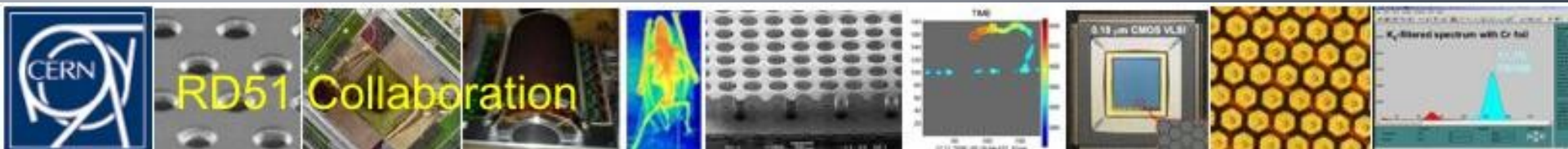


RD51 COLLABORATION MEETING 13/04/2011



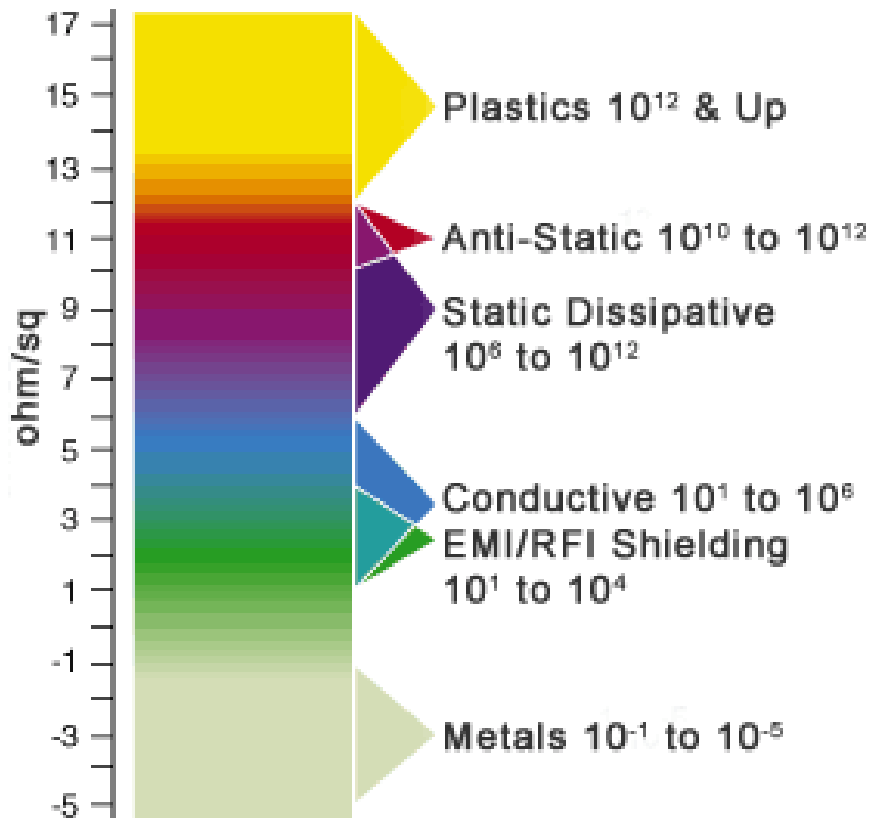
Resistors in Cern PCB workshop

Summary

- ▣ **Terminology**
- ▣ **Materials and techniques**
- ▣ **Structures made at CERN**

Terminology

Surface Resistivity



-A Resistor is define by:

- Value Ohms
- Precision %
- TCR ppm/Deg C
- max power W or W/m²
- breakdown voltage V

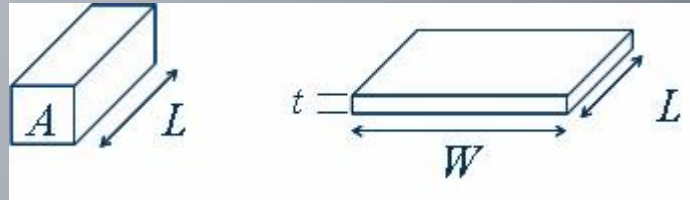
-Resistivity in Ohm*m

-Sheet resistance or surface resistivity in Ohm/sqr

-TCR: Temperature coefficient of the resistor

-Cermet: is a composite material composed of ceramic (cer) and metallic (met) materials.

Rs: Sheet resistance Ω/sq



$$R = \rho \frac{L}{A} = \rho \frac{L}{Wt}$$

$$R = \frac{\rho}{t} \frac{L}{W} = R_s \frac{L}{W}$$

Source: Wikipedia

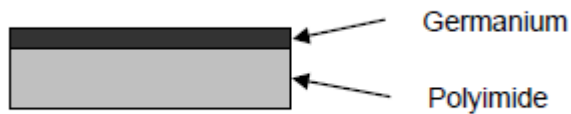
Some examples

- ▣ @ 300 K($\Omega \cdot \text{m}$)
 - Silver $16 \cdot 10^{-9} (\Omega \cdot \text{m})$
 - Ruthenium $71 \cdot 10^{-9} (\Omega \cdot \text{m})$
 - Germanium $460 \cdot 10^{-9} (\Omega \cdot \text{m})$
 - Ni/Cr $1000 \cdot 10^{-9} (\Omega \cdot \text{m})$
 - Carbone $35\,000 \cdot 10^{-9} (\Omega \cdot \text{m})$

Resistor families

- ▣ **Thin-film : Vacuum deposited metals/oxides**
- ▣ **Thick-film : (Cer-met)**
- ▣ **Polymer (epoxy, phenolic, polyimide)**

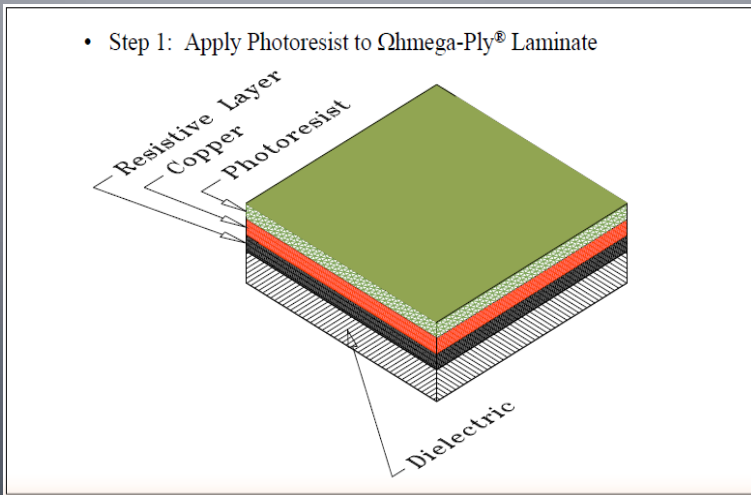
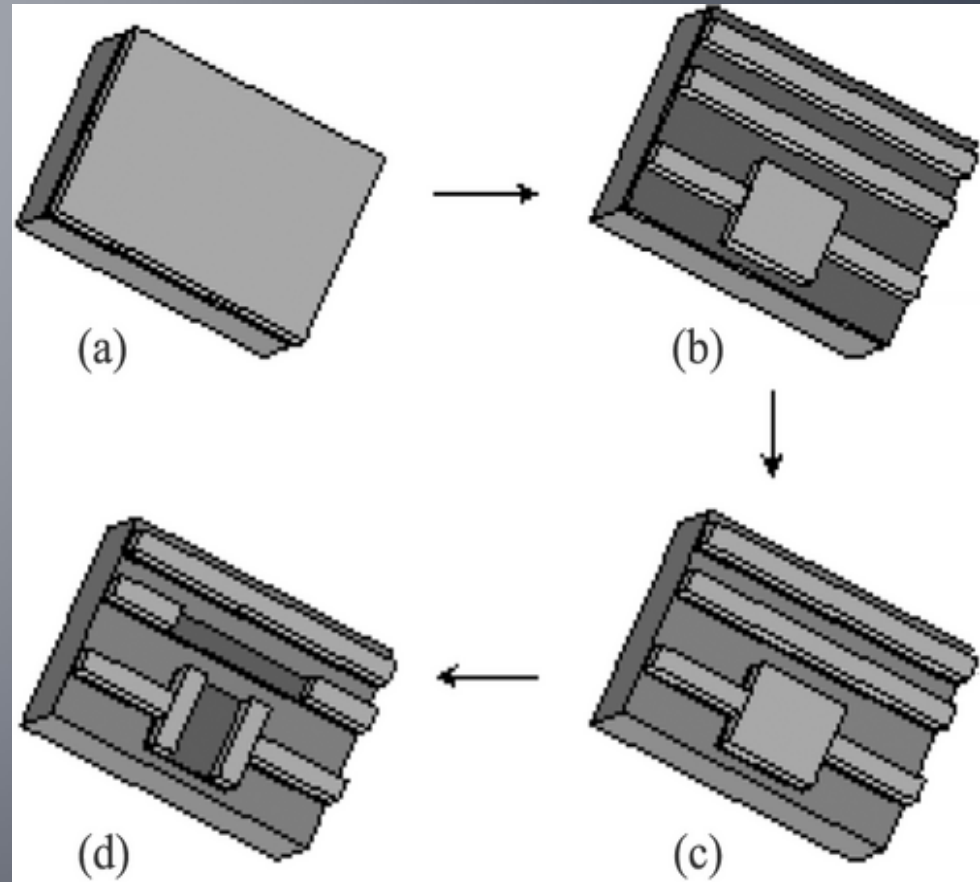
Thin film



Parameter (independent of film)	Specified Value
Germanium surface resistivity	$\leq 10^9 \Omega/\text{square}$ (typical $10^7 \Omega/\text{square}$)
Transmittance (Kapton HN only)	≤ 0.20
Solar Absorptance (α) Black Kapton Side	0.93 typical
Normal Emittance (ϵ_N) Black Kapton Side	0.84 typical
Intermittent temperature range	-250° C to 400° C (-420° F to 750° F)
Continuous temperature range	-250° C to 290° C (-420° F to 550° F)
Outgassing: (ASTM – E595)	TML - WVR $\leq 1.0 \%$; CVCM $\leq 0.1\%$

Thin film

Sheet Resistivity	Ohmega-Ply [®] Film Average Thickness	Material Tolerance
10 Ω/\square	1.00 Micron	3%
25 Ω/\square	0.40 Micron	5%
50 Ω/\square	0.20 Micron	5%
100 Ω/\square	0.10 Micron	5%
250 Ω/\square	0.05 Micron	10%

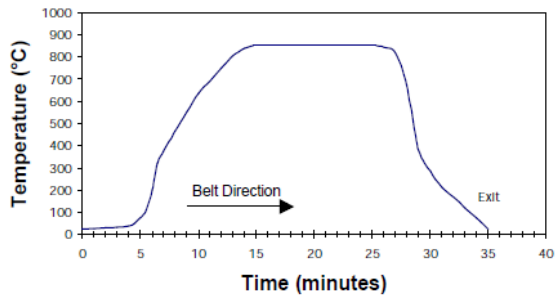


WEB SITE: <http://www.ohmega.com>

Thick film



Typical 850°C Firing Profile
R-300-A/B



Electro-Science Laboratories, Inc.

416 East Church Road • King of Prussia, PA 19406-2625, U.S.A
610-272-8000 • Fax: 610-272-6759 • www.ElectroScience.com • Sales@ElectroScience.com

PROPERTIES	R-310-A	R-311-A	R-312-A	R-313-A	R-314-A	R-314-B	R-315-B	R-316-B
RESISTIVITY ^a (Ω /square)	1	10	100	1 k	10 k	10 k	100 k	1 M
SHIPPING SPECIFICATION (%)	± 30	± 10	± 10	± 10	± 10	± 10	± 10	± 10
COEFFICIENT OF VARIATION (%)	< 8	< 8	< 8	< 8	< 7	< 5	< 5	< 8
VISCOSITY ^b (Pa-s)	225 \pm 25					300 \pm 50		
DRIED THICKNESS (μ m)	22.5 \pm 2.5					20.0 \pm 2.0		
THINNER	ESL 401							
TCR ^c (ppm/°C)	50 \pm 100	0 \pm 100	0 \pm 100	0 \pm 50	0 \pm 50	0 \pm 100	0 \pm 100	0 \pm 100
STOL ^d (V/mm)	1.65	7.38	24.6	76.8	137	150	350	330
STD. WORKING VOLTAGE ^e (V/mm)	0.66	2.95	9.84	30.7	54.8	60	140	130
MAX RATED POWER ^f (mW/mm ²)	436	871	968	944	300	360	190	17
QUAN-TECH NOISE (dB)	NA	NA	≤ -10	≤ -10	≤ -10	≤ 2	≤ 5	NA
LASER TRIM (% Δ R) (1000 hours at 150°C)	NA	≤ 0.3	≤ 0.3	≤ 0.3	≤ 0.3	≤ 0.3	≤ 0.4	≤ 0.5
TERMINATION OF CALIBRATION	ESL 9693-S							

Some supplier can build 100 Mohms/sqr pastes

Polymer resistive pastes

www.electrapolymers.com

<u>Product</u>	<u>Surface resistance</u>
----------------	---------------------------

ED7500 - 1Ω	1Ω□ ⁻¹
ED7500 - 10Ω	10Ω□ ⁻¹
ED7500 - 100Ω	100Ω□ ⁻¹
ED7500 - 1kΩ	1kΩ□ ⁻¹
ED7500 - 10kΩ	10kΩ□ ⁻¹
ED7500 - 100kΩ	100kΩ□ ⁻¹
ED7500 - 1MΩ	1MΩ□ ⁻¹

TECHNICAL DATA SHEET

ELECTRA²D'OR
ED7500 SERIES

PASTES for FIXED RESISTORS and
POTENTIOMETERS on RIGID CIRCUIT BOARDS

Curing:

ED7500 may be cured in a convection oven or by using IR radiation.

Typical Cure Schedules are:

Convection oven:

30 mins at 150 - 200°C

IR tunnel oven

6 mins at 200°C

1 Mohms/Sqr seems to be the limit for these polymers

Polymer Resistive foils



The miracles of science™

Constructions

100XC10E7 is our standard offering for anti-static applications. It is a one mil film with a nominal surface resistivity of 5 mega ohm/sq. Two grades are available as described in **Table 2**. Custom constructions are also available, and can be produced in thickness from 1 to 5 mil, and with surface resistances from 90 to 10^9 ohms/sq.

Table 2
Electrical Properties of Kapton® 100XC10E7 and 100XC10E5 Polyimide Film

Property	Typical Value	Test Method
Film Type 100XC10E7		
Surface Resistivity Aim, mega ohm/sq.	5	ETS 870 electrometer at 100V
Resistivity Range, avg, mega ohm/sq.	.5-50	
Film Type 100XC10E5		
Surface Resistivity Aim, mega ohm/sq.	5	ETS 870 electrometer at 100V
Resistivity Range, mega ohm/sq.	0.1-1000	



Other products



[Conductive TPES - Thermoplastic Elastomer Plastic Compounds - RTP Company.url](#)



[AI Technology, Inc. - ESD Protection Coatings & Materials.url](#)



[ESD EMI Engineering Corporation.url](#)



[Thermoplastic compound conducts electrical charge, Cover Story, Jobwrex.url](#)



THE RED BOOK

 **SHELDahl** Brand Materials

October 2010

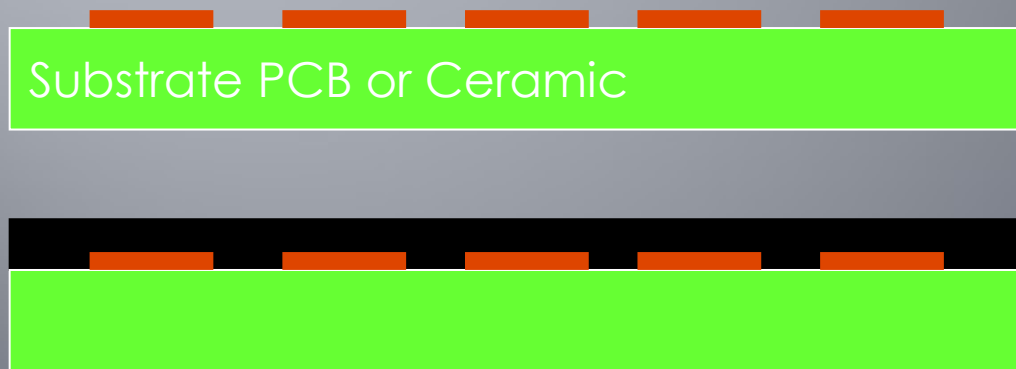
Selection guide

- ▣ **Substrate**
 - **Thin film**
 - ▣ **Mineral materials: Ceramic, glass, silicon, metals**
 - ▣ **Polymers**
 - **Thick film**
 - ▣ **Mineral materials: Ceramic, glass, silicon, metals**
 - **Polymers**
 - ▣ **All type**

Selection guide

- ▣ -High values
 - Thick-film on ceramic (up to 1-10 GOhms/sqr)
 - Thin-film on polymer (antistatic material 10G-100GOhms/sqr)
 - Polymer patterned layers
- ▣ -Precision
 - Thick film on ceramic (up to 1 GOhms/sqr)
 - Thin film low values (up to 100kOhms/sqr)
- ▣ -Large size
 - Polymers
 - Thin-film on polymers

Full Resistive I



-Type:





Thin film
Thick film
Resistive polymer

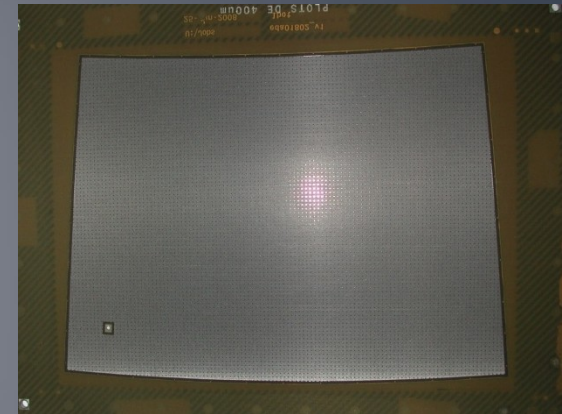
-Deposit:

Vacuum deposit*
Painting
Screen printing
Spraying*

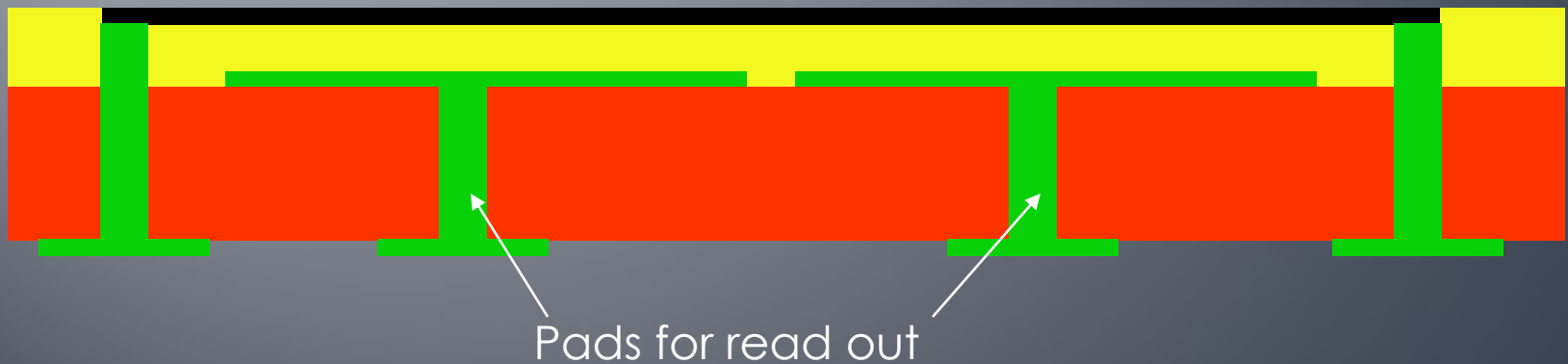
* Not made at CERN

FULL RESISTIVE II

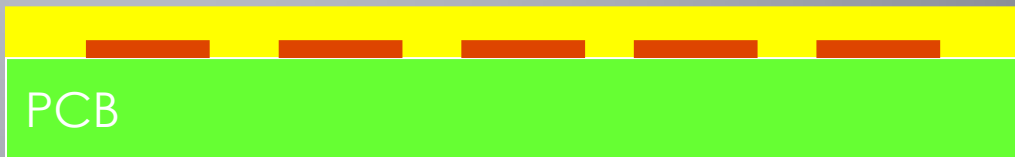
-  Copper
-  Dielectric: polymer or ceramic
-  PCB or ceramic
-  Resistive layer (all types)



200mm x 150mm
Bulk Micromegas with
Full Resistive layer



Patterned resistive layer

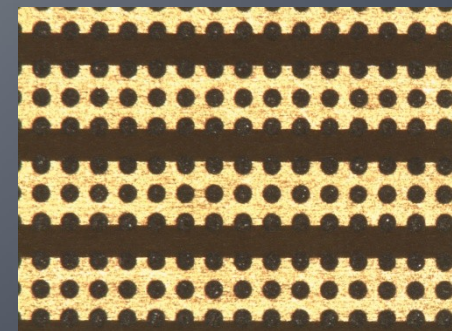
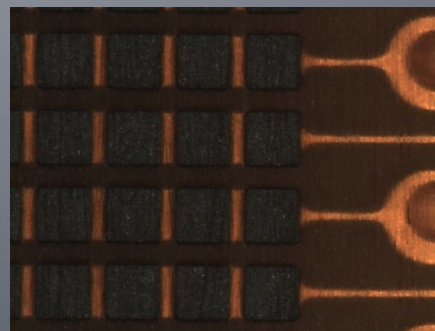
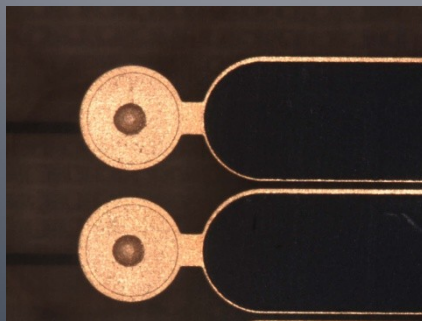


All resistor type but needs:

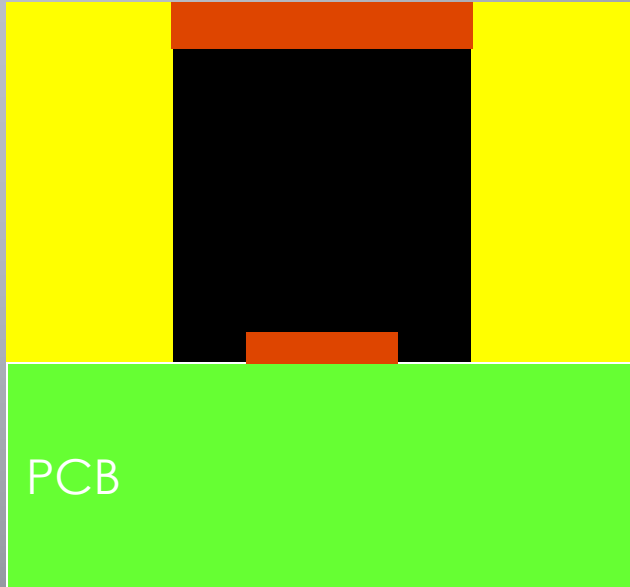
-photolithography

-and/or Wet etch

-and/or laser ablation



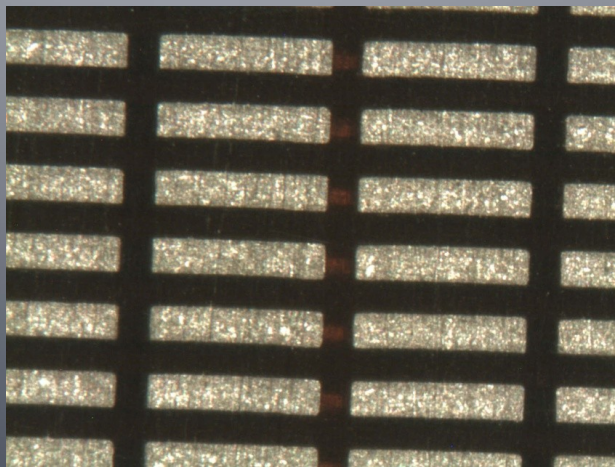
Thick and plated



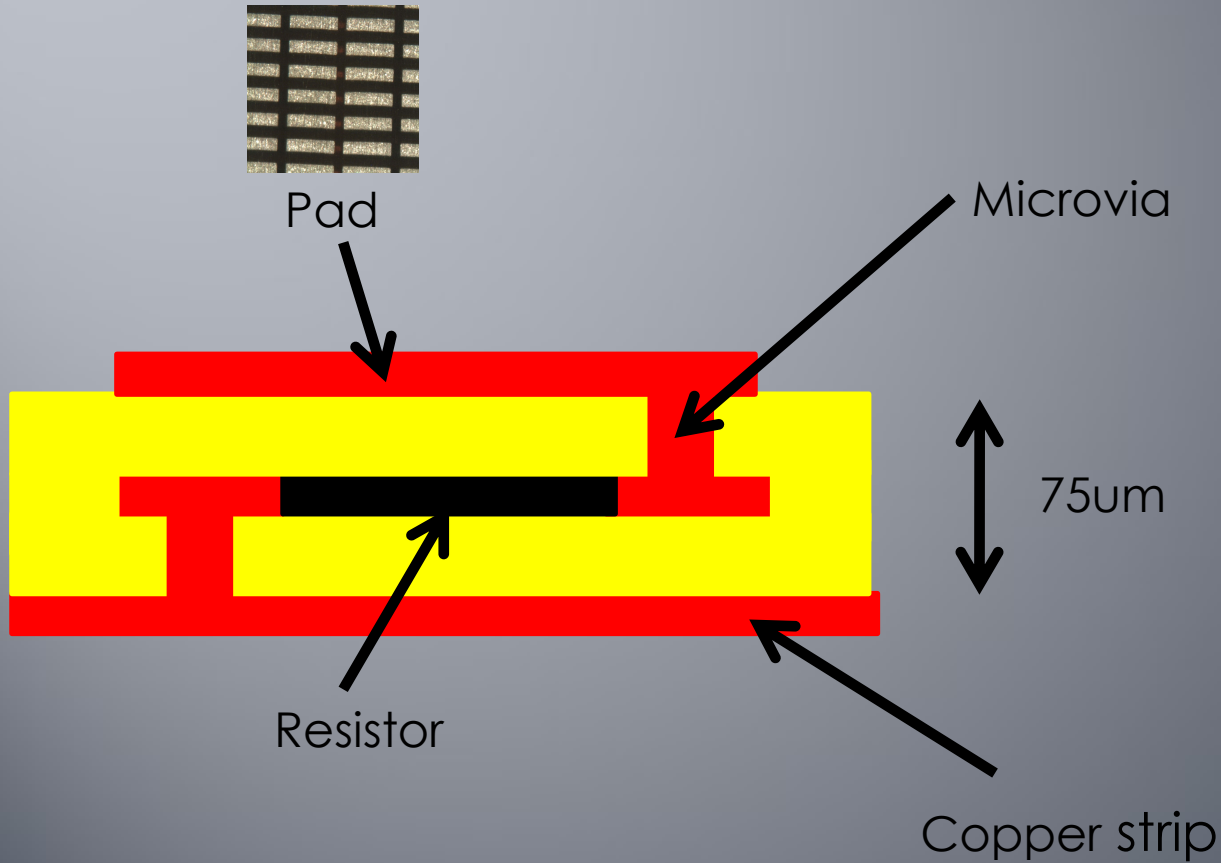
Only Polymer resistors

-Thicknesses up to 200um

-Silver based glues for the top

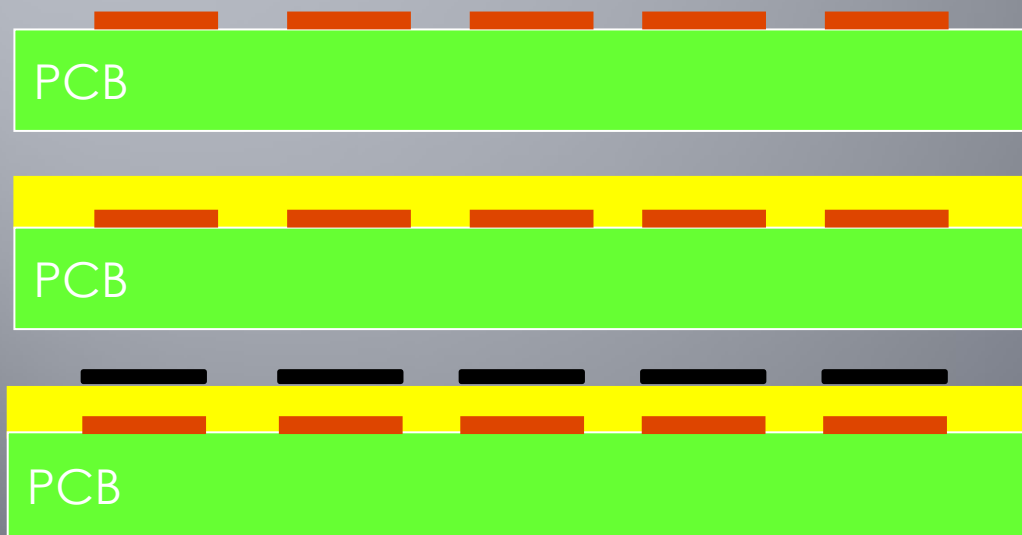


Embedded



- All Resistors types

Resistive strip I



All resistor type but needs:

-photolithography

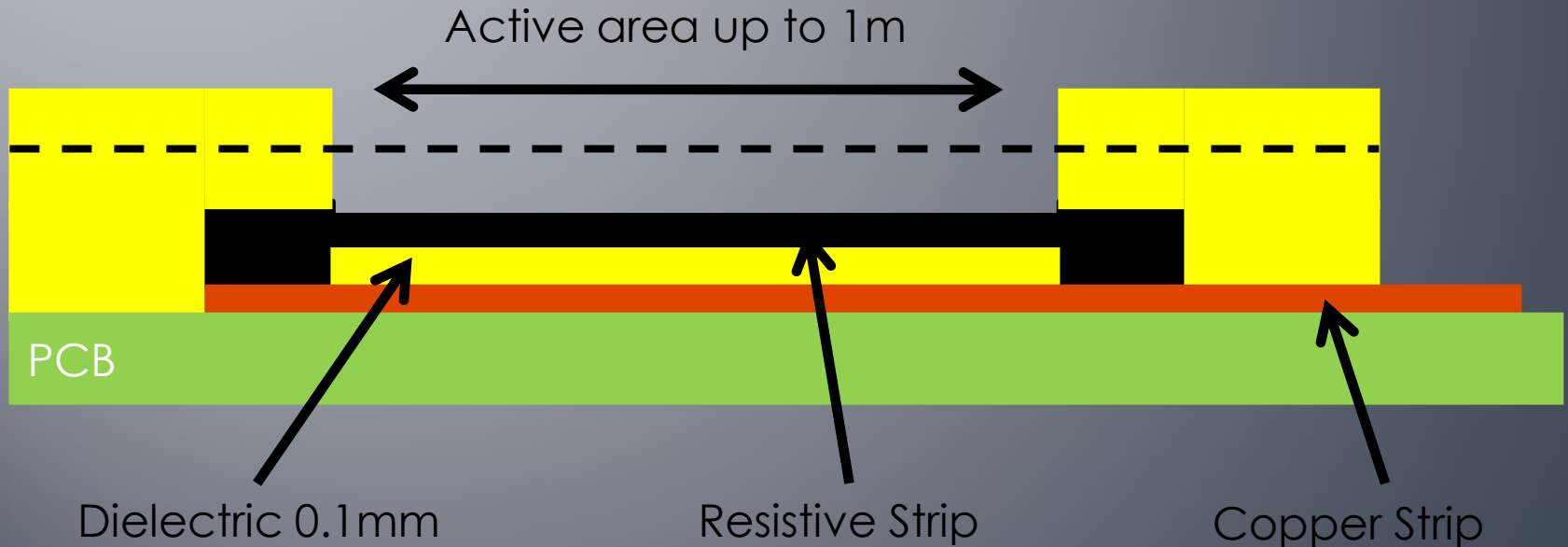
-and/or Wet etch

-and/or laser ablation

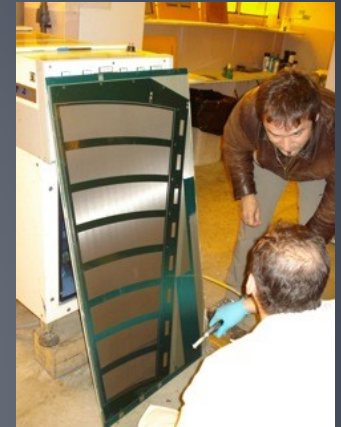
Resistive strip II



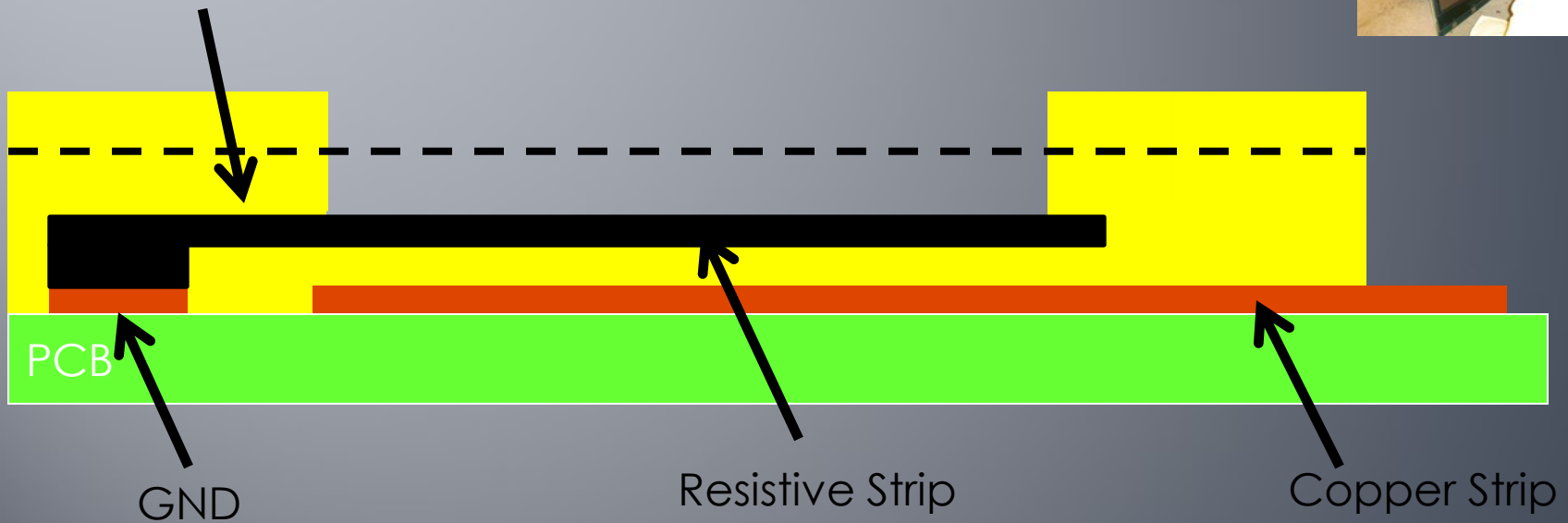
Cross section



Resistive strip III



Embedded resistor



Thank you