Photolithography and Chemical etching

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CERN

TS-DEM

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Contents

History of photolithography
Usage of photolithography
Principles of photolithography
Detailed process of the production steps
Photolithography at CERN
Conclusions

Definition of Photolithography

A process involving the
photographic transfer
of a
pattern
to a
surface
for
etching

History of photolithography

- **Lithography**
  - Invented by Aloys Senefelder, 1796 (Germany)
  - lithography (greek lithos: stone and graphein: write) technique based on a special use of limestone to multi-replicate an image on paper
- **Photography**
  - Albert Magnus (Germany) (1193–1280) discovered silver nitrate (light sensitive compound)
  - The first permanent photograph was an image produced in 1826 by the French inventor Nicéphore Niépce
- **Photolithography**
  - Alphonse Louis Poitevin (France) invented photolithography in 1855
  - 1935- Louis Minsk of Eastman Kodak developed the first negative photoresist
  - 1940- Otto Suess of Kalle Div. of Hoechst AG, developed the first positive photoresist

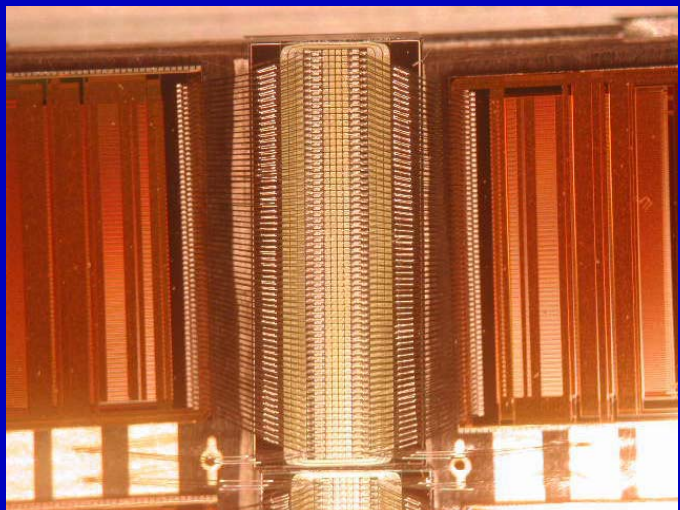
Contents

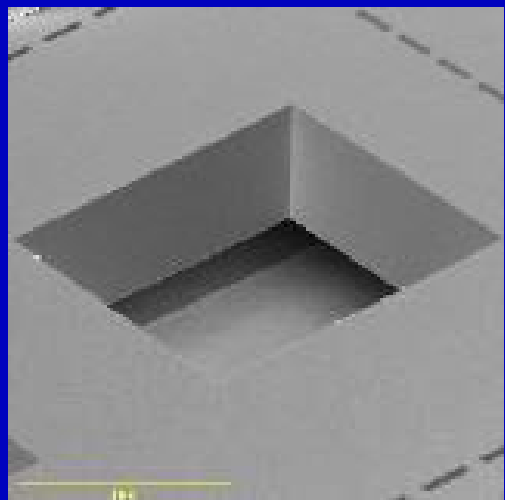
Daily life

- All electronics boards and components
- Offset lithography or offset printing
- Lots of pictures are made by the help of photolithography: posters, screen printed images
- Special products like:
  - LCD displays
  - Heads for inkjet printers
  - Accelerator sensors for air bag ignition

Semiconductor industry

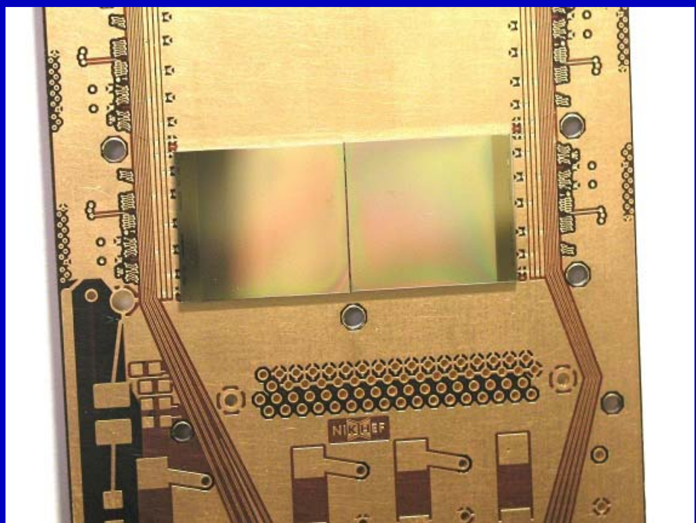
- Creation of metal lines for interconnection
- Mask areas for selective dopings
- Patterning of protective layers
- Micromachining of silicon

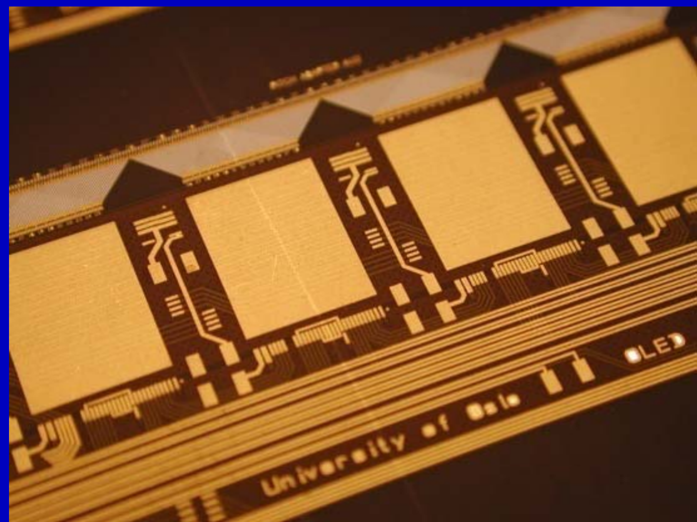




PCB industry

- Creating all the conductive tracks
- Protective layers (soldermask)
- Legend ink layer
- Micro via generation

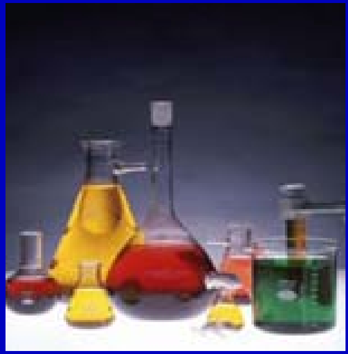




Chemical milling and electroforming

- Wave guides
- Heat sinks
- Decorative items
- Ink jet nozzles
- Optical parts
- Fuel cell parts
- Micro sprockets
- Lead frames
- Encoder discs
- Name plates
- Flow sensors

Thin metal plates +



MEMS
micro electro mechanical systems

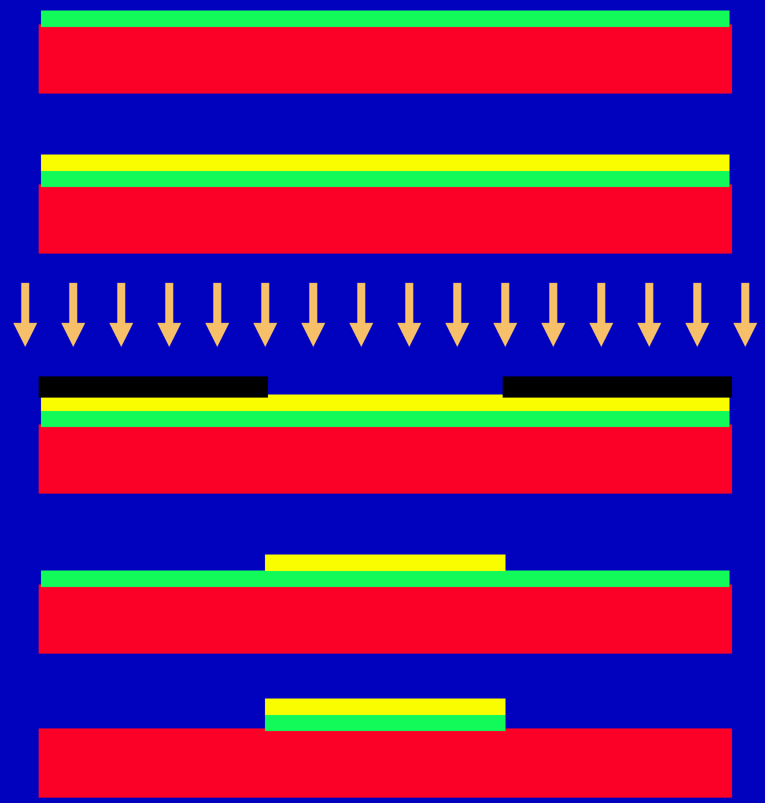
Main applications

- Ink jet printer heads
- Pressure sensors
- Accelerometers (automotive, gaming)
- Micro motors
- Magnetic sensors and actuators by electroforming magnetic materials

Contents

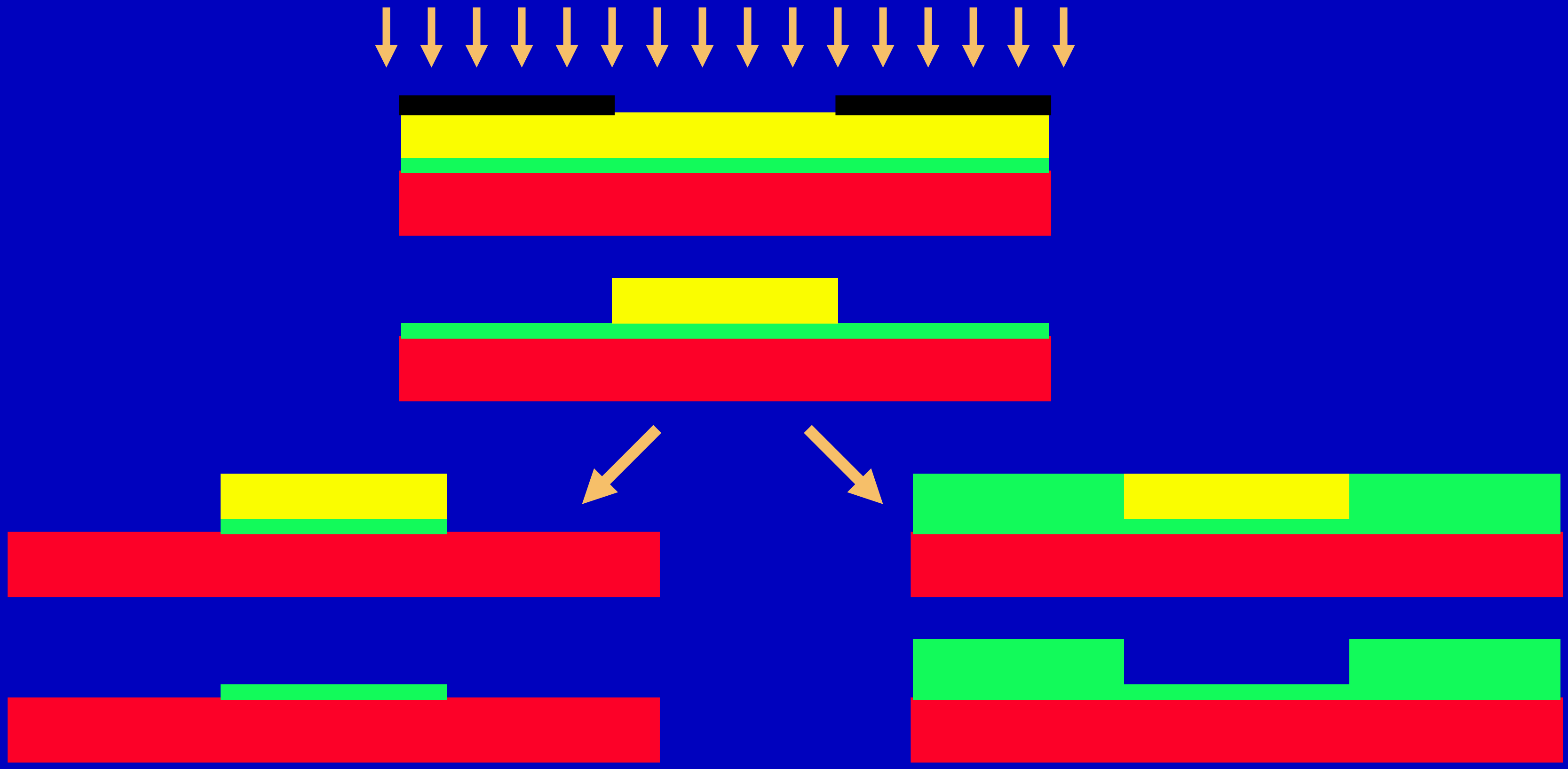
- History of photolithography
- Usage of photolithography
- Principles of photolithography
  - principle
  - etching/ electroforming
  - positive/ negative images and resists
- Detailed process of the production steps
- Photolithography at CERN
- Conclusions

Photolithography principle



support metal resist mask

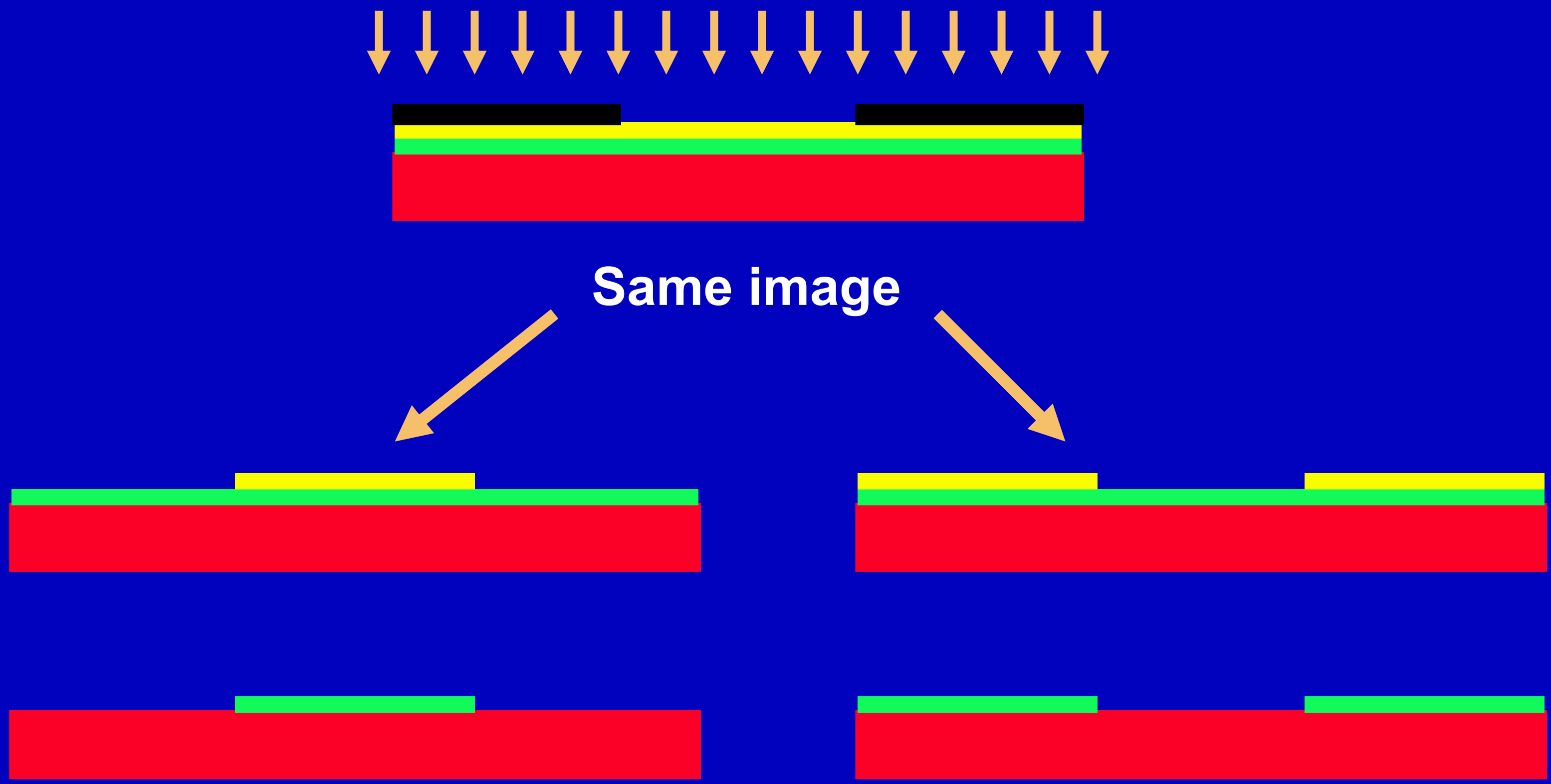
Etching/electroforming



etching

Electroforming
Adding metal by galvanoplasty processes
Creating molds for micro 3d objects

Positive/negative image



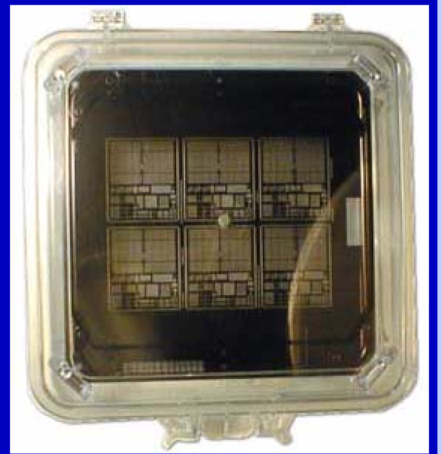
Negative resist
UV light starts the polymerisation in the polymer

Positive resist
UV light degrades links in the polymer

Contents

Artwork generation

- **Glass masks** (sub micron precision) 20 cm x 20 cm
  - photographic emulsion on soda lime glass (cheapest)
  - Fe_2O_3 on soda lime glass
  - Cr on soda lime glass
  - Cr on quartz glass (most expensive, needed for deep UV litho)

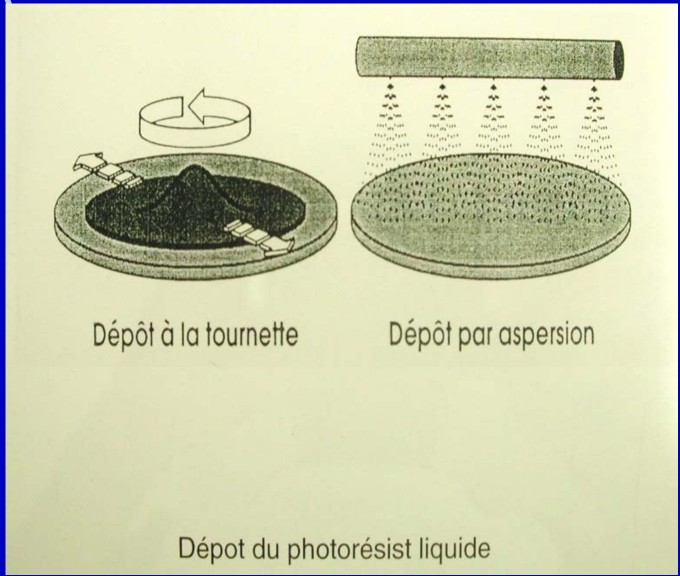


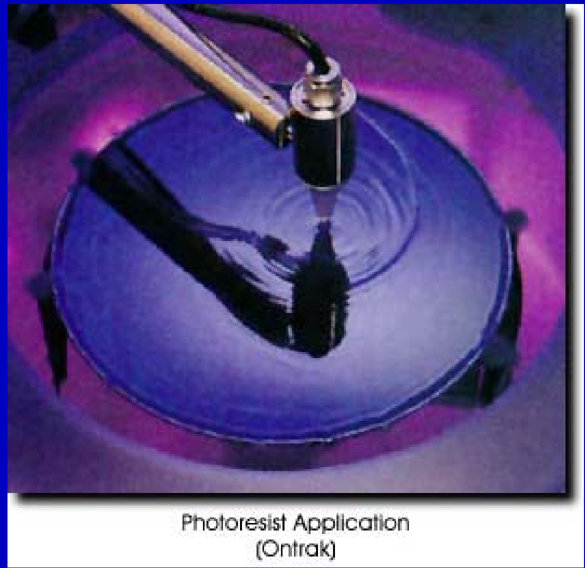
- **Polyester films** (10 um precision) 80 cm x 60 cm
  - Laser exposure of a photosensitive layer on a polyester film

Resist deposition

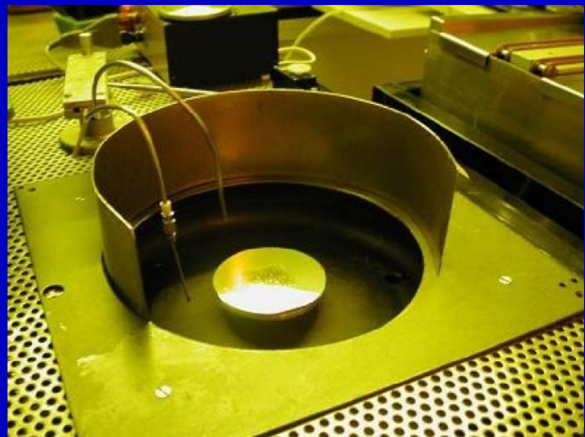
- **Spinning** - semiconductor production
  - Highest resolution
- **Dip coating** - fine lines for PCBs or 3D objects
  - Fine lines, large sizes
- **Curtain coating** - solder mask deposition
  - Fast, not accurate, cheap
- **Spray** - liquid resist, solder mask deposition
  - 3d best coverage, best quality for solder mask
- **Screen printing** - solder mask deposition
  - Medium quality solder mask, fast when the image is directly printed without photolithography
- **Dry film lamination**- PCB production
  - Fast, good resolution

Spinning resist

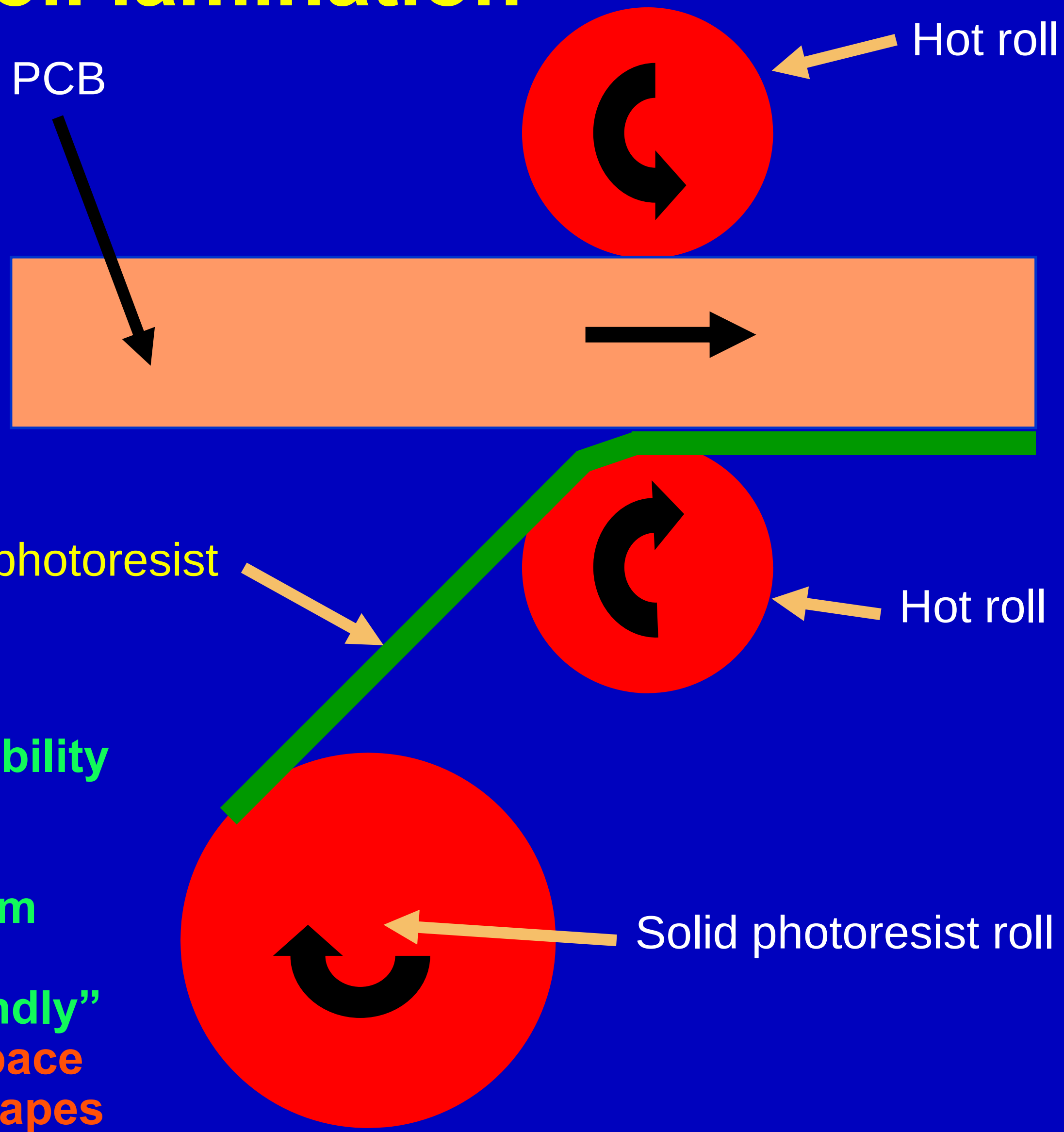




- Very precise deposition
- Uniform thickness
- Ultra thin :down to 1 µm
- Large window in the process
- Good repeatability
- Clean rooms needed class 100 to 1
- Solvent based resists



Hot roll lamination



- Large volume/area capability
- Fast deposition
- Dry process
- Medium class clean room
- Large size
- More “environment friendly”
- Resolution 30µm line/space
- not compatible to 3D shapes

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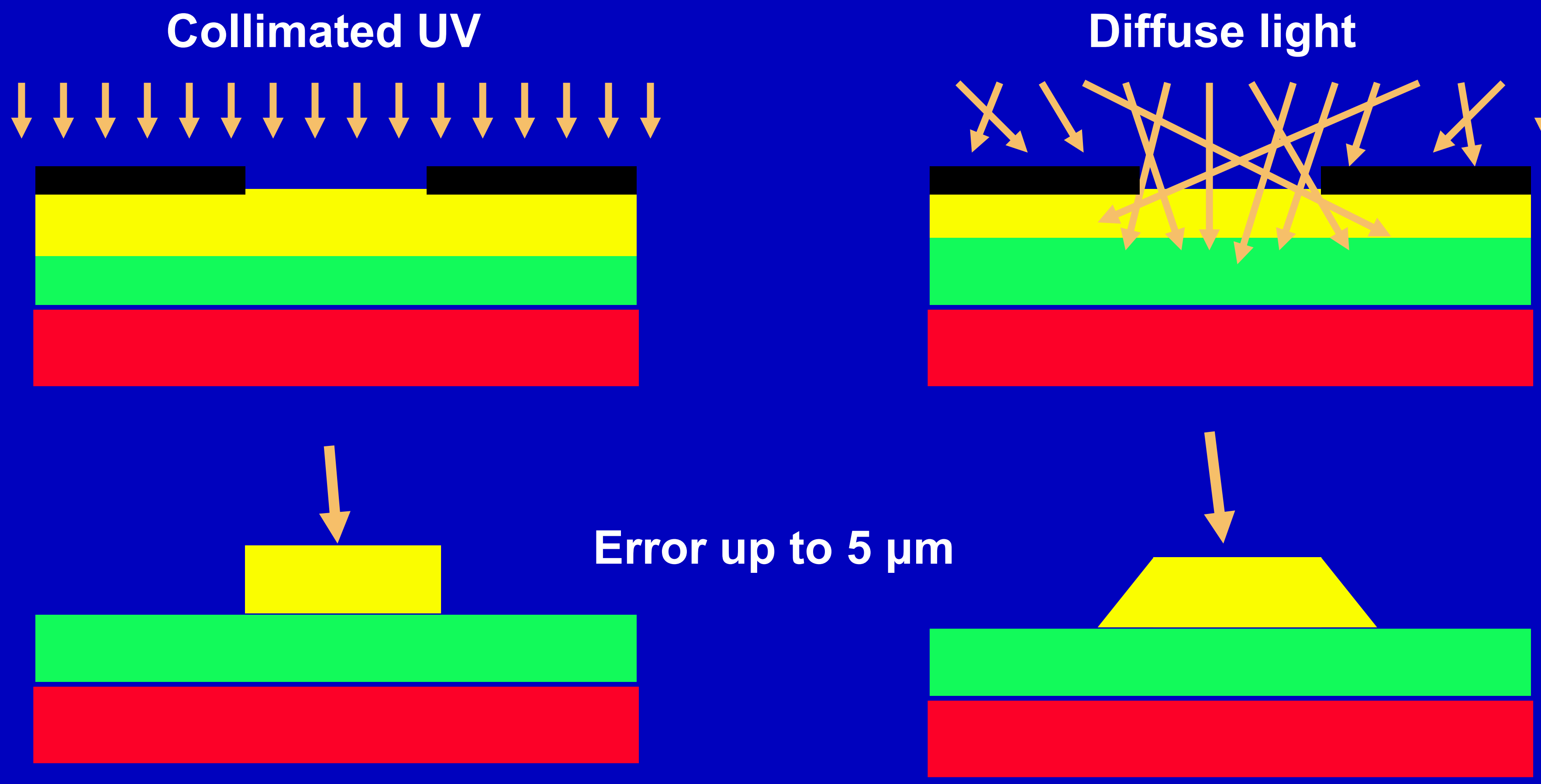
EXPOSURE

collimated/diffuse light problem

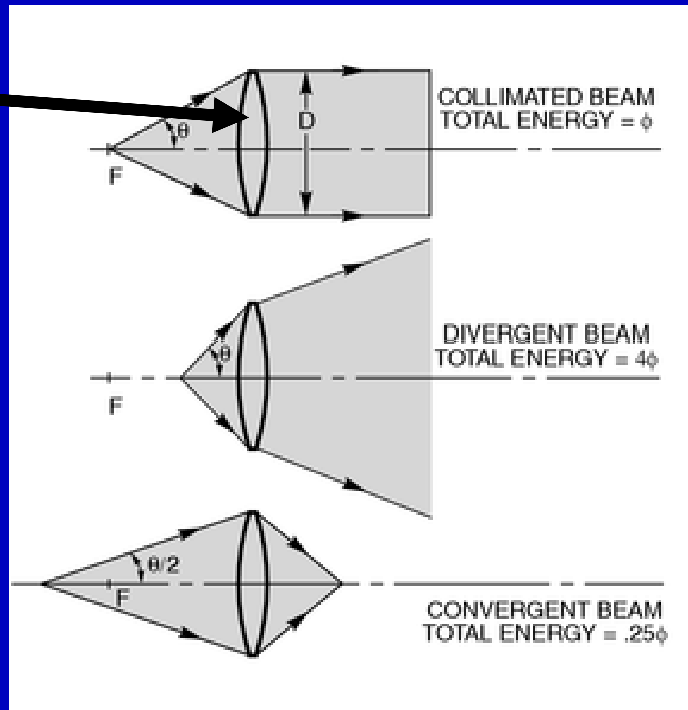
Application:
fine line PCBs, standard semiconductors



Collimated UV lamps

Precise large size lens up to 12 inches

The lens quality is the base of this system

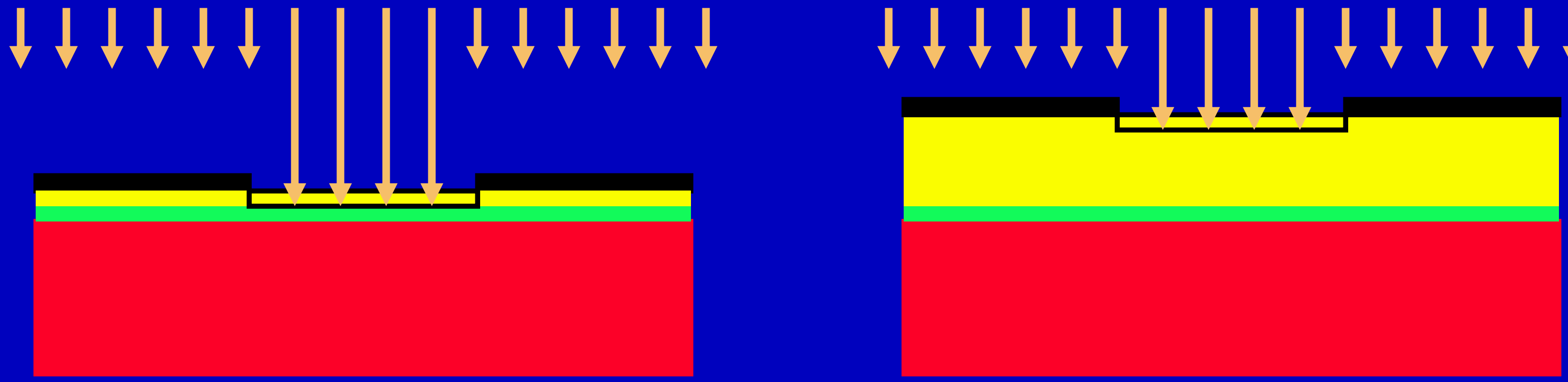


Source alone for multipurpose application
or
Combined with a high precision mechanical system for alignment: "Mask aligner"

CERN

EXPOSURE
light absorbtion problem

Application:
fine line PCBs with solid resist
Thick resists for electroforming



After development
the precision is lost

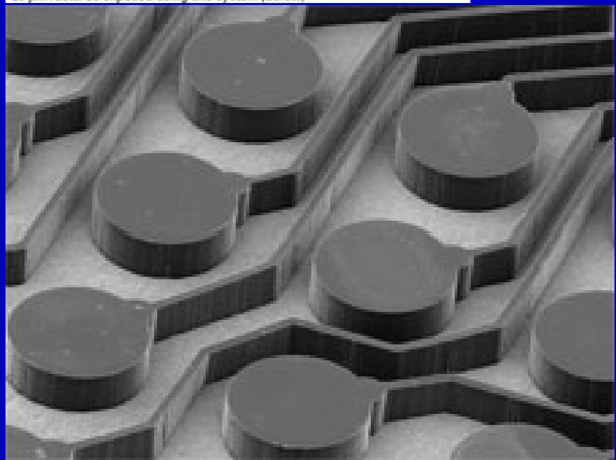
Thin resist ok

Problem with thick negative resist

CERN

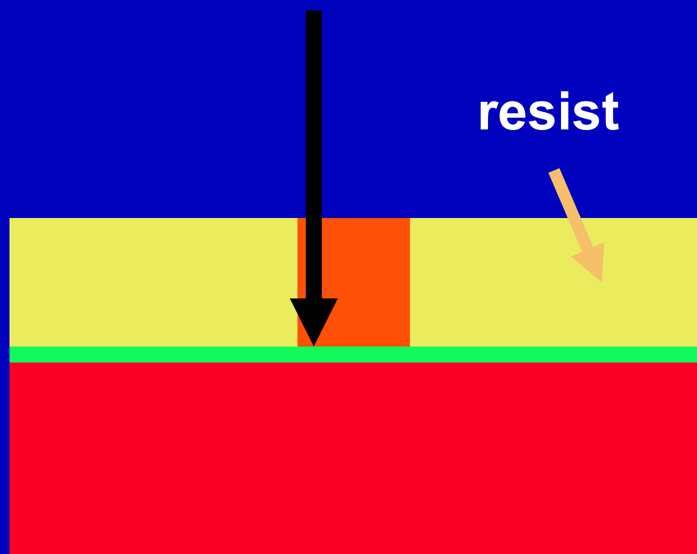
Laser UV direct exposure

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



25 µm lines
100 µm thick resist

UV direct exposure
No mask!



Increasing local energy can beat light absorbtion in the resist
Precision: 0.5 µm to 2 µm
(depending on laser type)

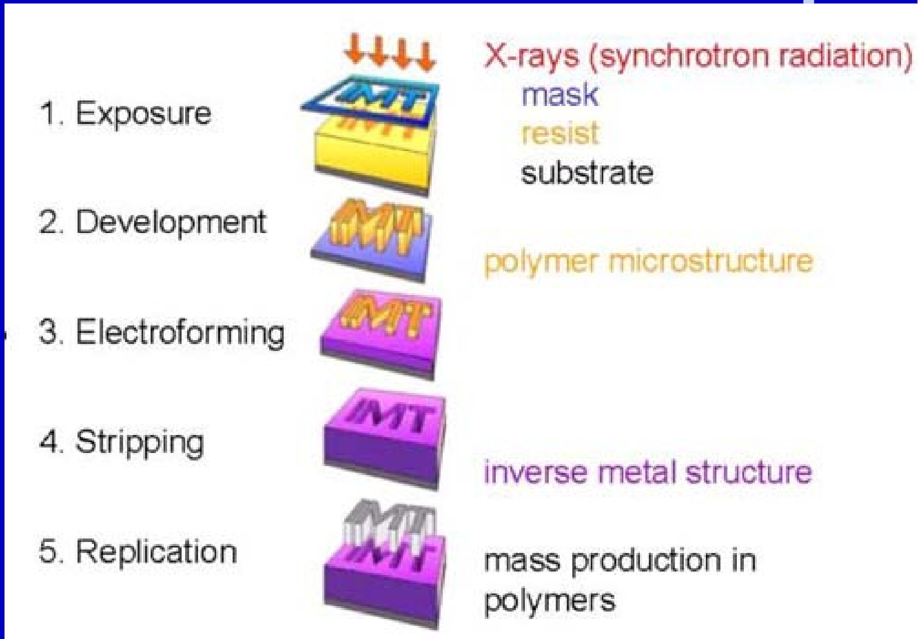
X ray exposure 'LIGA'

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, a German acronym for "Lithographie, Galvanoformung, Abformung,"in English (X-ray) Lithography, Electroplating, and Molding.

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

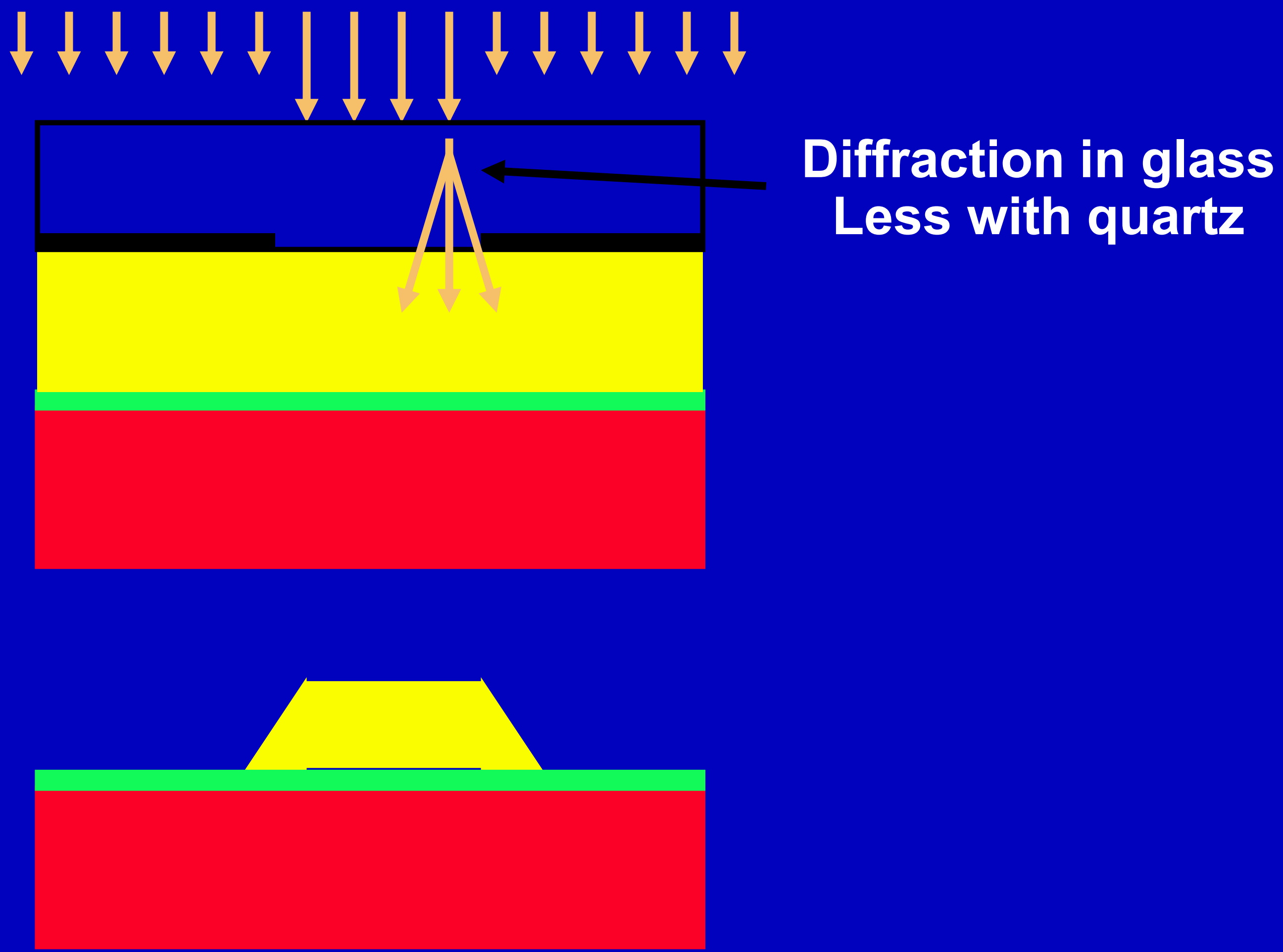
This technology is the base of many MEMS, It beats the limitation of light absorbtion in the photoresist



CERN

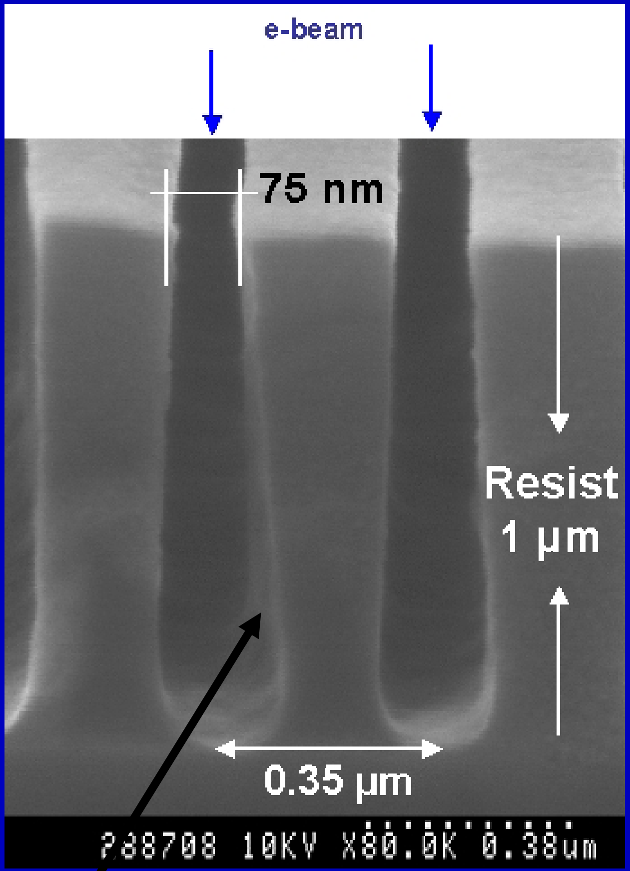
EXPOSURE
light diffraction problem

Ultra thin patterns
Semiconductor prototypes



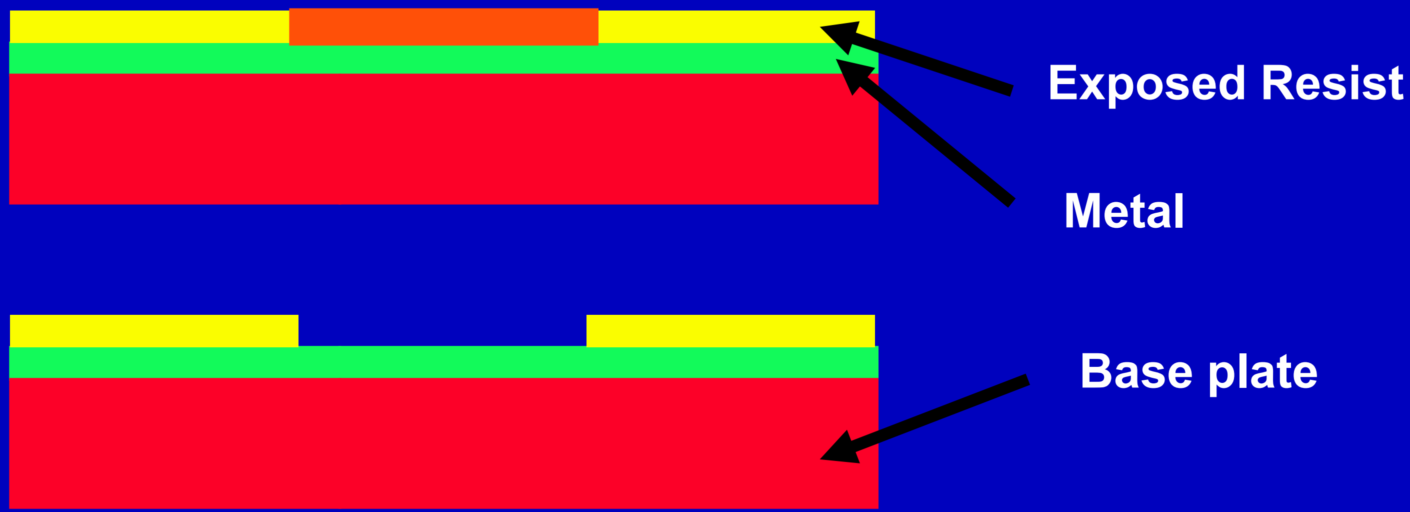
Electron beam exposure

- 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 of light and make features in the nanometer regime
- High accuracy but sensitive to electric and magnetic fields



Electron scattering in resist
Positive resist

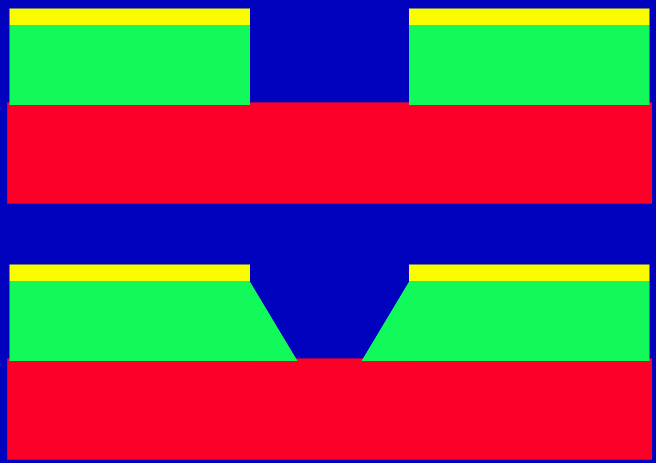
Chemical development



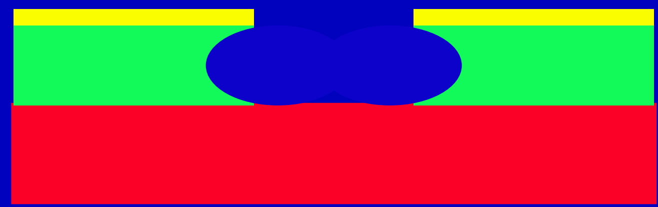
Horizontal spray chemical
Development :acqueus or solvent

Etching

- Most metals can be etched (isotropic etching)
- Most Polymers also (isotropic etching)
- *Silicon etching can be anisotropic*
- *Polyimide etching can be anisotropic*



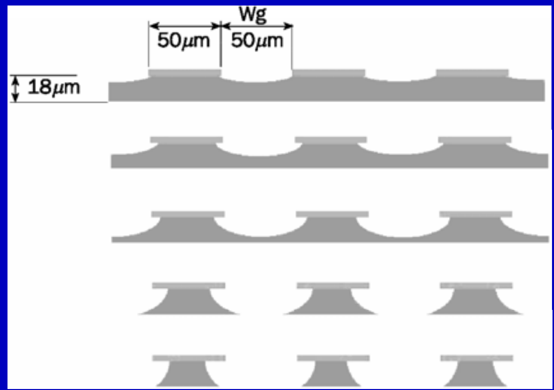
anisotropic



isotropic

Spray Chemical etching

But also dry etching
Laser direct ablation
Not described



Industrial equipment

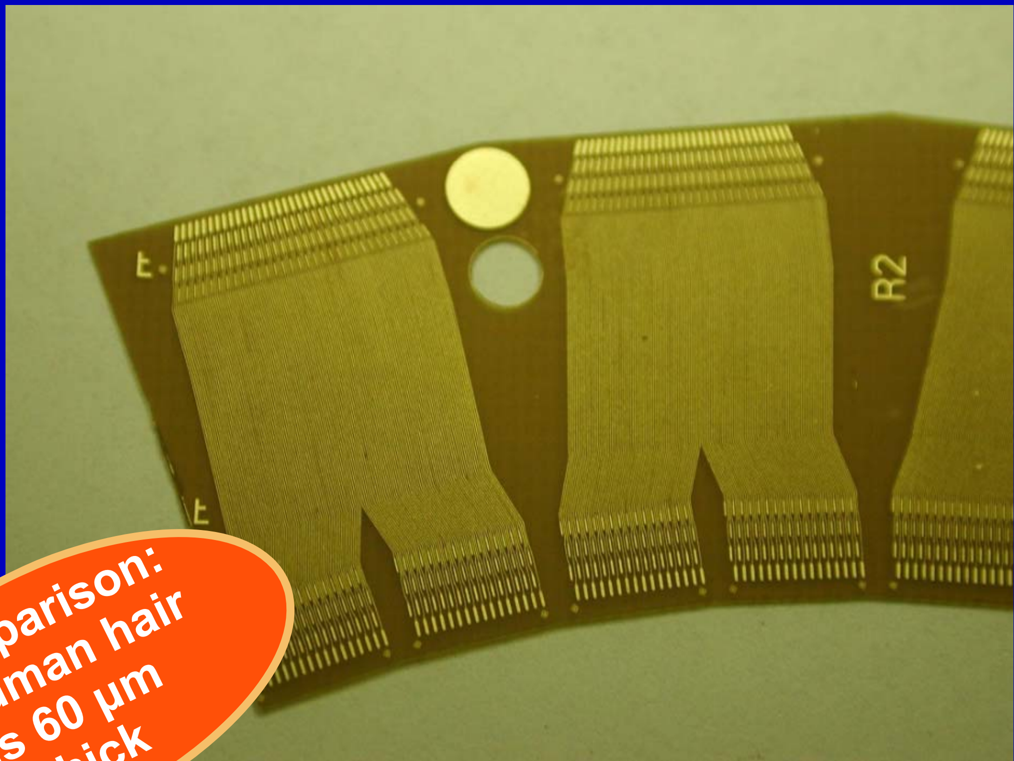
or

Human hand

Highest accurate equipment

Contents

Fine line and large size at CERN

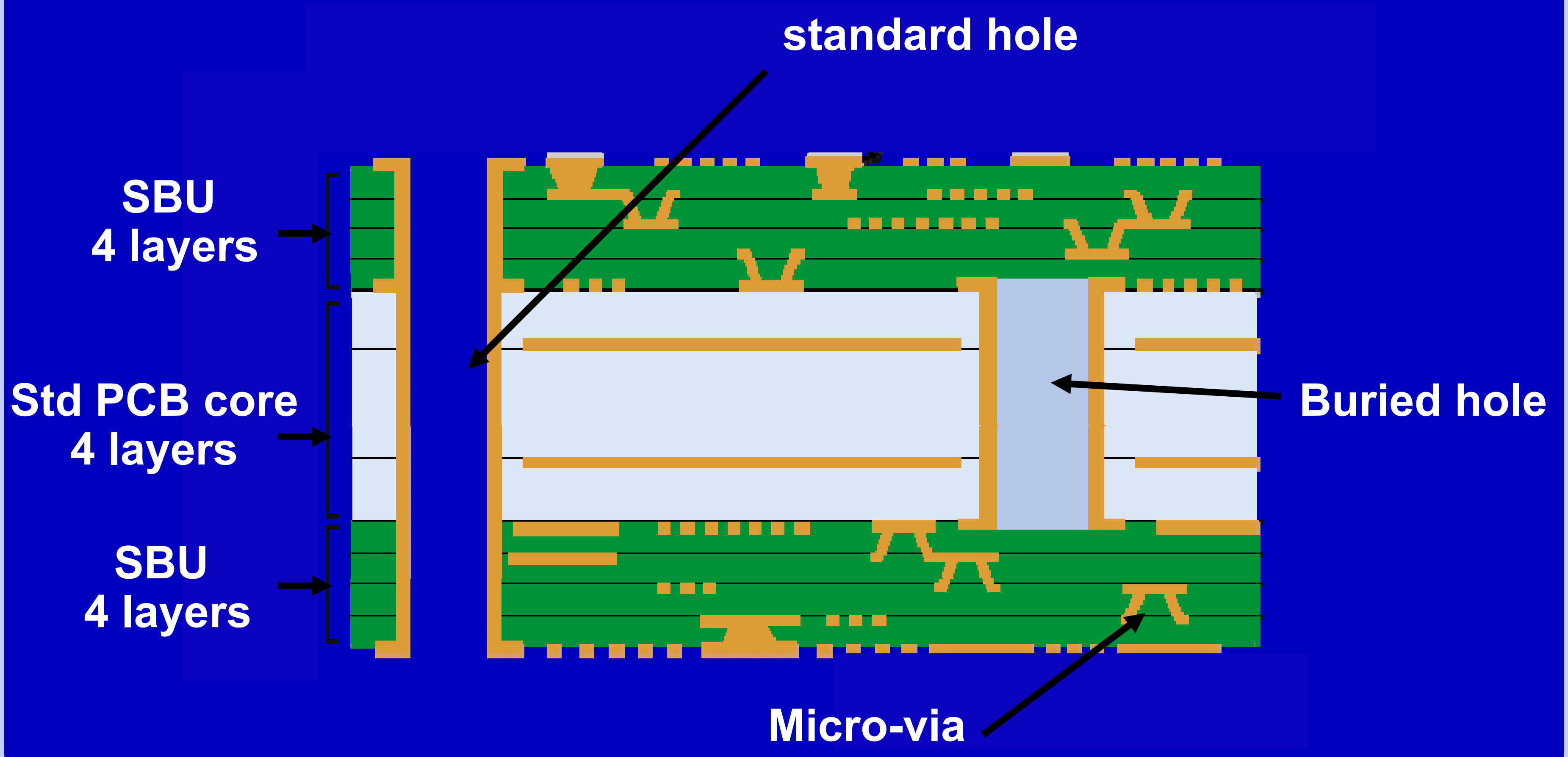


Comparison: a human hair is 60 µm thick

15 µm line and space
LHCb VELO hybrid
Pitch adaptor

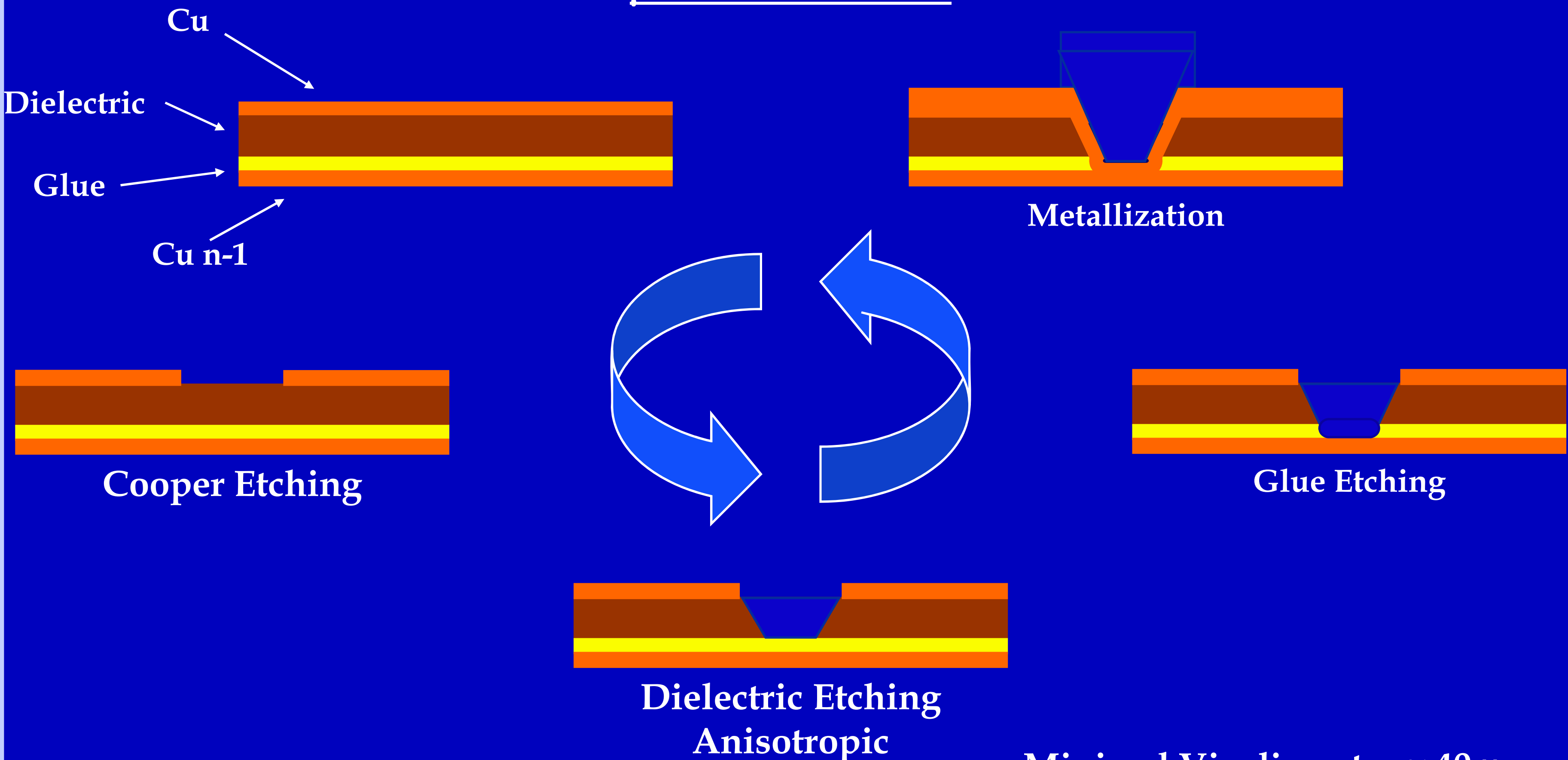
4 meter long flex
LHC injection kicker prototype

Micro via PCB structure



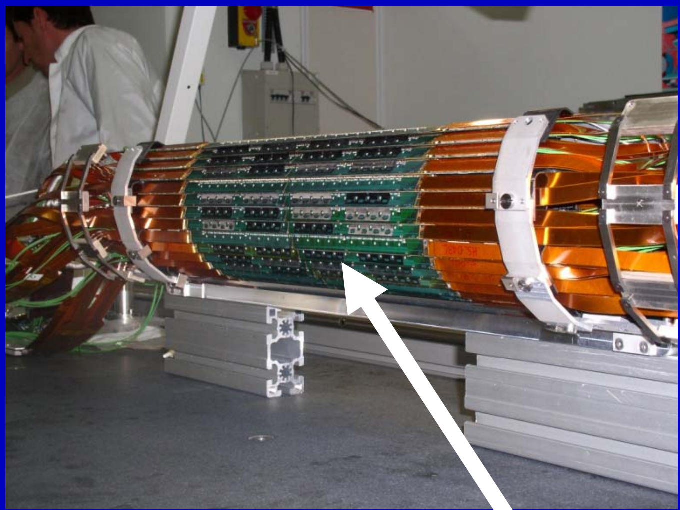
µvias – Process

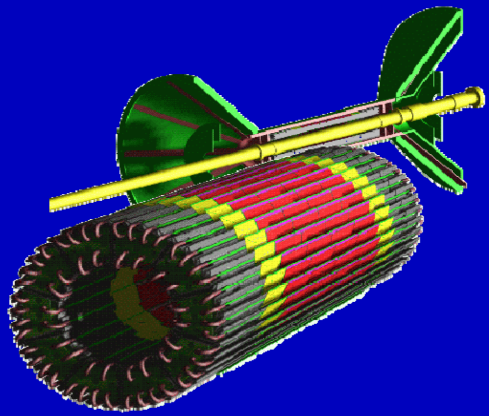
µ Chemical Via



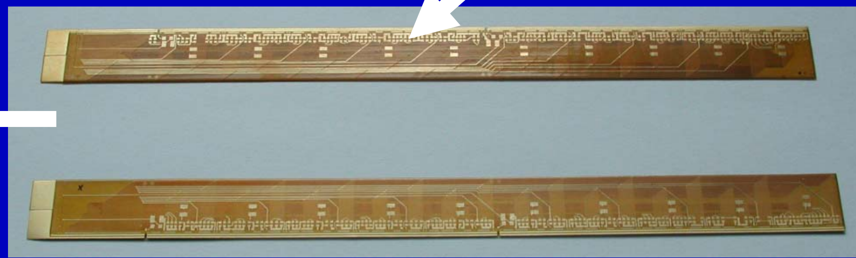
Minimal Via diameter ≈ 40 µm

ALICE Pixel Detector





Aluminum bus
Size: 160 mm x 16 mm
5 layers, chemical micro via



GEM manufacturing

GEM foils are produced at CERN using proprietary process

Process based on anisotropic etching of polyimide

50 µm Kapton
5 µm Cu both sides

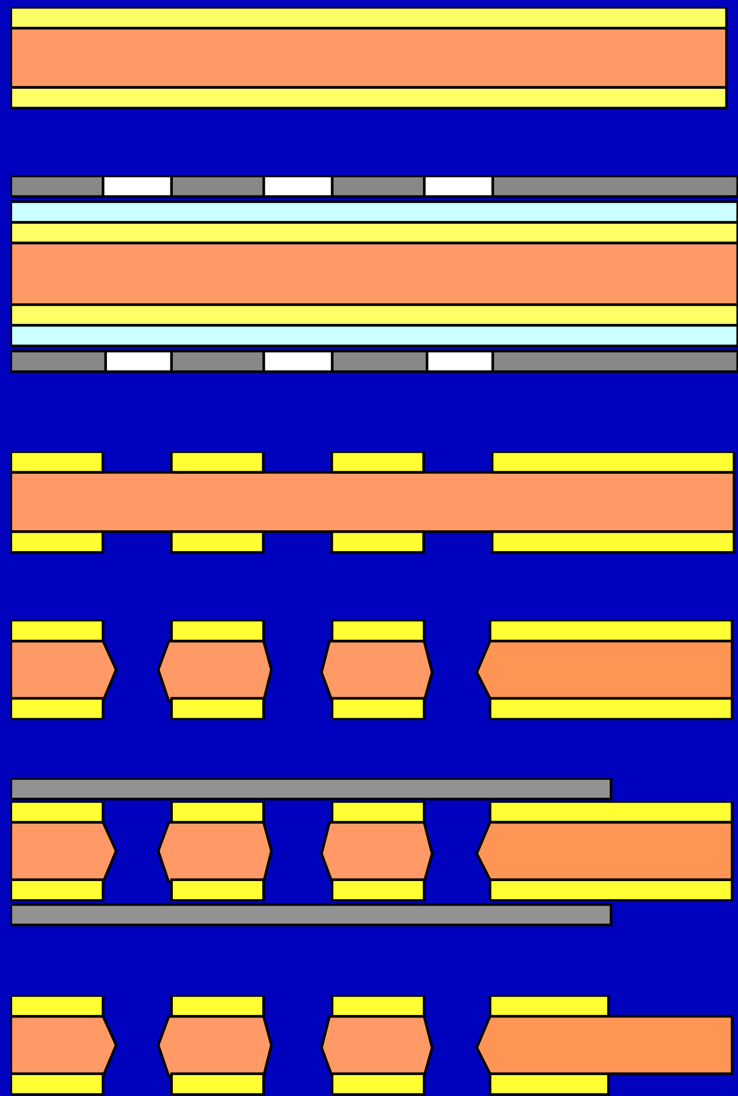
Photoresist coating, masking and exposure to UV light

Metal chemical etching

Kapton chemical etching

Second masking

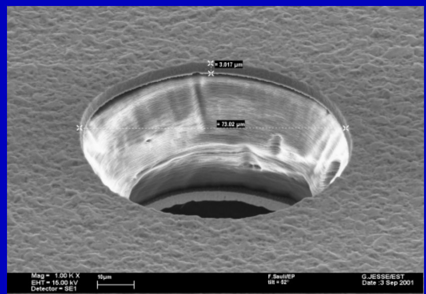
Metal etching and cleaning

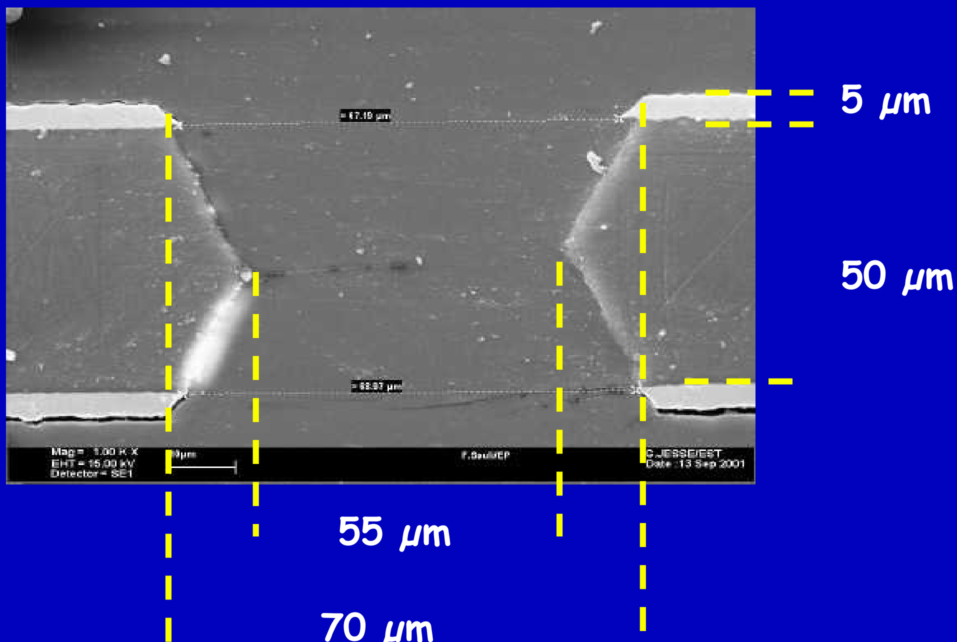


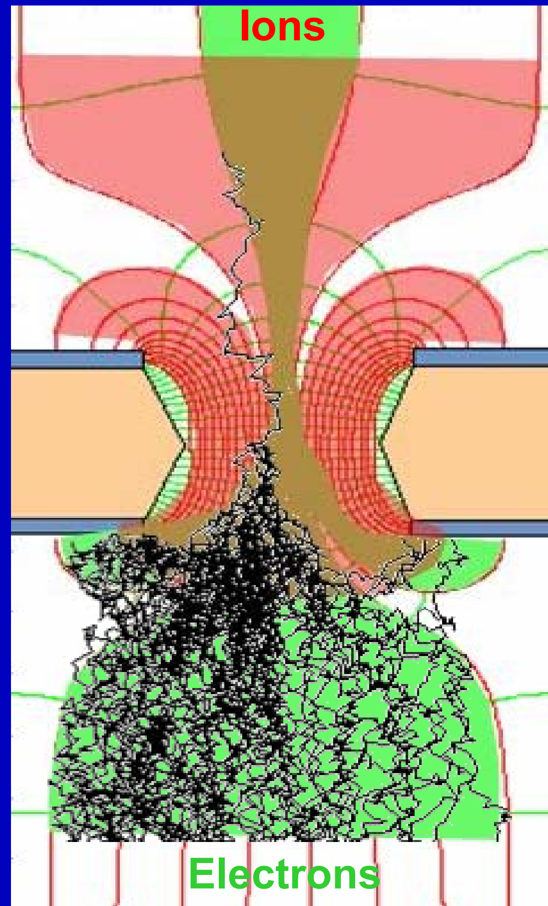
GEM operation principle

CERN Patent

A potential difference of ~500V is applied to each GEM foil.
Primary electrons released by the radiation drift towards holes where
the high electric field triggers an electron multiplication (avalanche) process



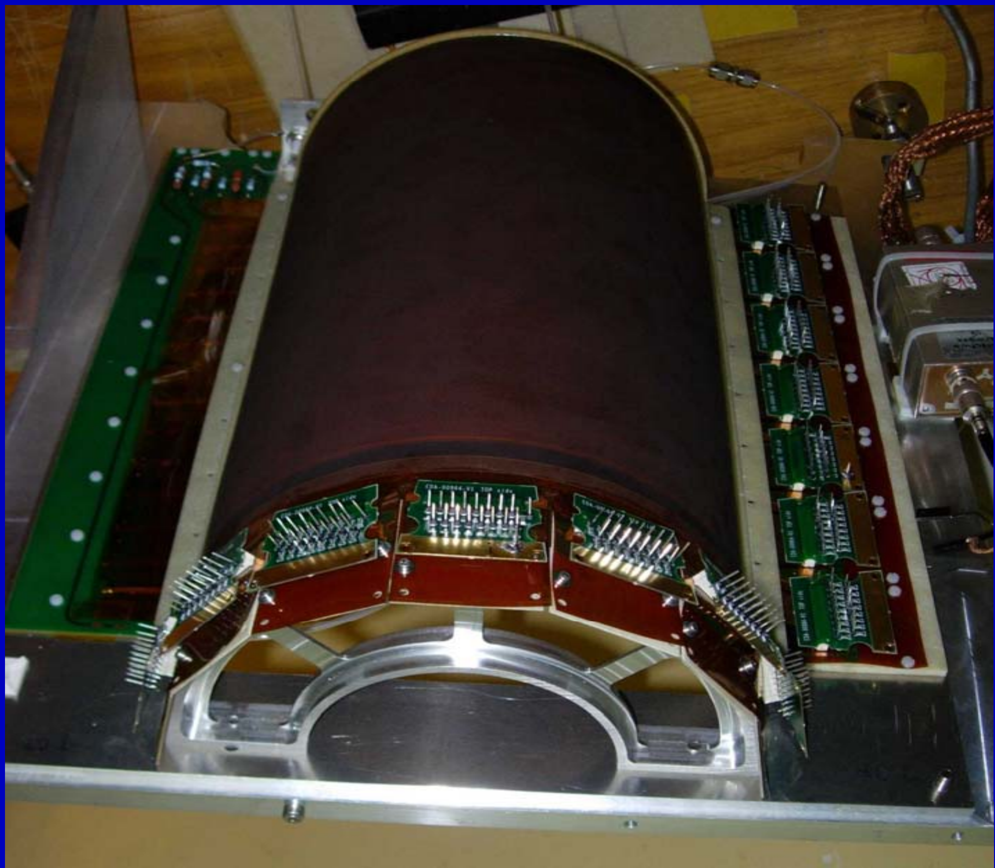




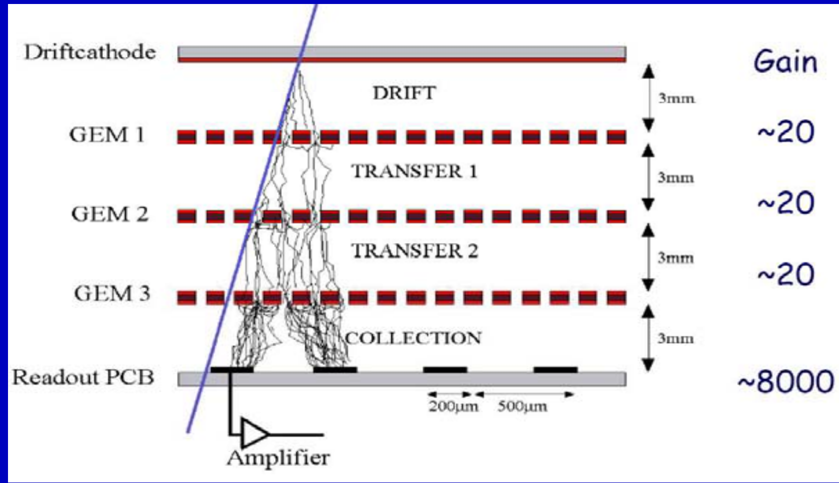
GEM detector

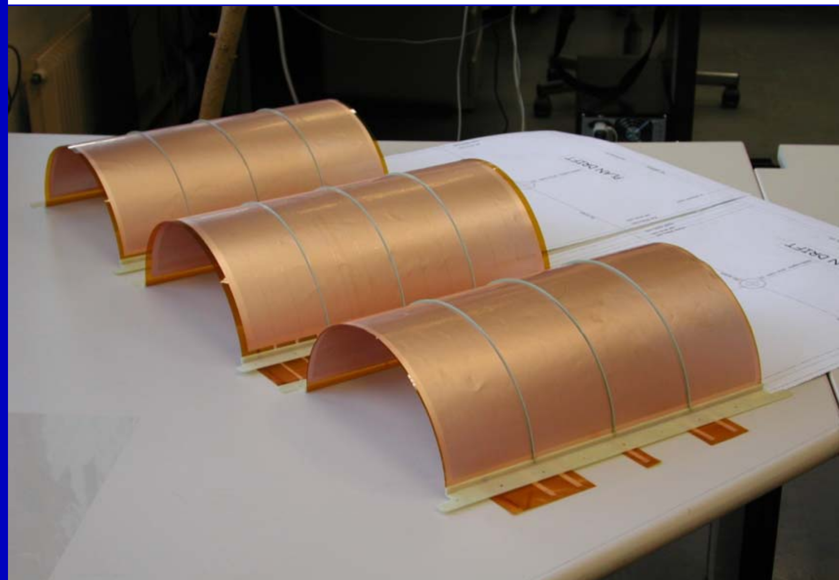
A GEM Detector consists of:

- a drift electrode
- 3 GEM foils
- a readout electrode



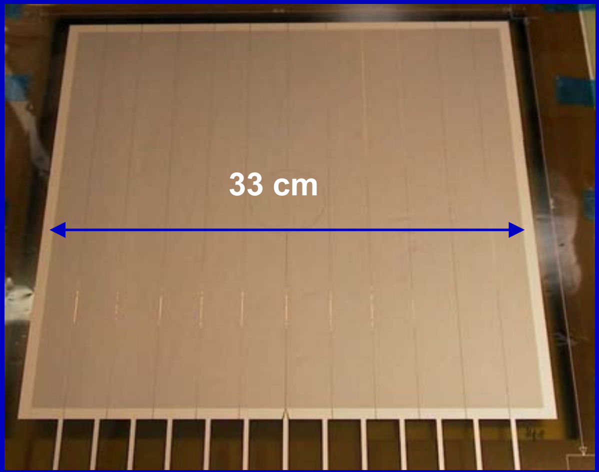
Semi-cylindrical GEM detector

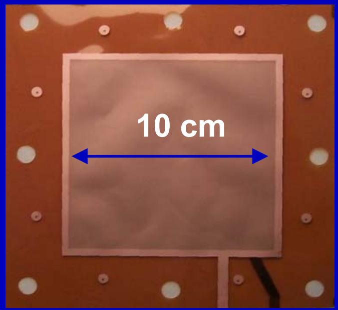


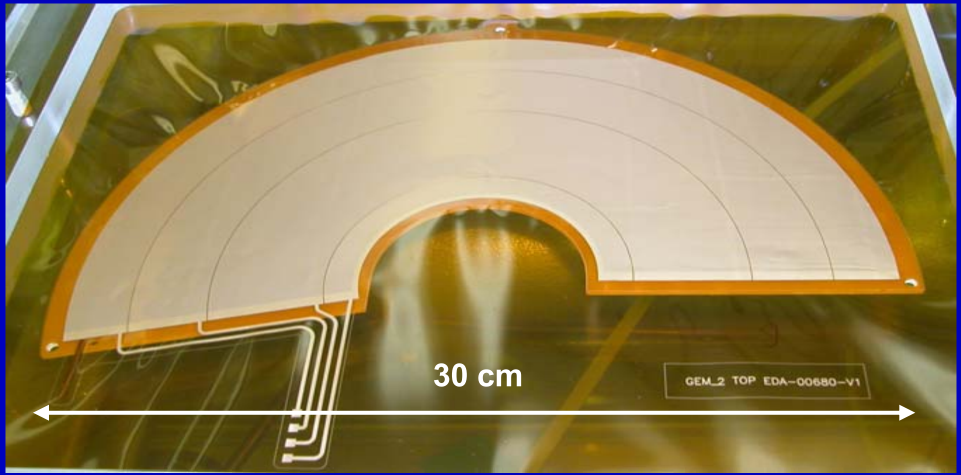


GEM foils before being mounted into detector

Examples of GEMs







25-200 µm holes, 50-300 µm pitch

Wide range of shapes and sizes

1500-2000 foils manufactured at CERN
1 cm^2 to 1000 cm^2

Conclusions

- **Old technology but still the best to face future challenges**
  - PCB fabrication
  - Semiconductor industry
  - MEMs
- **Easy to set up but extremely complicated for sub-micrometer range patterns**
- **Future competition (cost still too high)**
  - Direct laser imaging, electron beam lithography
  - Direct laser ablation