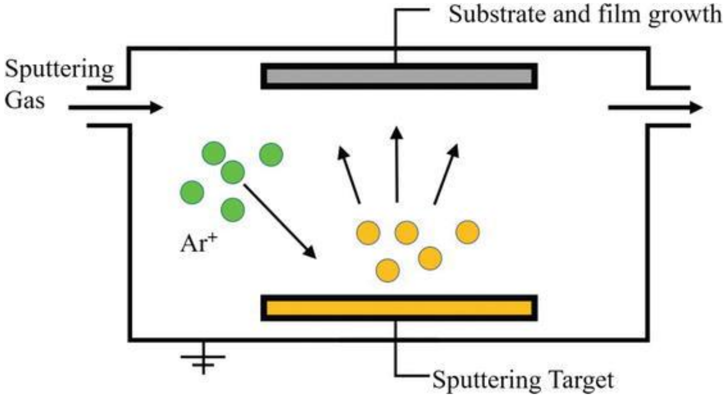
ENIG : Electroless nickel (5um) , Immersion Gold (0.07um)
ENEPIG: Electroless nickel , electroless Palladium , Immersion Gold
Ag: Chemical silver less than 1um
Tin: Chemical Tin

Immersion Au

Electroless Ni



Vacuum plating



Pulsed DC Magnetron vacuum deposition machine

70cm copper target

Drum unloading after processing

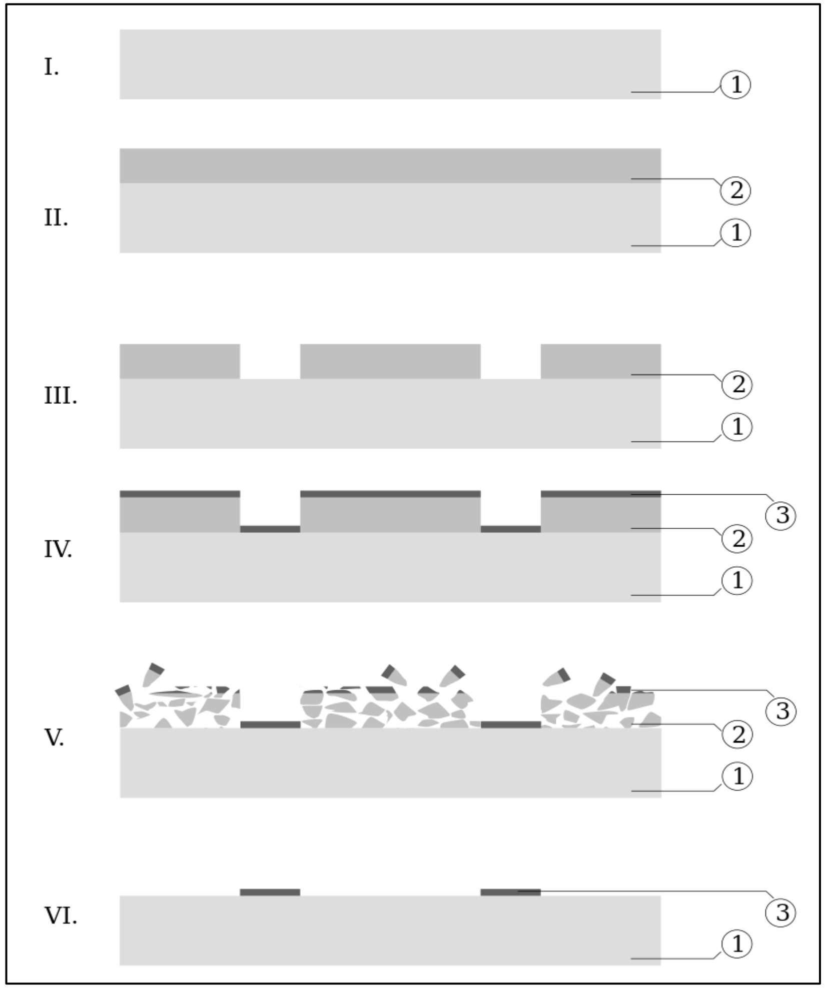
Possibilities

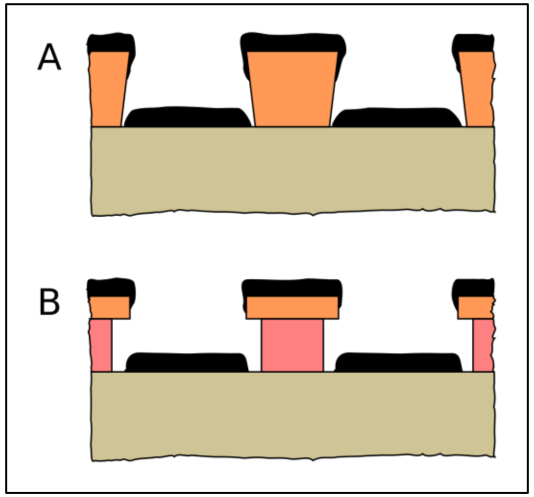
- Deposited Materials.
  - Metals : Cu , Al ,Cr
  - Resistive materials DLC, Si
  - Converters B4C
- Possibility to co-deposit 3 materials.
- Possibility to sequentially deposit 3 materials.
- Built in heater.
- RF plasma cleaning.
- 3 gas inputs for reactive sputtering.
- Can treat flex or rigid substrates.

Applications

- Inner trackers
  - Low mass flexes, Al conductors.
  - Solid-state detectors embedded in flex.
- MPGD
  - Resistive protection layers.
  - Layers for neutron detection.
  - Photoelectric layers

Thin film deposition→ Lift Off



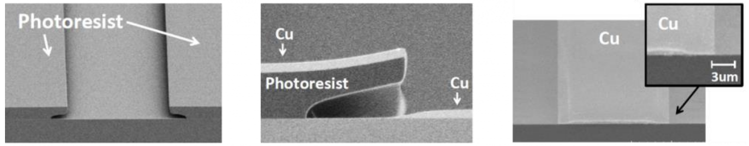


L:S 2.73µm:1.27µm

L:S 2.14µm:1.06µm

L:S 1.56µm:0.84µm

L:S 1.29µm:0.71µm



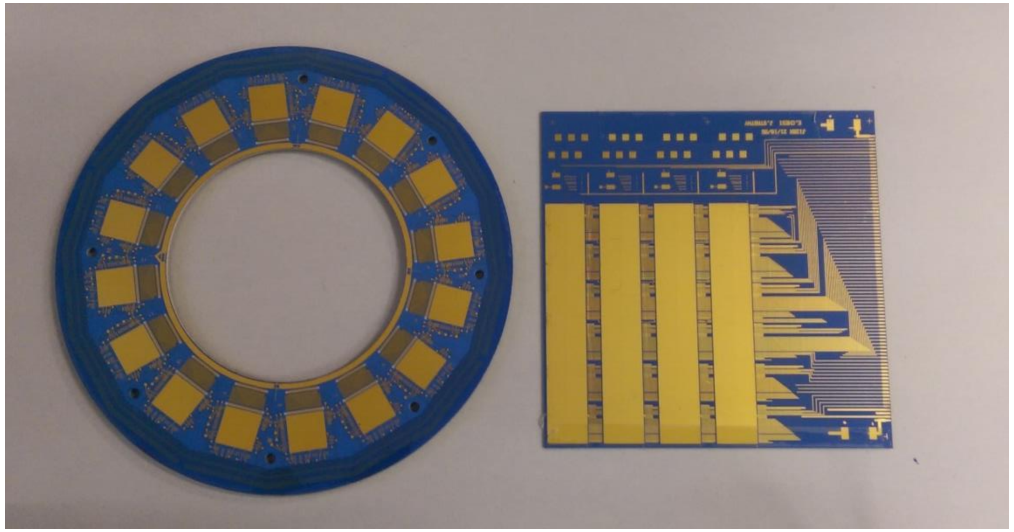
Post lithography

Post sputtering

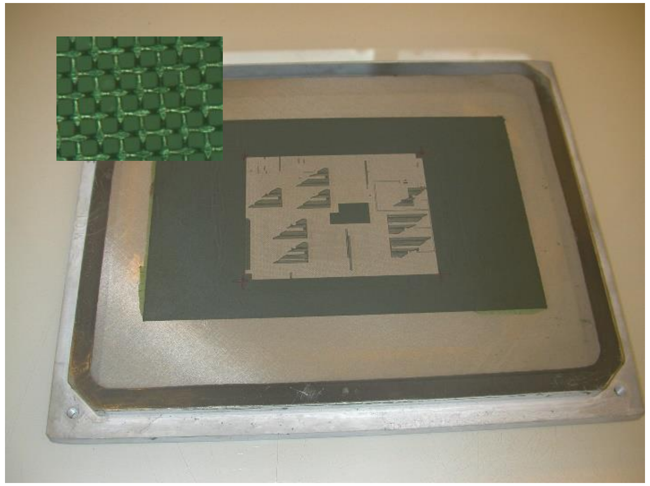
Post stripping

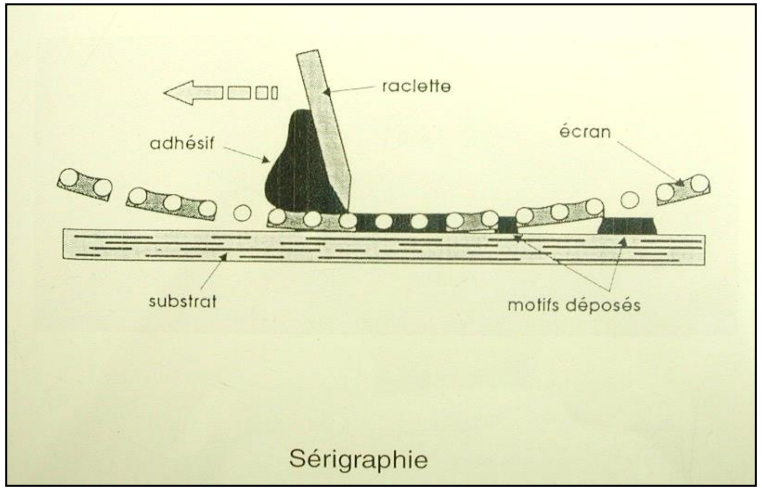
Thick Film Printing

High density
High Thermal Conductivity
Low Vacuum compatible

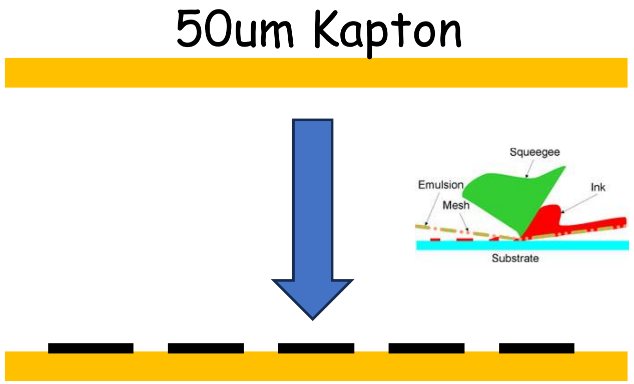


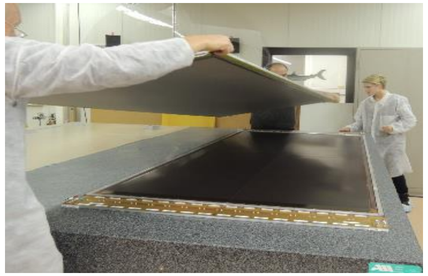
Conductive Layers: noble metals
Dielectrics : Ceramic
Sequential deposits by screen printing
Followed with 850 Celsius curing





Resistive materials deposition

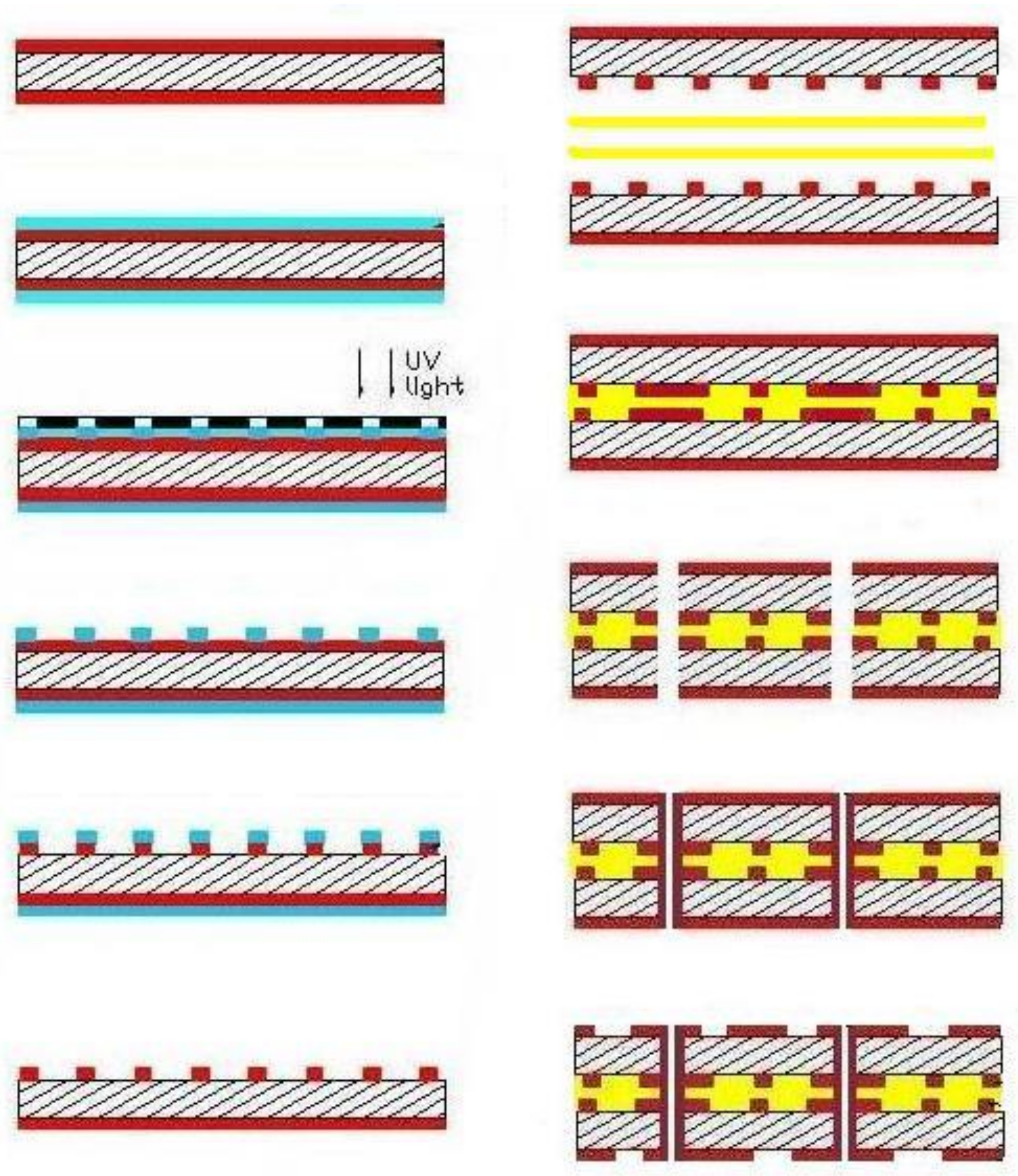

50um Kapton


ATLAS
NSW

Direct screen printing
with resistive paste

Full layer deposition

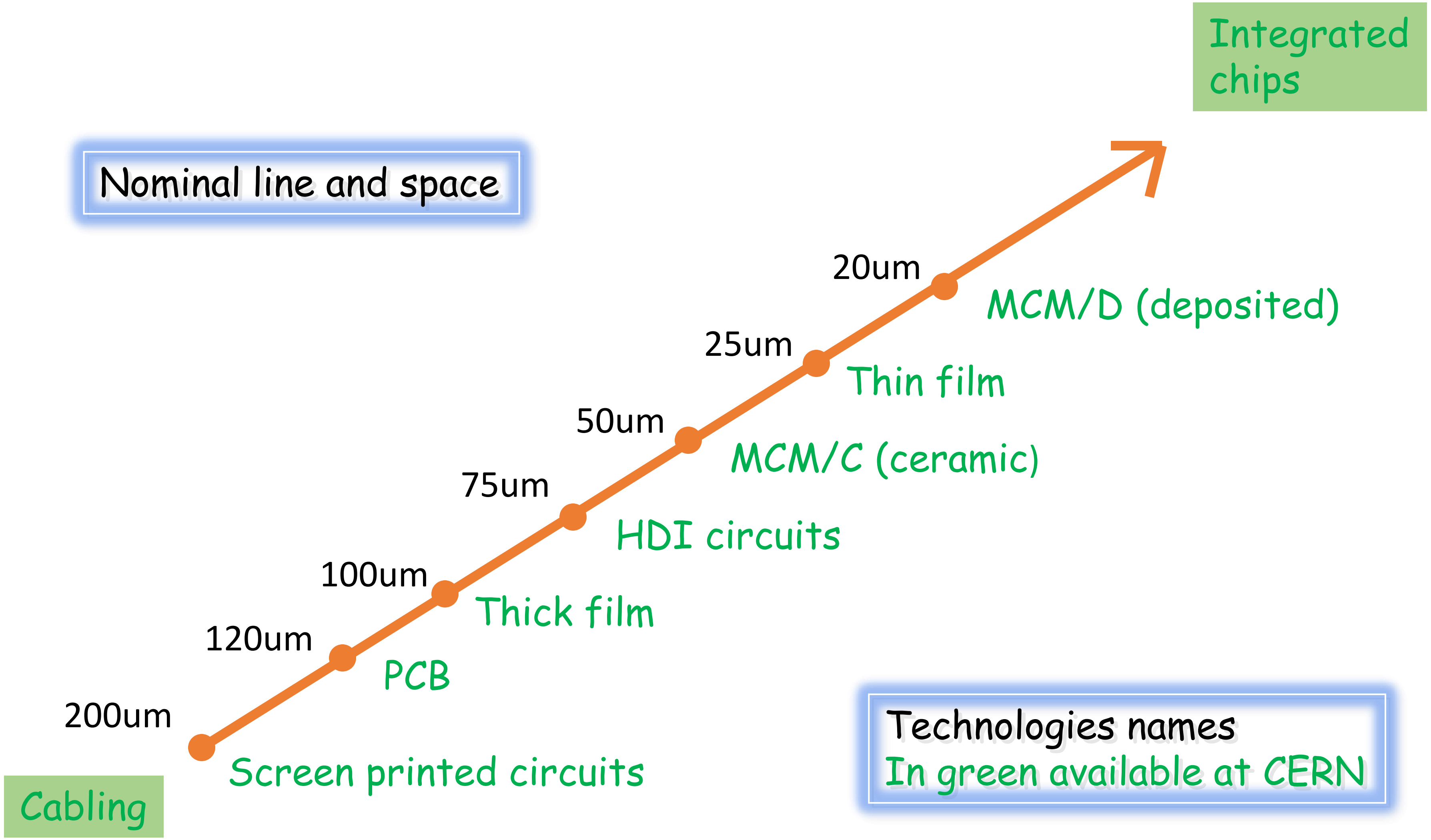
Pattern DLC with :
- -sand blasting
- -lift Off



End of production
or back to the beginning

Examples

Interconnection technologies names



Nominal line and space

Technologies names
In green available at CERN

Cabling

200um
Screen printed circuits

120um
PCB

100um
Thick film

75um
HDI circuits

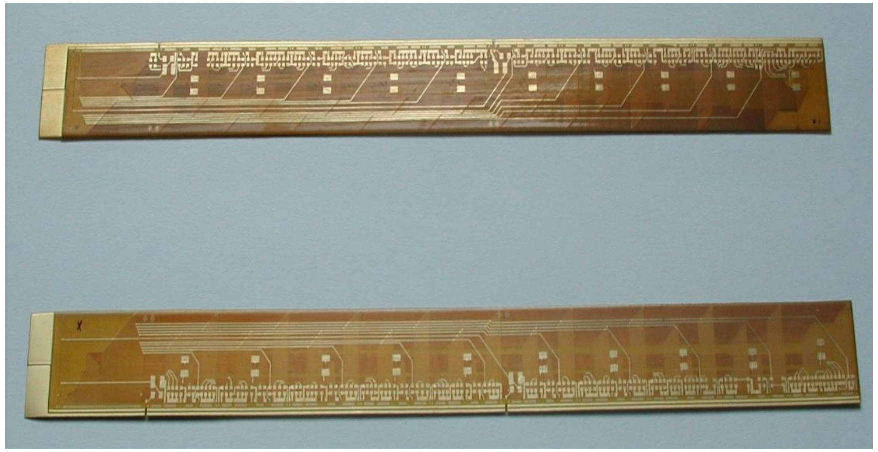
50um
MCM/C (ceramic)

25um
Thin film

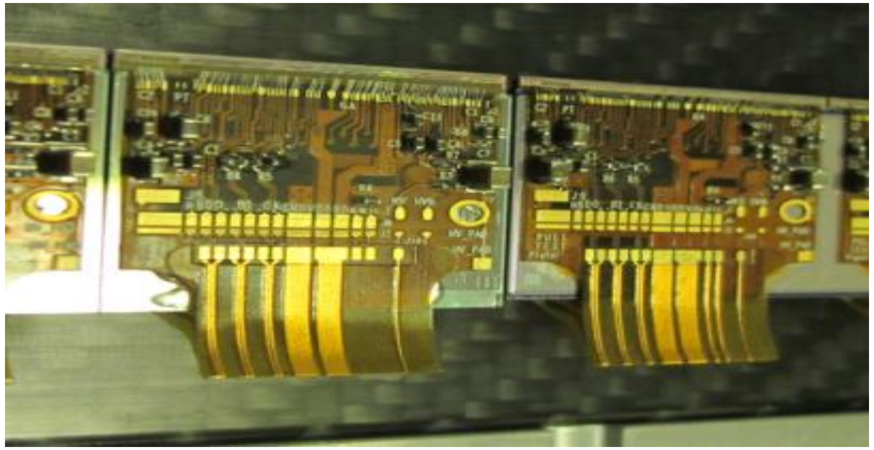
20um
MCM/D (deposited)

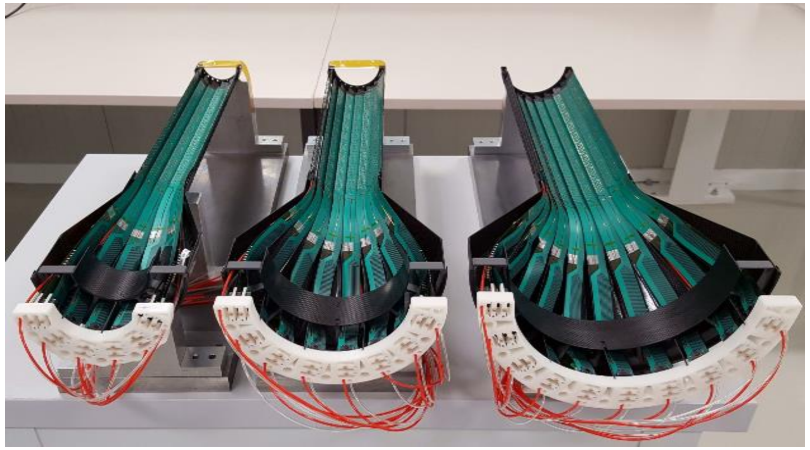
Integrated chips

Inner Trackers → Low Mass Aluminium circuits

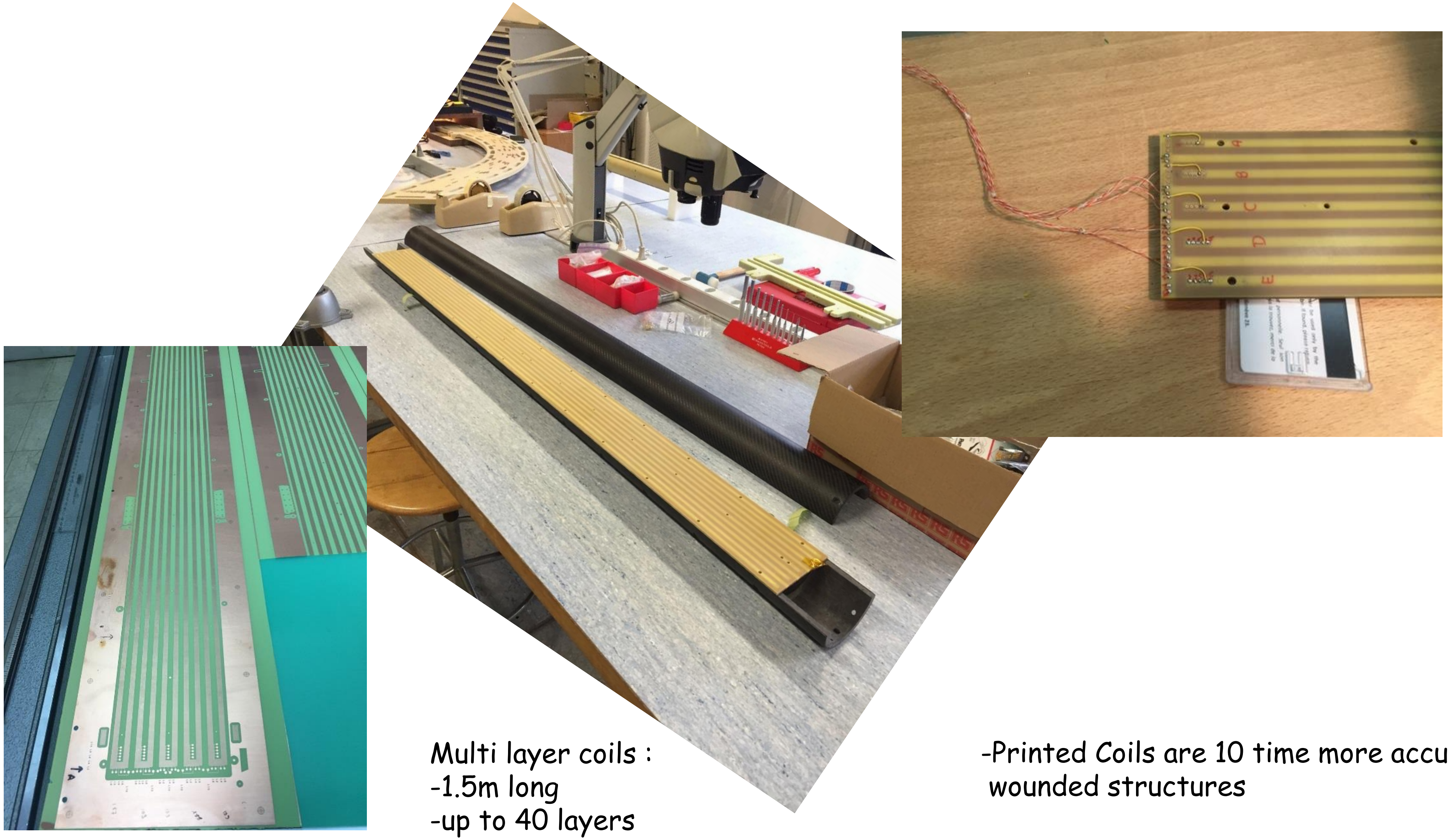

ALICE inner tracker BUS (5 Aluminum layers)


Double-sided flex for ILC Vertex sensor


ATLAS IBL Low Mass 8 layers


ALICE inner tracker

Magnets calibration → ultra precise field sensors

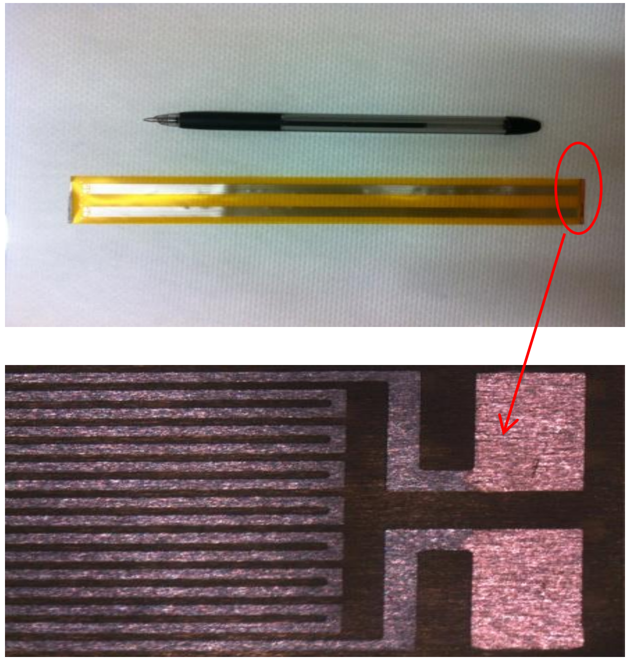


Multi layer coils :
-1.5m long
-up to 40 layers
-30um maximum registration error
-Line and space down to 50um/50um

-Printed Coils are 10 time more accurate than wounded structures

LHC machine protection

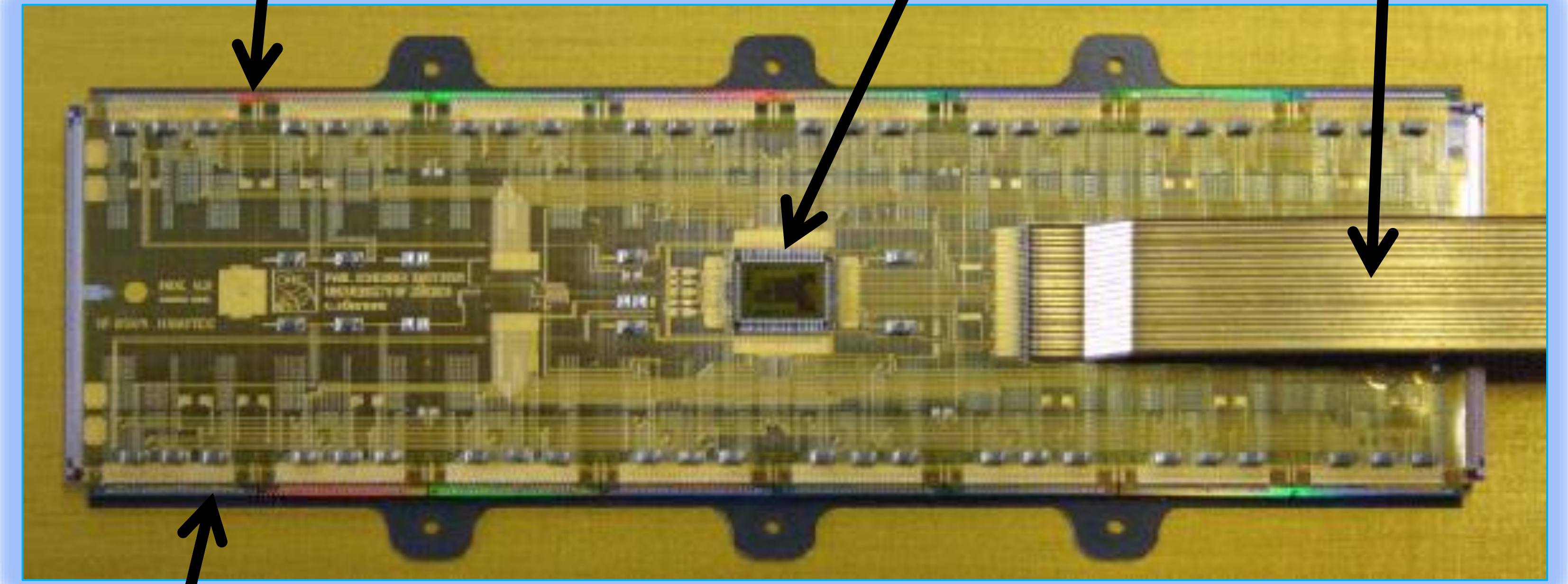
Stainless steel or SS/Cu mix Quench Heaters
Long flexes up to 15m x 0.6m



Niobium Titanium supraconductor quench detector.

Others:
-Heating foils
-High power resistors
-Optical targets for UHV
-etc..

HDI for ATLAS pixel detectors



Silicon pixel detector below

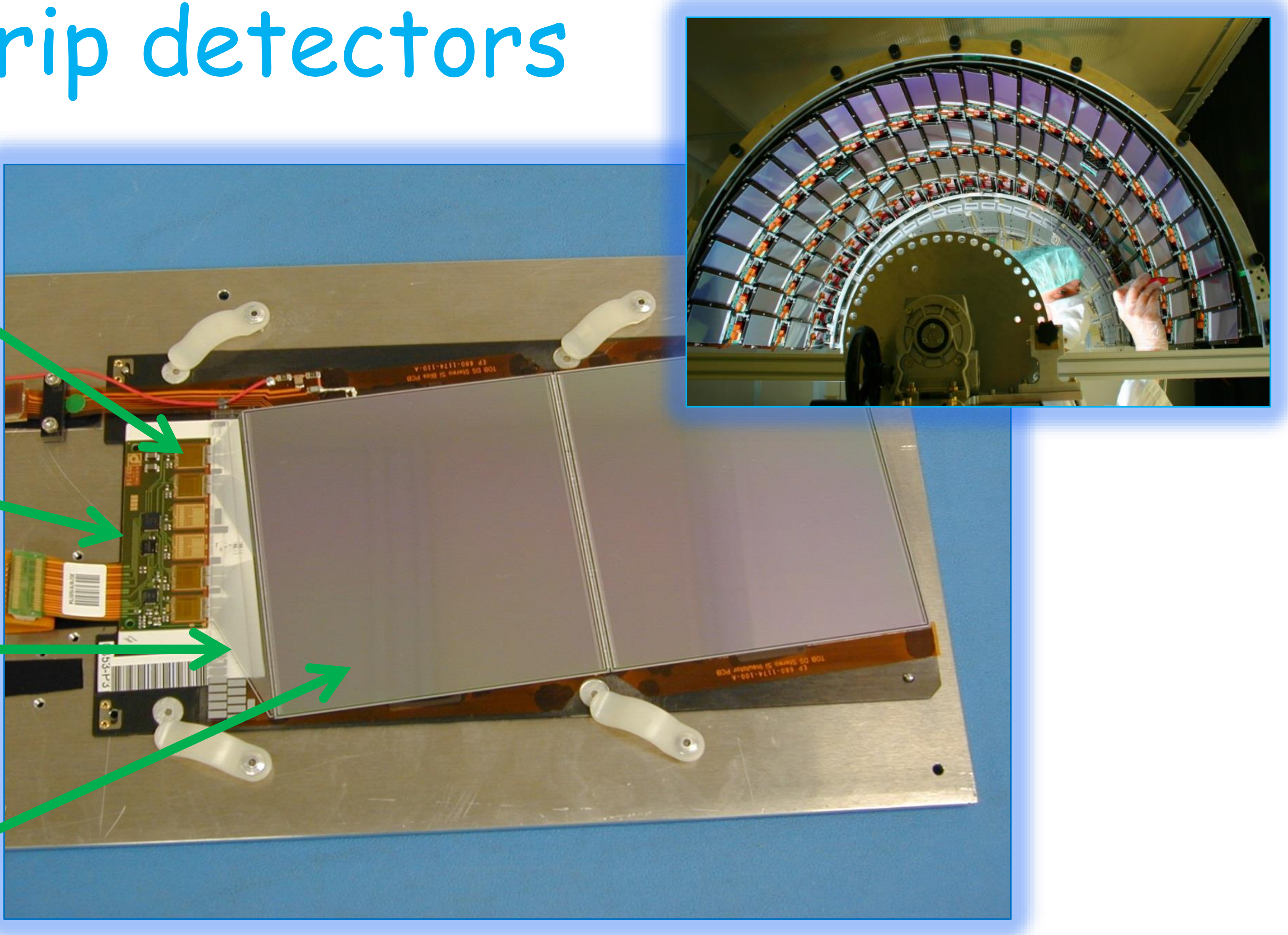
control chip

Output bus

bonding

Size in the range of 8cm x 2cm

HDI CMS strip detectors



Front end Asics

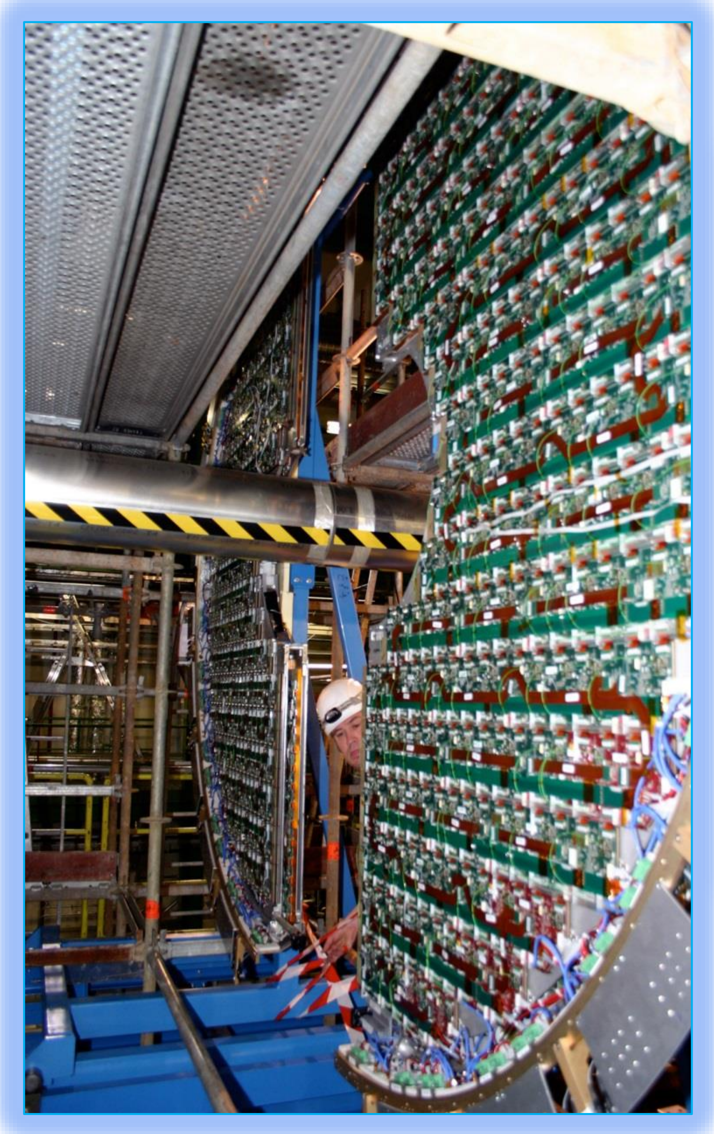
Rigid flex

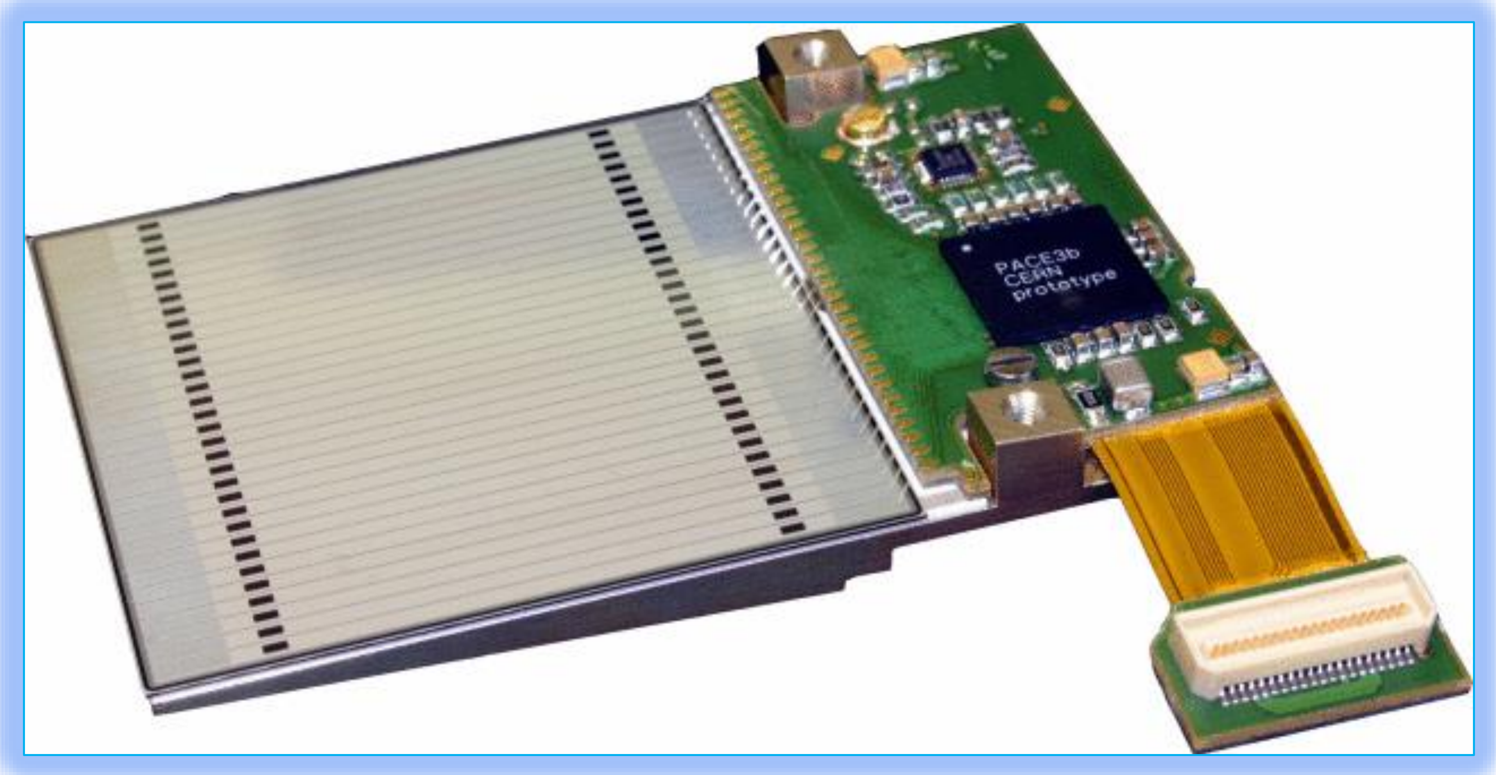
Glass pitch adaptor

Silicon strip detector

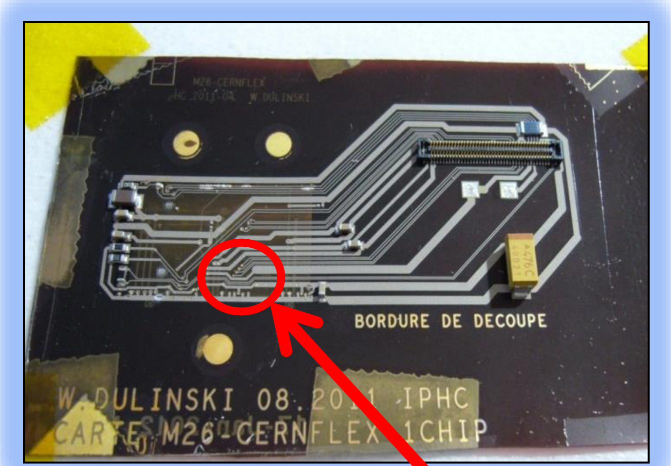
Size in the range of 10cm x 20cm

PCB for CMS Pre-shower

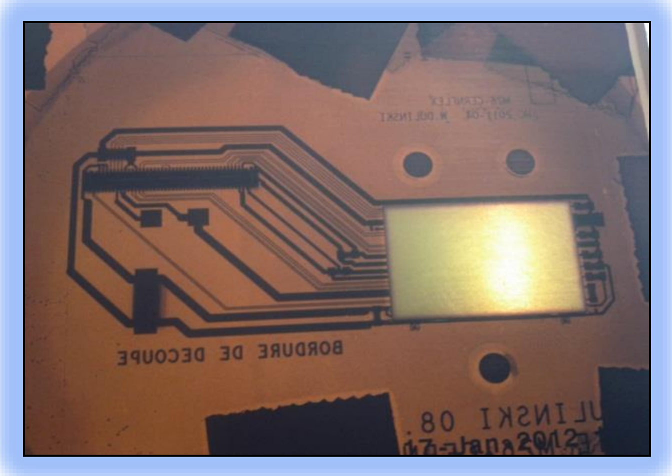




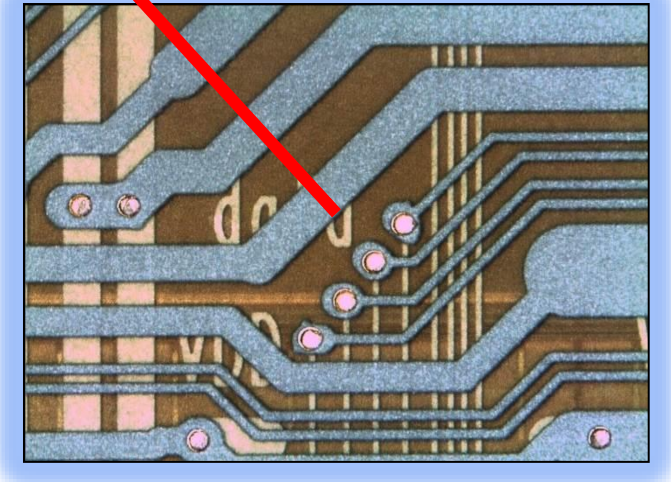
Full Aluminium flex with embedded silicon detector (R&D)



Top

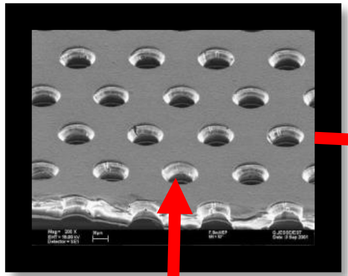


bottom



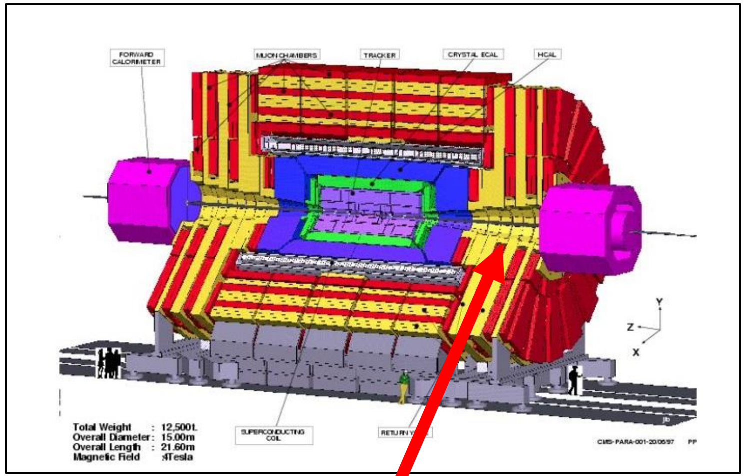
Thinned chip 50um
100um thick end device
Full aluminium
No bonding

CMS GEM with single Mask

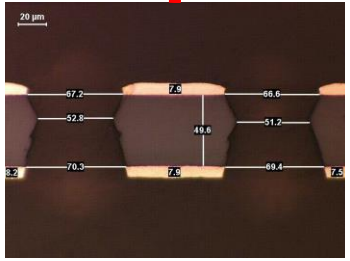


Microscopic view

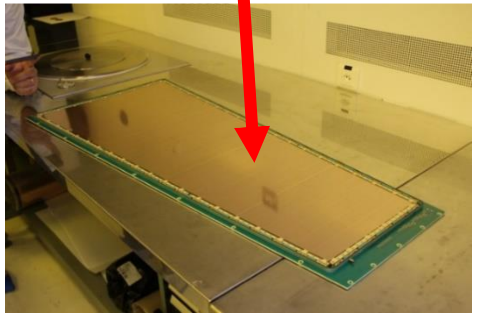
Single mask GEM



CMS experiment

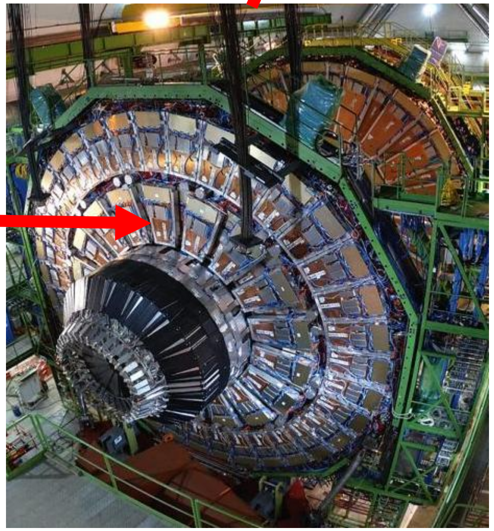


Cross section



Triple GEM stack

GE1/1 Muon detector



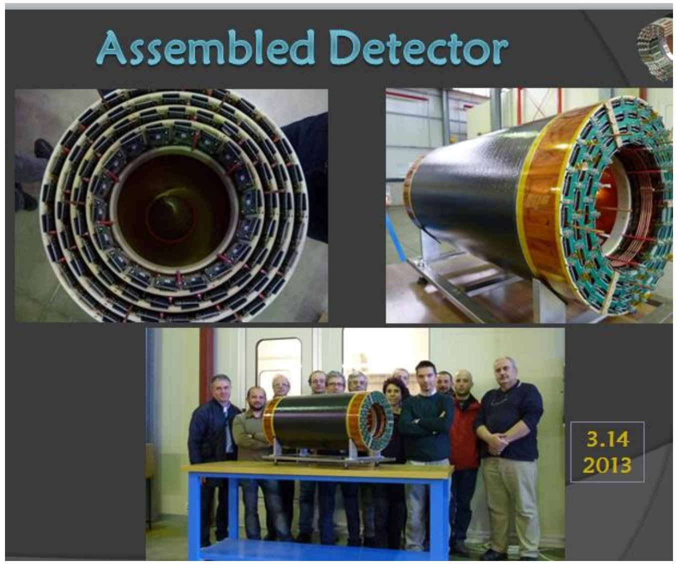
CMS nose

GE1/1 → 400 GEM (1.3m x 0.5m) made at CERN
GE2/1→ 1000 GEM (1.3m x 0.5m) CERN/Korea

GEM producers' capabilities:
-CERN MPT : 500m2/year
-Mecaro Korea : 250m2/year

Other detectors with GEM single mask technique

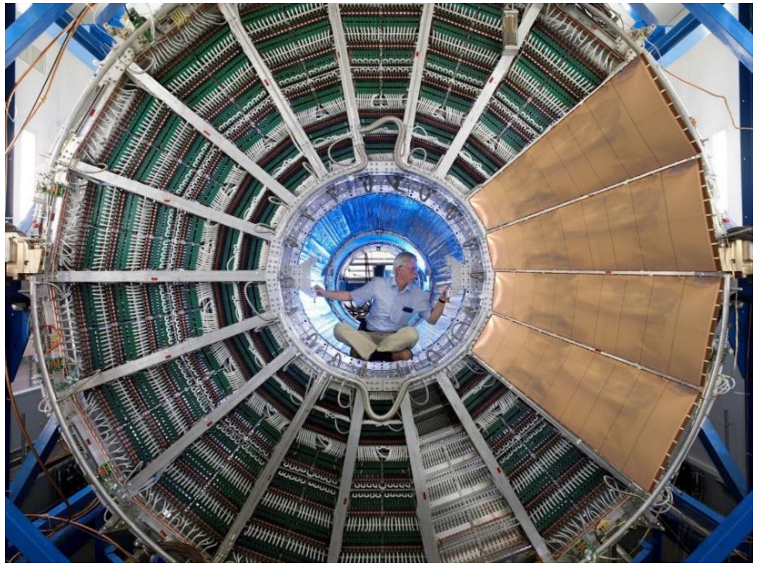
Future CMS ME0 → 1000 GEMs



Assembled Detector

3.14 2013

KLOE – Cylindrical Detector



ALICE TPC → 700 GEM

And many more

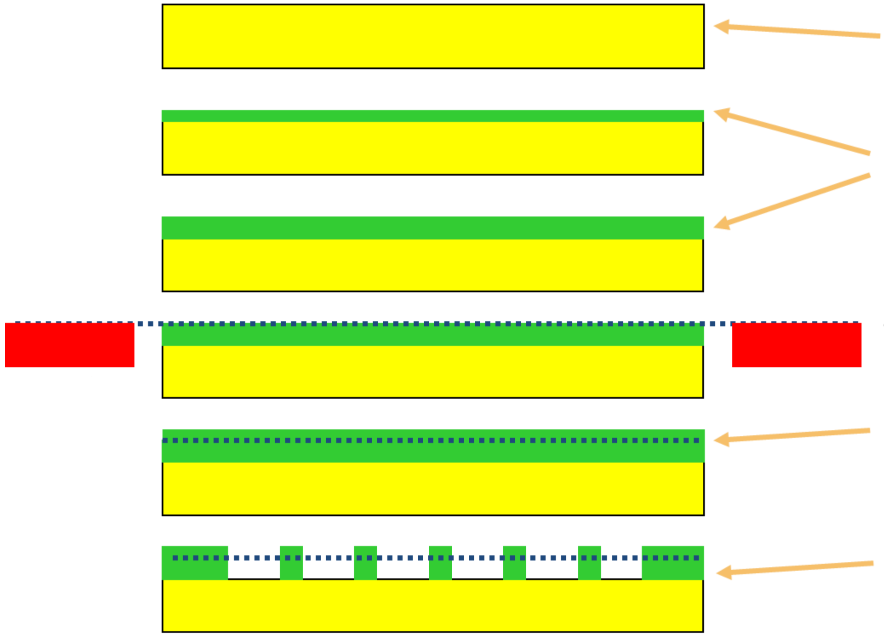
-BM@N in Dubna (1.6m x 0.5m)
-SBS tracker Jefferson lab
-CBM at Fair
-BESIII China

-SOLID
-BONUS 12
-P-RAD
-S-Phenix TPC

-COMPASS upgrade
-GEM for nuclear physics TPCs
-ESS for neutron detectors
-and lot of small GEMs for academic purpose

BULK and Floating mesh Micromegas detectors

BULK Micromegas



Read-out board
with Cu strips

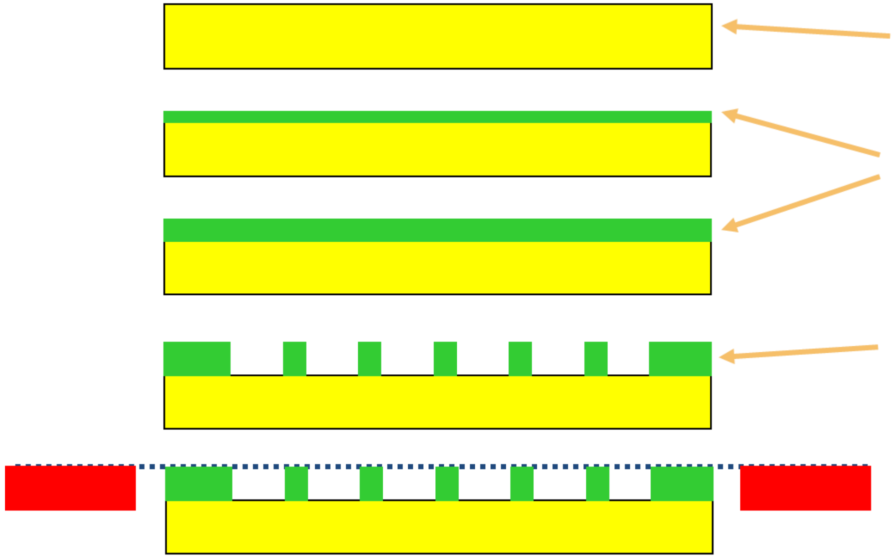
Laminated
Photoimageable
coverlay

SS Stretched mesh
on metal frame

Laminated
Photoimageable
coverlay

Exposure
Development
+ cure

Floating mesh Micromegas

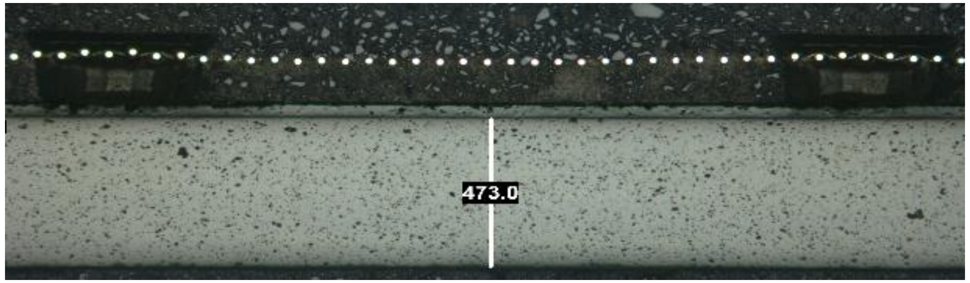


Read-out board
with CU strips

Laminated
Photoimageable
coverlay

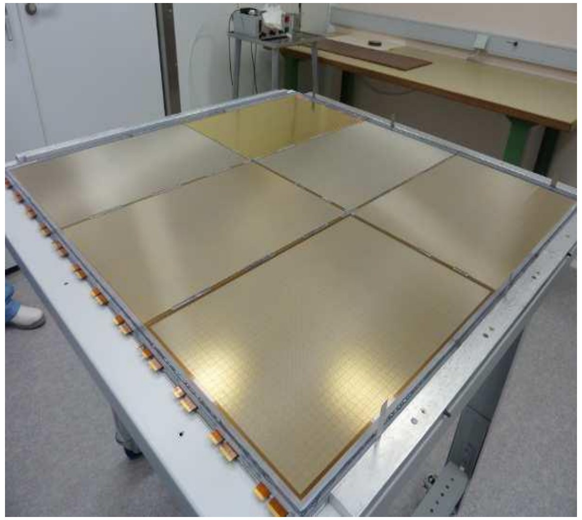
Exposure
Development
+ cure

SS Mesh on
metallic frame

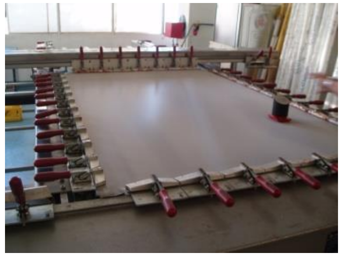


BULK Micromegas detectors

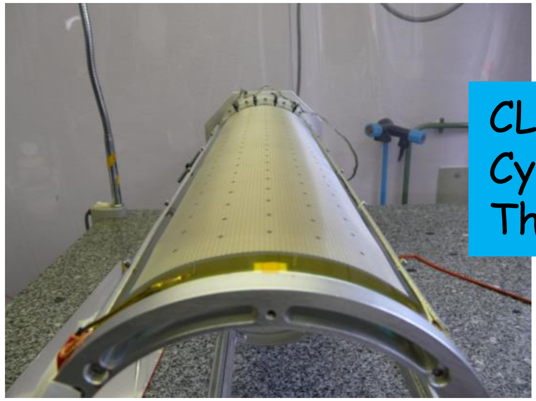
T2K TPC ,J.Beucher
1.8m x 0.8m plane
With 12 detectors



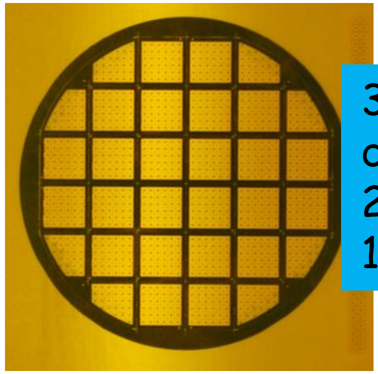
ILC DHCAL , M.Chefdeville
1m x 1m plane
With 6 detectors



Early ATLAS NSW R&D
Joerg Wotschack
1.5m x 0.5m plane
Single panel

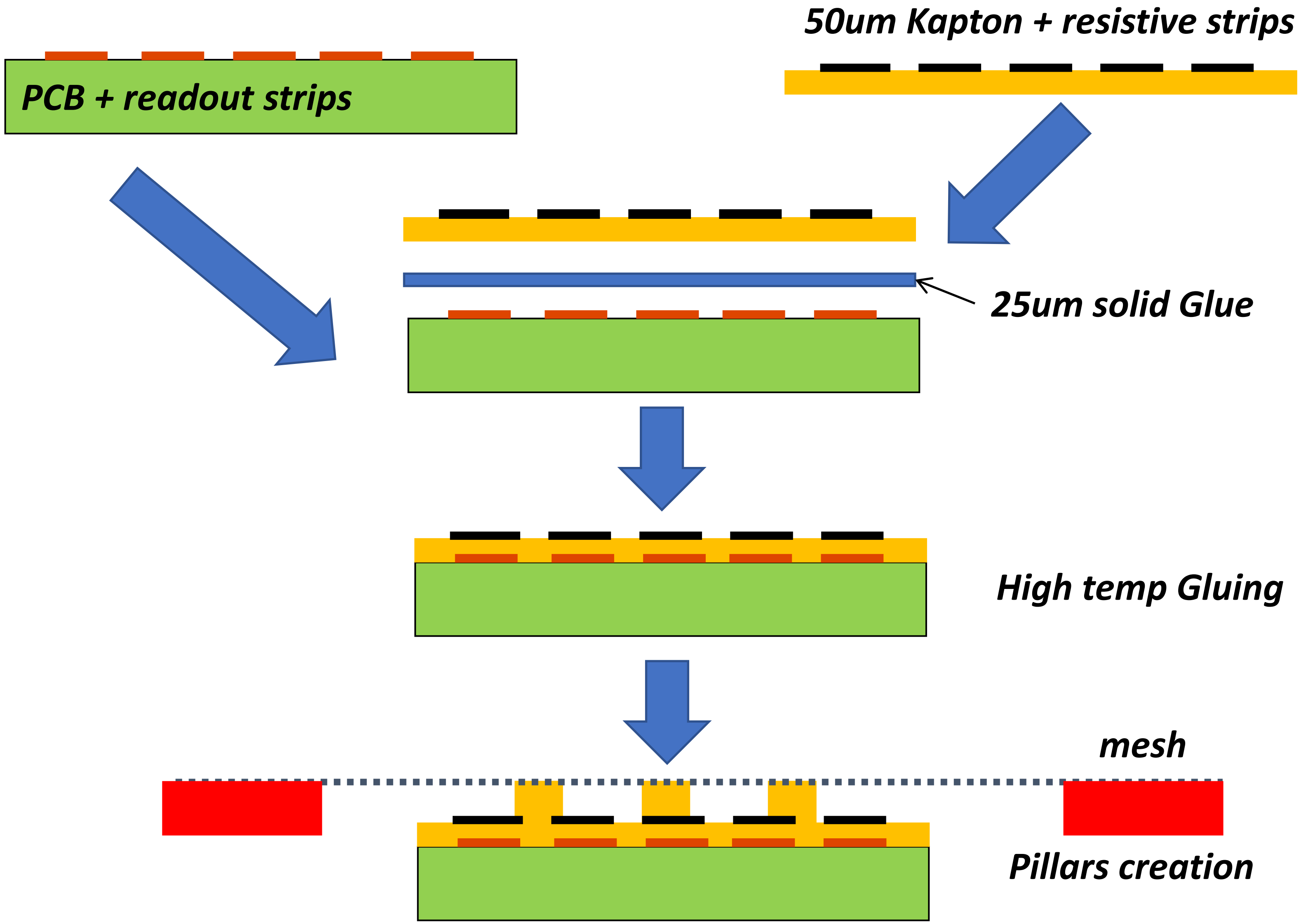


CLAS 12
Cylindrical Micromegas bulk
Thin substrate



33 sectors , 12cm diameter detector
2.5mm dead space for sectorizing
1mm hole for HV connection

Introduction of a resistive layer in floating MM



50um Kapton + resistive strips

PCB + readout strips

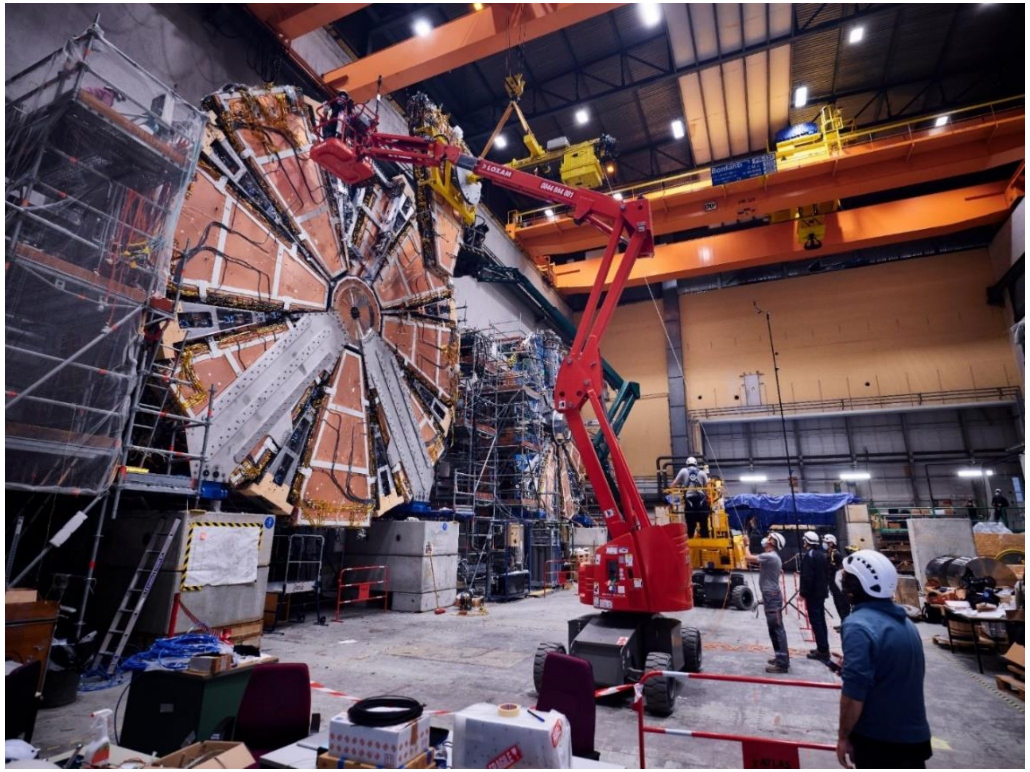
25um solid Glue

High temp Gluing

mesh

Pillars creation

Atlas NSW



Close to 2000 Micromegas detectors produced with modules sizes up to 2m x 0.5m

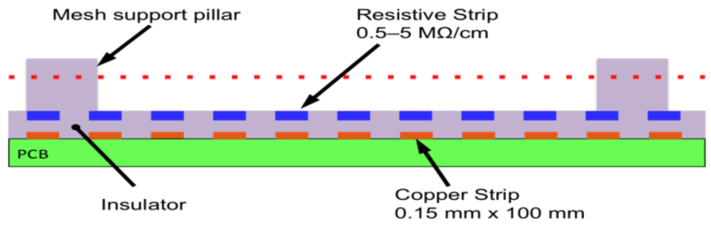
PCBs with pillars built at ELTOS (IT) and ELVIA (FR)
Panels construction and detector Assy :
- Dubna
- INFN Frascati
- CEA Saclay
- LMU Munich

MPT participated to the R&D and was also involved in the mass production with industry
- Specification
- Companies selection
- Technology transfer

All Resistive MM structures

Medium-rate detectors 100kHz/cm2

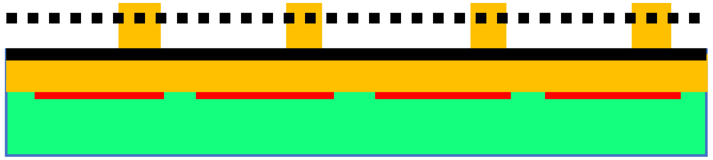
Side evacuation of the charges



Screen printed resistive strips (ATLAS NSW)

2013

or

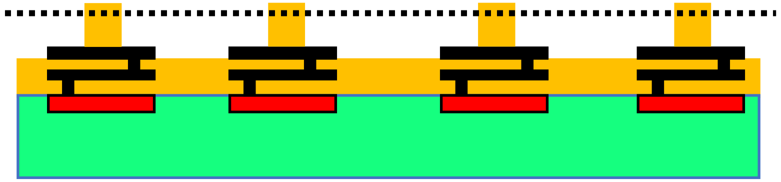


1 full DLC layer

2015

High-rate detectors 10Mhz/cm2

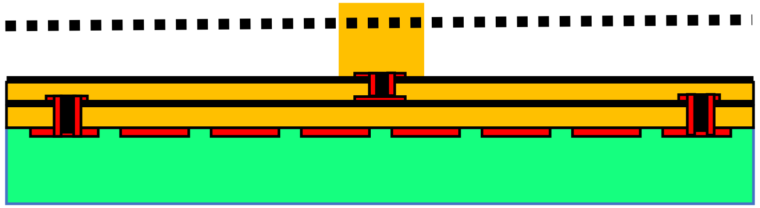
Charge evacuation inside active area



2 layers with screen printed pads

2015

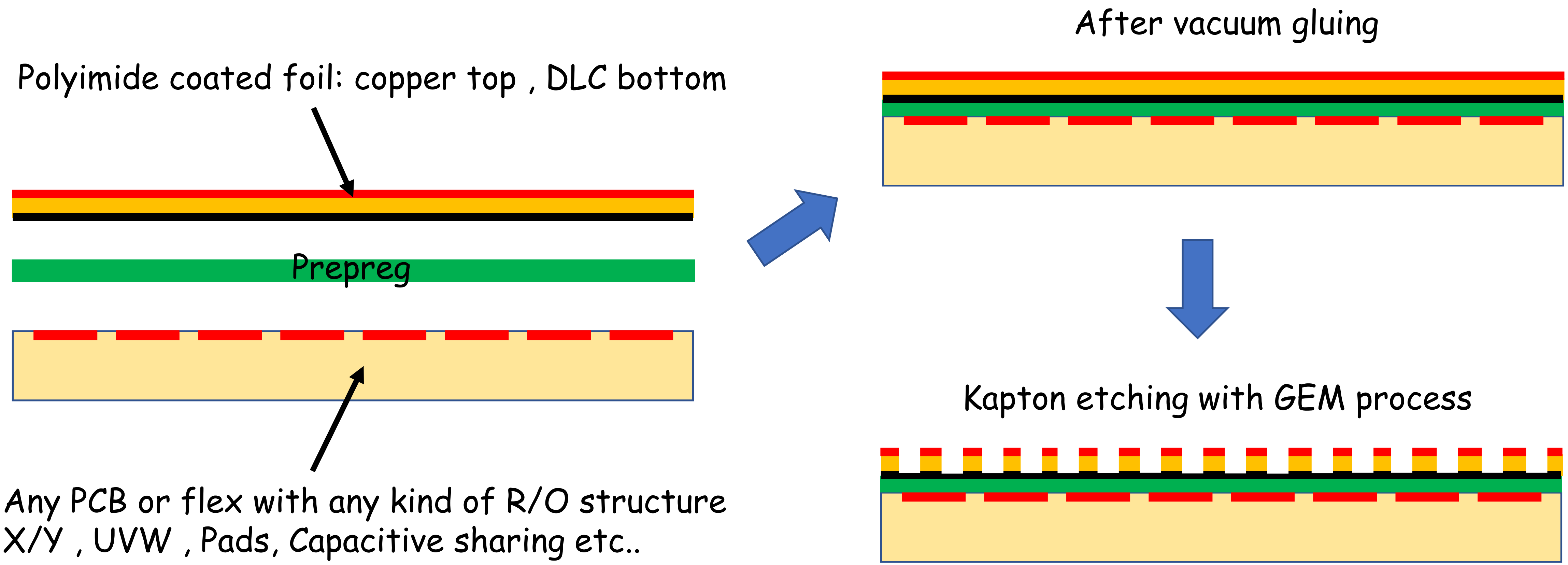
or



2 DLC layers without patterns

2020

uRwell detectors



Polyimide coated foil: copper top , DLC bottom

Prepreg

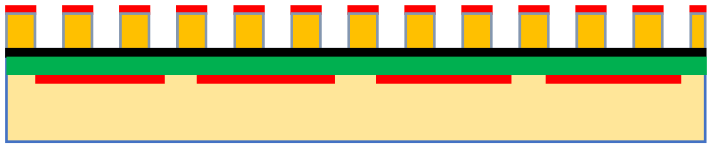
Any PCB or flex with any kind of R/O structure
X/Y , UVW , Pads, Capacitive sharing etc..

After vacuum gluing

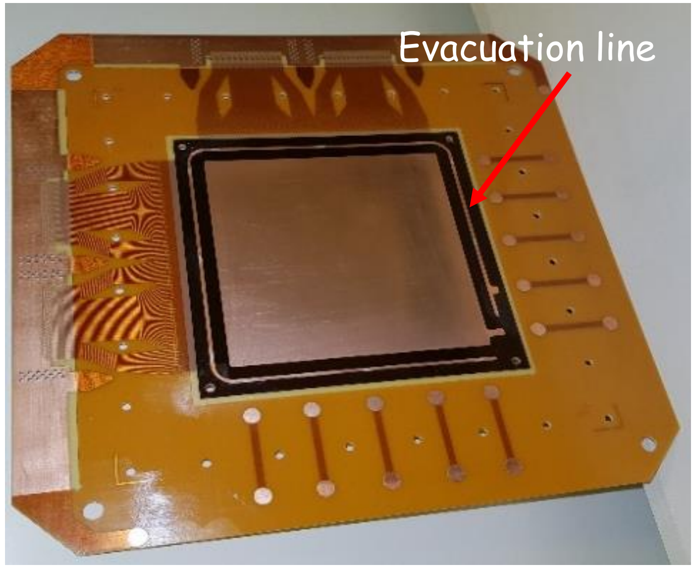
Kapton etching with GEM process

Medium rate μRwell

Lateral evacuation of charges



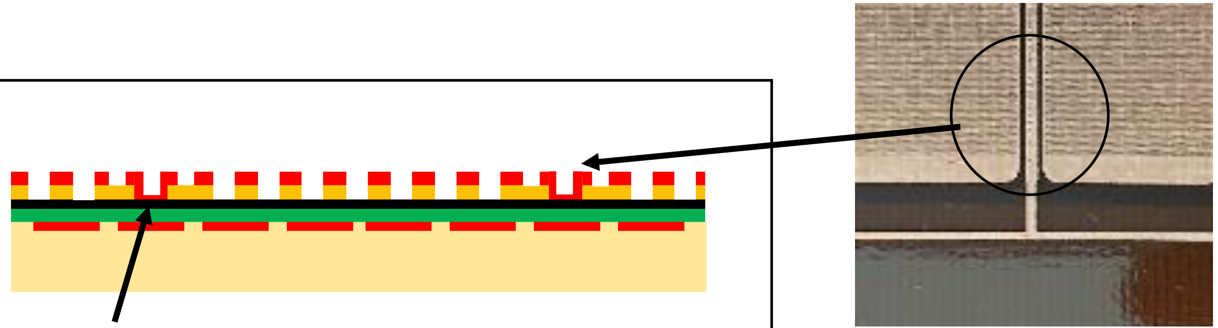
- 1 DLC layer



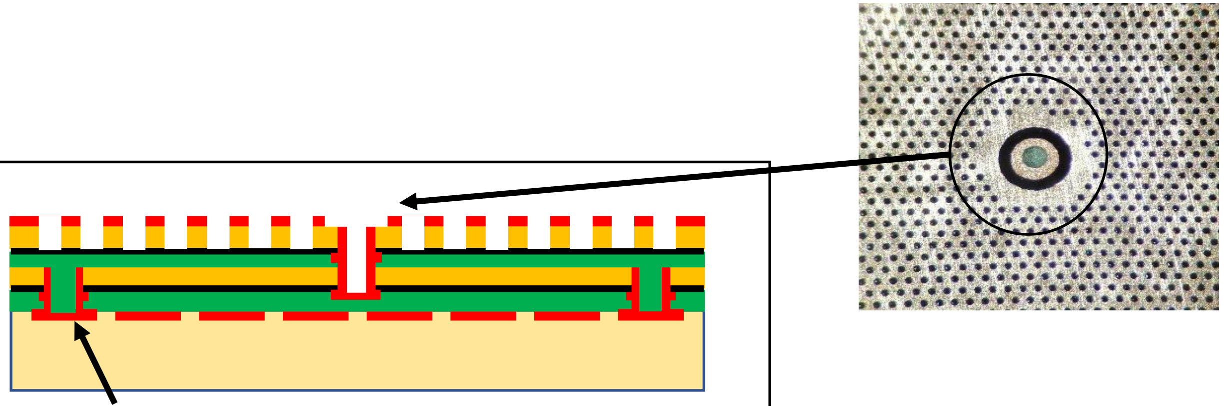
10cm x 10cm μRwell detector
"STD kit"

High rate uRwell

Charge evacuation in the active area



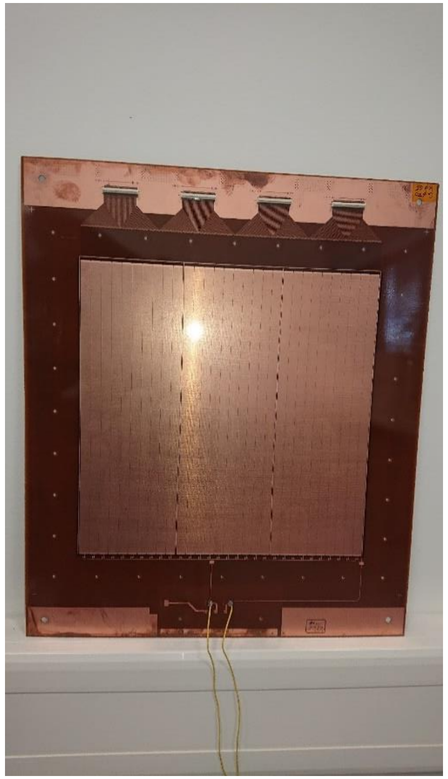
- DLC connected by plated grooves or holes



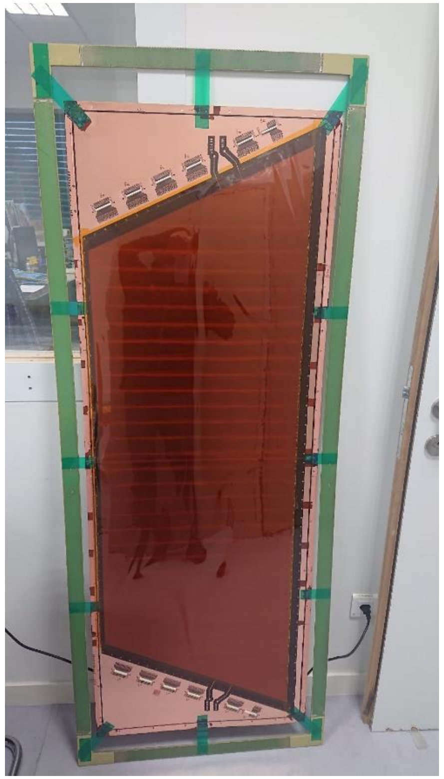
- 2 DLC layers connected by plated holes

uRwell examples

Frascati R&D
1D PEP uRwell
Active area:
40cm x 5cm



Frascati R&D
1D PEP uRwell
Active area:
30cm x 30cm



CLAS12 R&D
2D PEP uRwell
Active area:
150cm x 50cm

CLAS12 uRwell
rolled in an oven
for E-cleaning

Thank you for your attention