Embedded Passive Components

Trend & Applications

Aliza Mizrachi

Presentation Purpose :

Providing general overview of different technologies types.

Introduce various of advantages and disadvantages.

Agenda

Background

Several Options for Embedded Passive Technology in:

** Resistors

** Capacitors

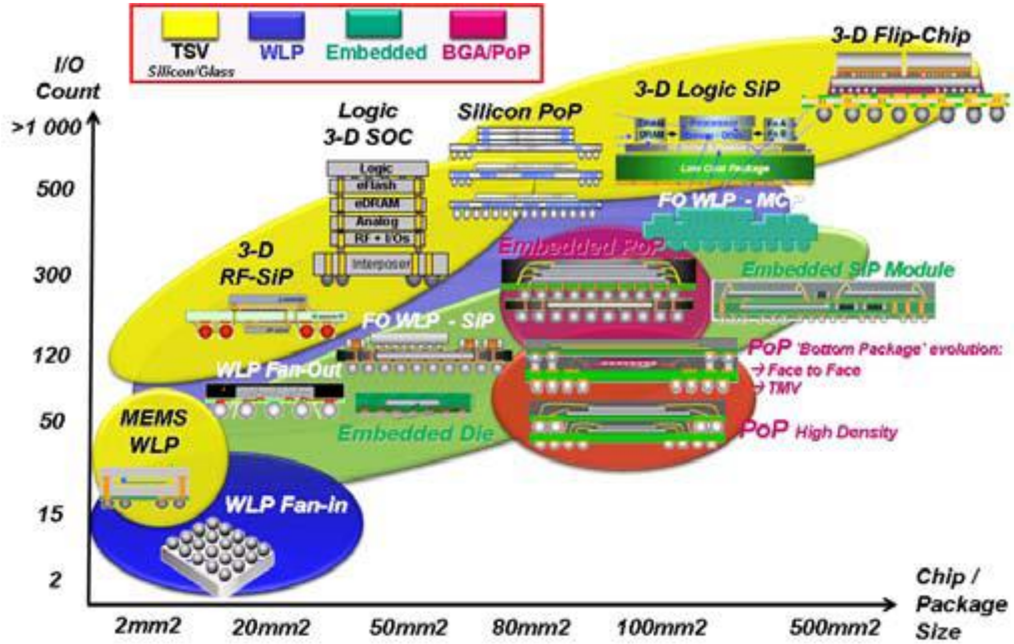
** Inductors

Advantage

Disadvantage

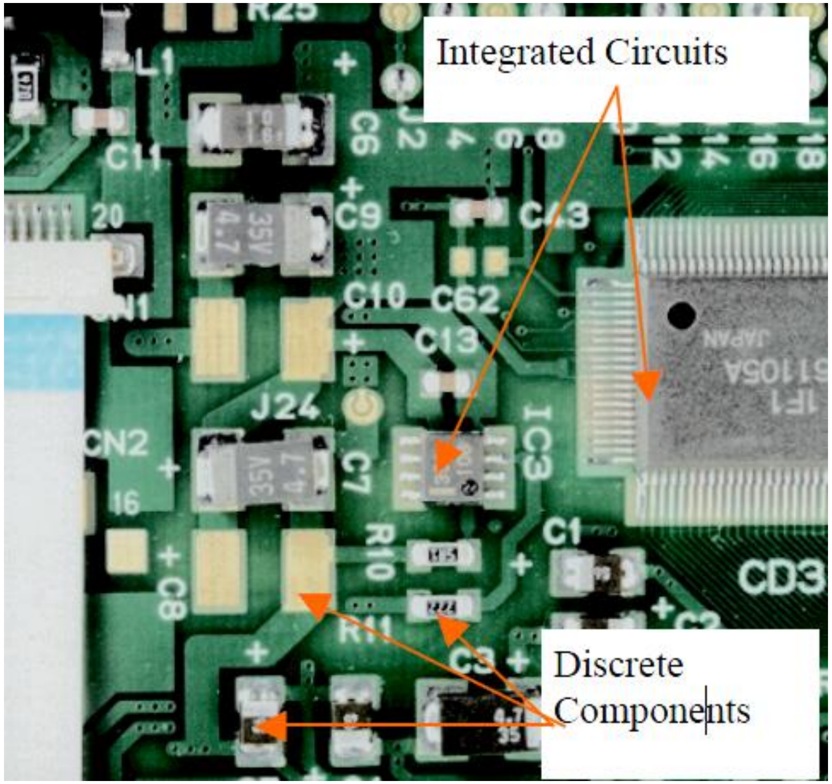
Embedded Passive Components

Passive components technology has a strong potential to meet the requirements of a large spectrum of applications.



Embedded Passive Components

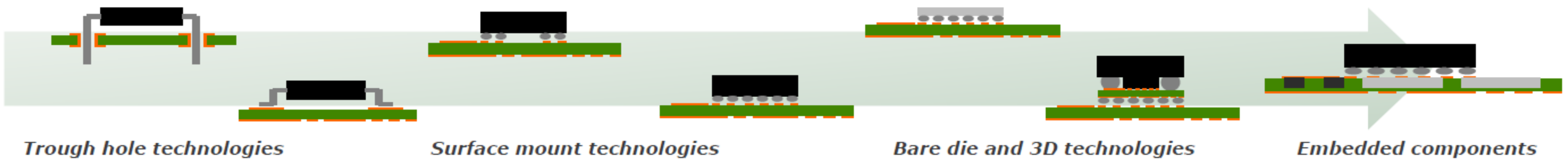
Today in a typical PCB , over then 70% are passive components:
Capacitors, Resistors, Inductors which is reduces the area for functionality.



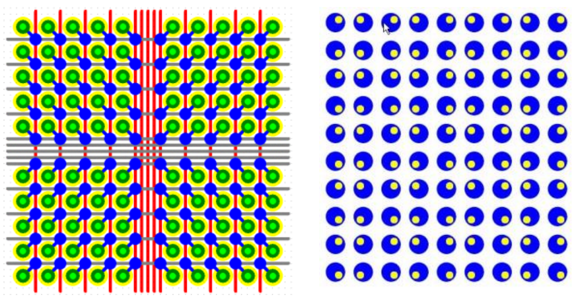
Embedded Passive Components

Products required to be smaller without reducing the functionality.

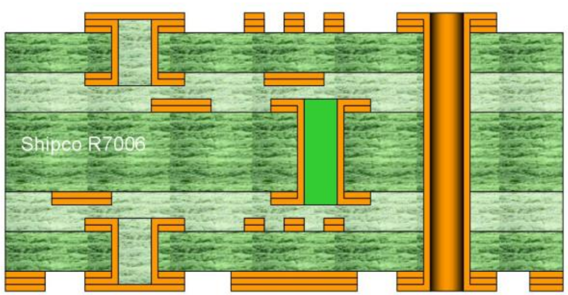
Over the years technologies moved from T.H to SMT both sides, Bare Die and now embedded components.



T.H via changed to via in pad when needed.



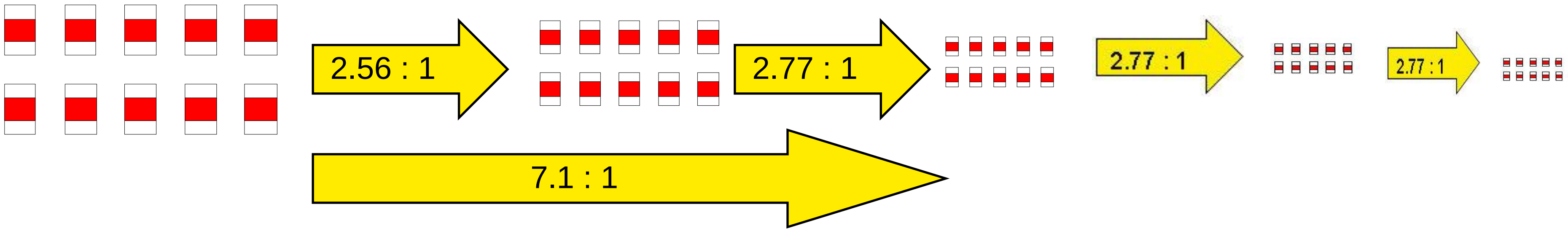
For high density design
technology moved to blind and buried via's.



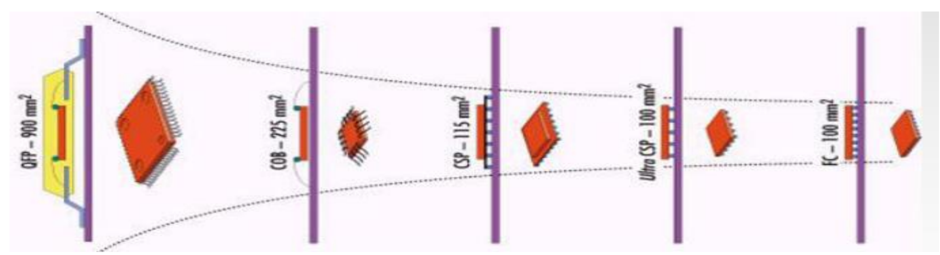
Embedded Passive Components

Electronics industry is always following the process towards increased density and complexity.

0603	0402	0201	01005	0050025
1.6 x 0.8 mm	1 x 0.5 mm	0.6 x 0.3 mm	0.254 x 0.127	0.127 x 0.0635



As well as active components become smaller and smaller for saving space.



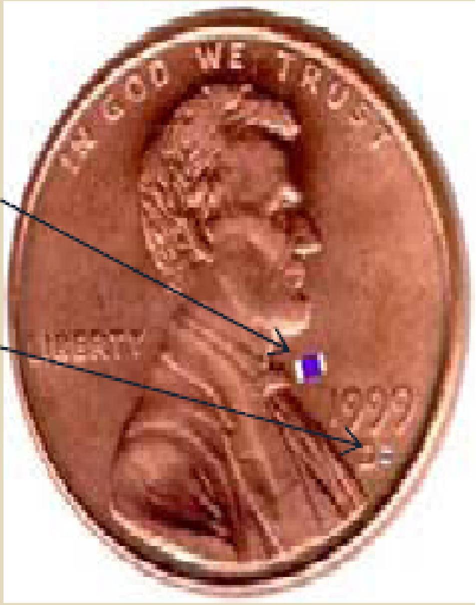
Embedded Passive Components

0402 resistor:

- (It's the same size as President Lincoln's bow tie)

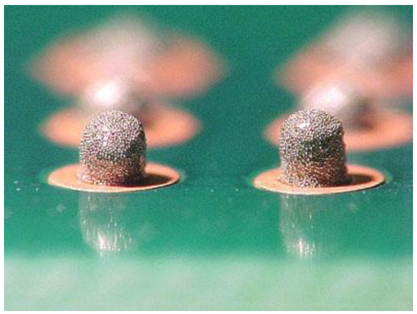
0201 capacitor:

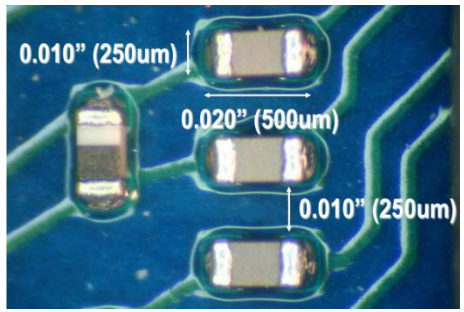
Now inspect 2000 parts like this on one board.

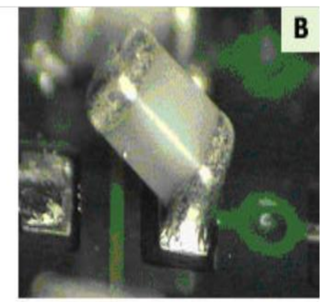


Embedded Passive Components

Placing this tiny component on both surface in high volumes can be a big challenge for reliability.







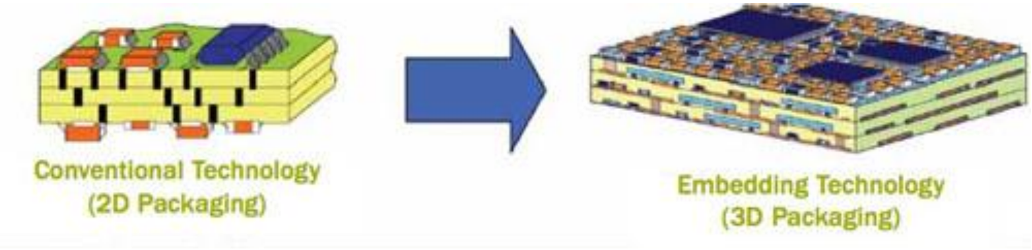
Changing density of electrons in metal when soldering small packages helps to Thomson phenomenon.

The process of this micro-miniature component can demand investing new equipment.

Special nozzle for placing the components.
Re-design of Solder Paste Stencil for better paste release.
Rework process required automation machine.

Embedded Passive Components

Therefore PCB embedding of passive devices, is one of advanced options with a strong potential, to increase functionality without increasing the area of the substrate.



Moving components from surface to inside of PCB frees the surface between 30% - 50%.

It means that the same PCB size can hold new functions,
Or, if there is no extra features or functions to add, total PCB size can be reduced, which is less material wasted.

Embedded Passive Components

<u>The idea of embedding components to save space has been around for 10 years</u>.

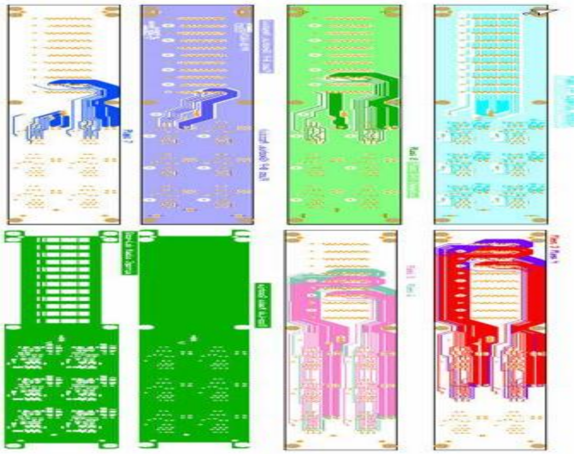
The practice has now really taken off.

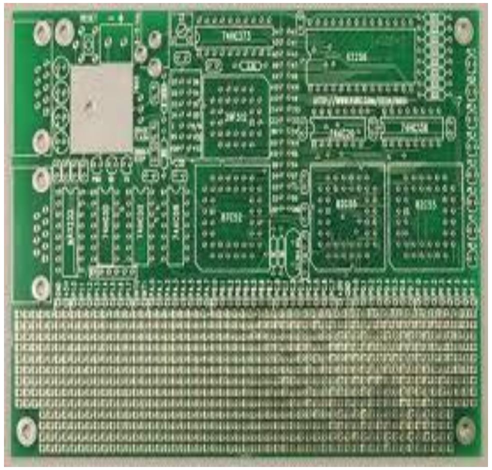
Next generation of mobile/smart phones, need to integrate newer functions in thinner and smaller products.

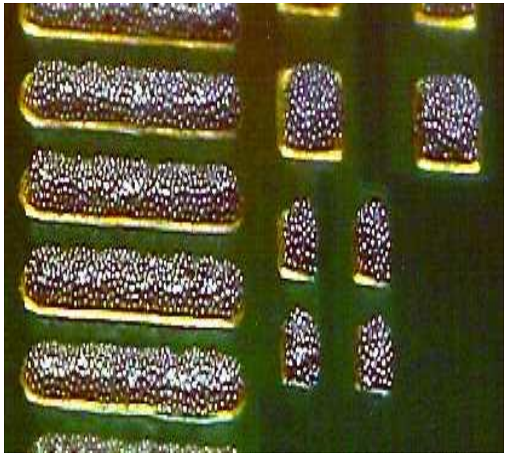
Consumer demand for more functions, features and applications means that passive part counts will only increase in phones that continue to shrink in size.

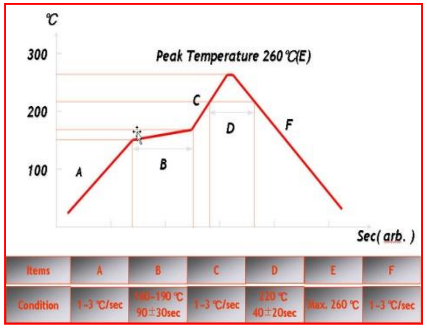
Embedded Passive Components

The traditional process





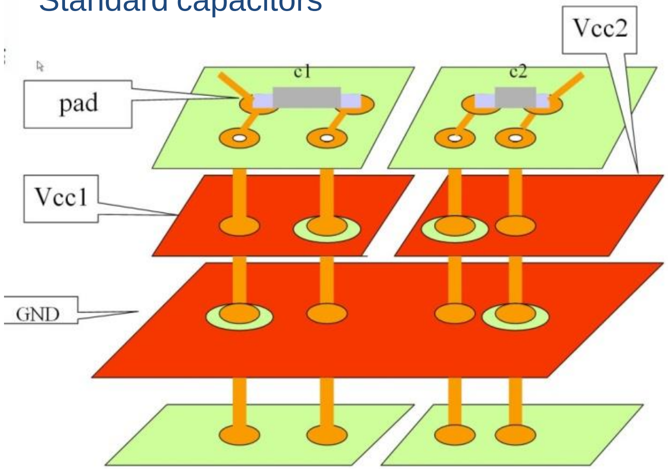




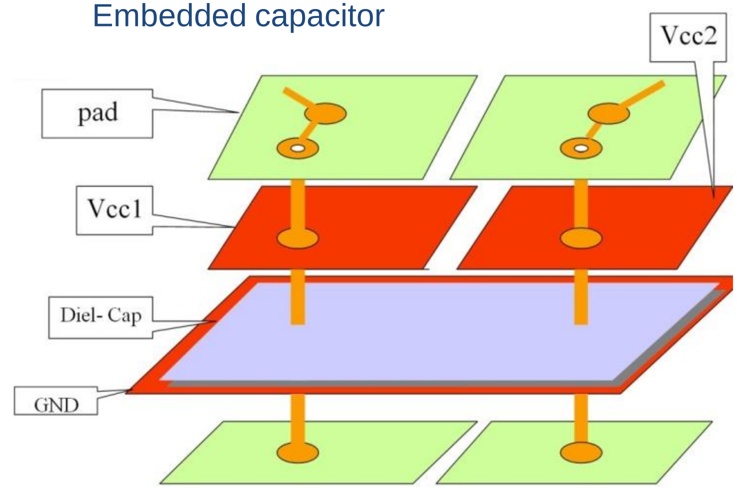
Embedded Passive Components

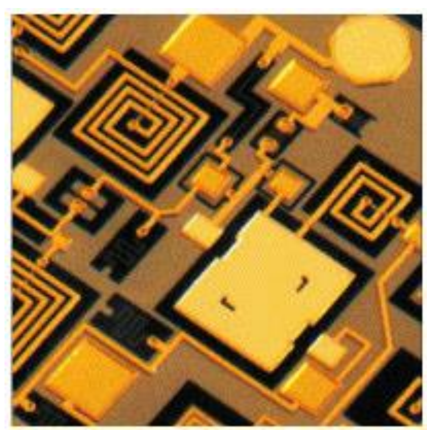
The traditional process compared to embedded

Standard capacitors



Embedded capacitor





Embedded Passive Components

Embedded Passive Standards

- IPC – 4821Specification for Embedded Passive Device Capacitor Materials.

- IPC – 4811 Specification for Embedded Passive Device Resistor Materials.

- IPC – 2316 Design Guide for Embedded Passive Device Printed Boards.

- IPC – 6017 Qualification and Performance Specification for Printed Boards Containing Embedded Passives.

- IPC – 2227 Sectional Design Standard for Embedded Passive Printed Board Embedded Passives.

Embedded Passive Components

** Embedded resistors - Additive Fabrication Technology - Thick Film.

Embedded Passive Technology – Several Options:

** Chip embedded within the substrate - placing chip modules as a components.  

** Embedded - Subtractive Fabrication Technology - Thin Film.

Resistors, capacitors, inductors - each layer separately.

Capacitors & Resistors - (R - C) Laminate.

** Embedded - Additive Technology -Thick Film.

Resistors, capacitors, inductors

Embedded Passive Components

• Chip embedded within the substrate - placing chip modules as a components.

Components are becoming thinner (Avx, Murata etc.)

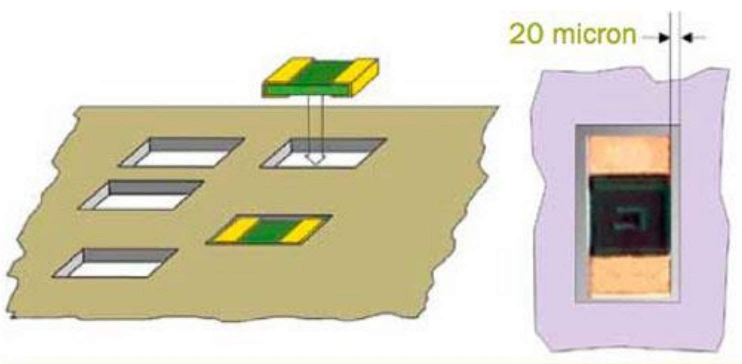
Standard: 

 Copper leads thin comp.

Great similarity between placing a chip modules or placing a component.

Component manufacturers are already produce thin components for this purpose.

Traditionally pick & place equipment with adaptation moved:
from SMT assembly industry to PCB manufacturing industry.



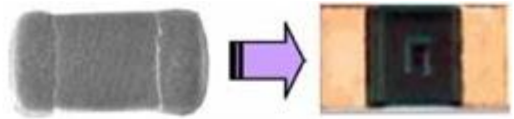
Assembl'eon Machine

Components placed on substrates, these required great accuracy of repeatability and reliability.

Embedded Passive Components

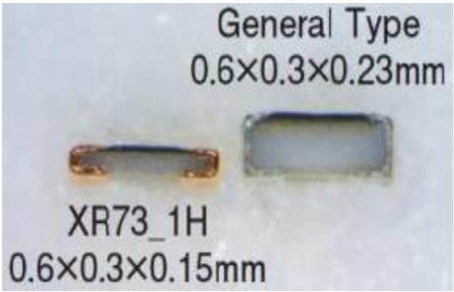
• Chip embedded within the substrate - placing chip modules as a components.

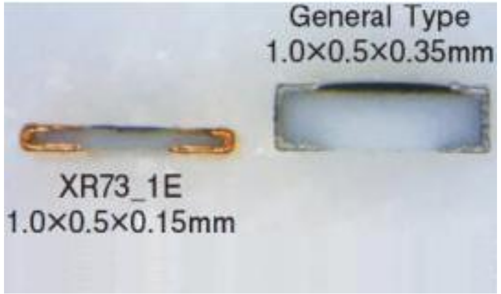
substrate should be absolutely flat and required support by frame.

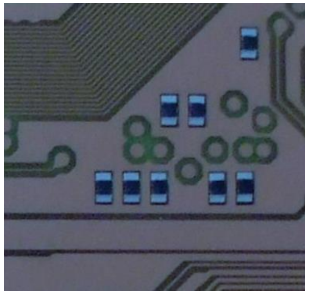


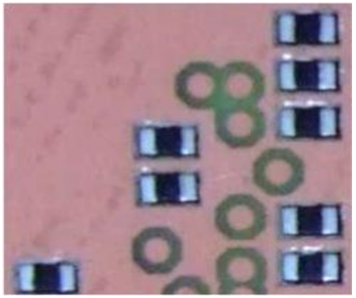
To prevent stress, or micro-crack on PCB which is 400x500 mm size and 0.3 mm thickness.

Connection between the substrate and components can be by copper or by conductive adhesive
Instead of nickel and tin soldering .









0402 & 0201 components embedded into the substrate

Many traditional pick& place machines will have to adapt to these new components .

Substrates are delivered after AOI (3D) checking to continuation process.

Embedded passive components allow to transfer faster and cleaner electric signals - EMI reduction.

Embedded Passive Components

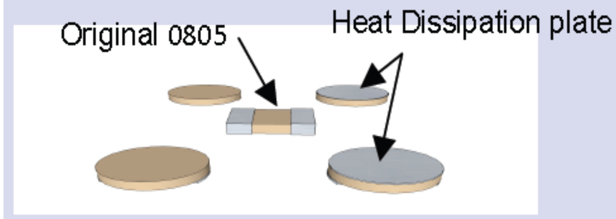
Mulpin Embedded active & passive Technology

Components placed into an opening drilled into the PCB.

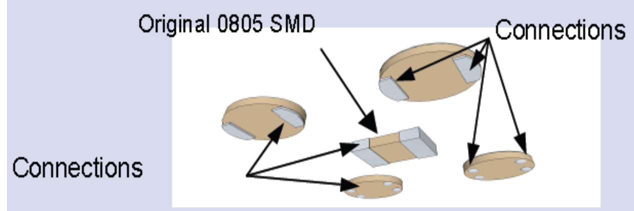
Similar to SMT components placement but on more than one layer.

Pick & place machine and reflow.

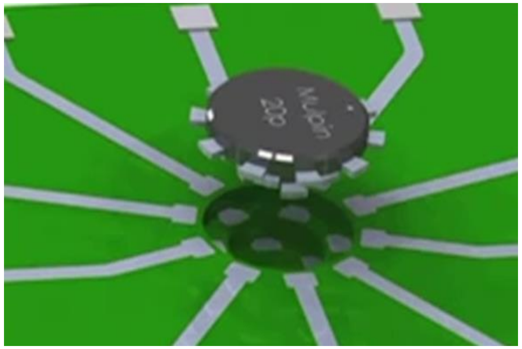
Much better heat dissipation which improve reliability and safety.

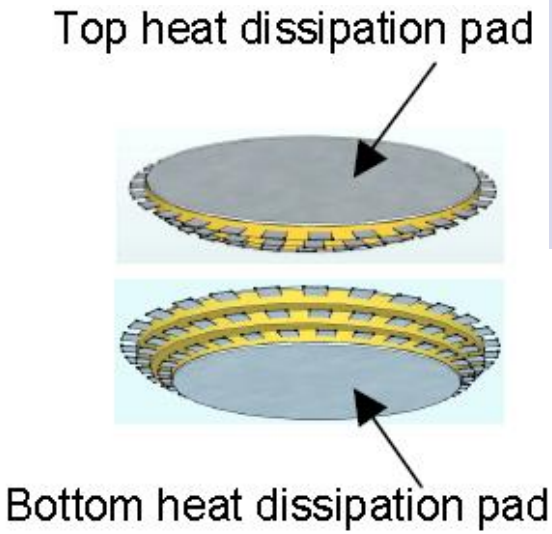


Mulpin Passive Component 0805 replacements top view

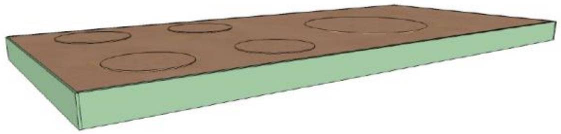


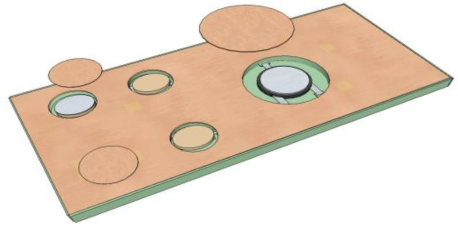
Mulpin Passive Component 0805 replacements bottom view





96 connections over three PCB layers

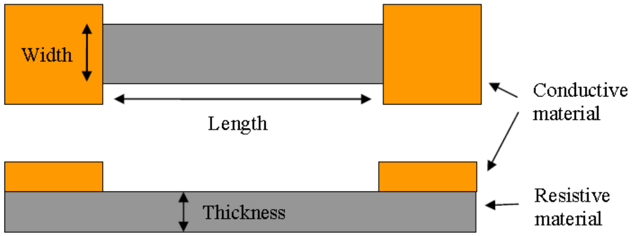




Embedded Passive Components

Currently….

Resistor - contains a strip of the resisting material, with two conducting pads at the ends.



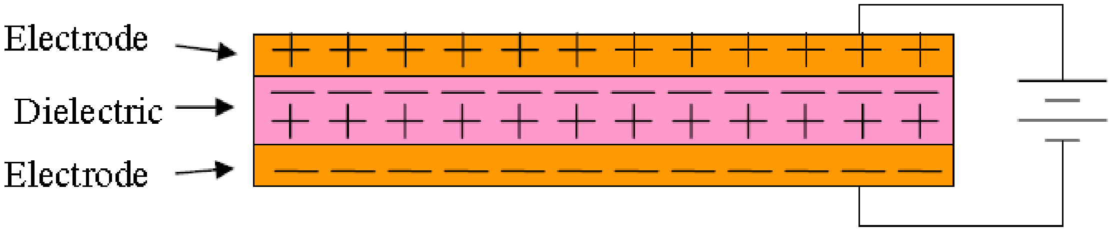
Resistors made from coal, electricity passing through the coal encountered opposition.

Resistance size determined during manufacturing.

Capacitor - contains two conducting metal plates separated by an insulator or dielectric material.

Capacitors made from tantalum, ceramic, plastic metalized etc.

When a voltage is applied, electric field passing negative charges to one electrode, and positive charges to the other electrode.



Embedded Resistors

Embedded Passive Components

** **Subtractive** Fabrication Technology - Thin Film (Resistors)

Process is similar to the most PCB’s fabrication method:
Imaging, Electroplating and Etching process.

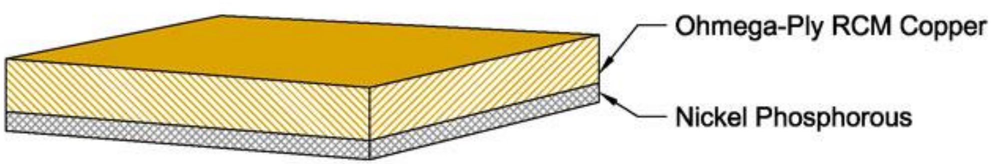
Copper laminate is used as a basis for electrical interconnection.

A laminate supplier provides a copper foil sheet with a thin resistive layer.

The resistive material has a resistance in terms of “Ohms/square”.

Sheet resistance between 25 - 250 Ω/sq with low TCR (Temperature Coefficient of Resistance),

Result of tolerance after etching is 8%-16%.



Example resistive material

Embedded Passive Components

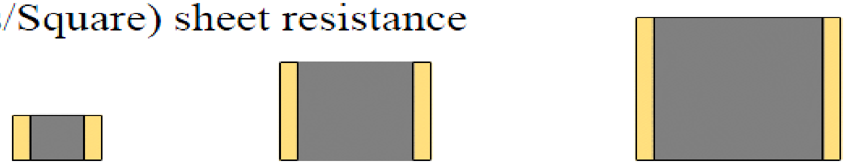
Basic Design Overview

Sheet resistivity (stated in Ohms per square) is dimensionless

- A square area of resistive material = sheet resistivity of resistive material

  E.g., a 25 Ω/(Ohms/Square) sheet resistance

The Same Ratio L/W
Same value



L1 = W1	L2 = W2	L3 =W3
N1 = 1	N2 = 2	N3 =3
R1 = 25 Ohms	R2 = 25 Ohms	R3 = 25 Ohms

- Resistor value = sheet resistivity x ratio of element length to width (R =Rs x L/W)

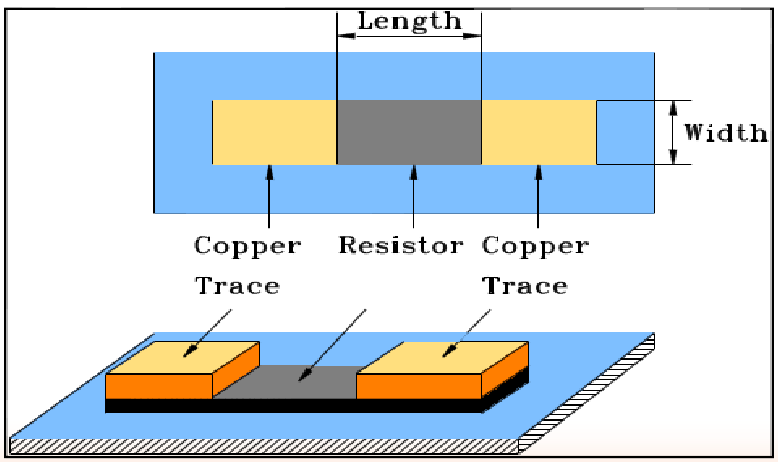
  E.g., a 25 Ω/ sheet resistivity

  Length = 0.030” (30 mils)

  Width = 0.015 “ (15mils)

  Resistor value = 25 Ω/ x (30mils/15mils)

  = 25 Ω/ x 2 squares = 50 ohms

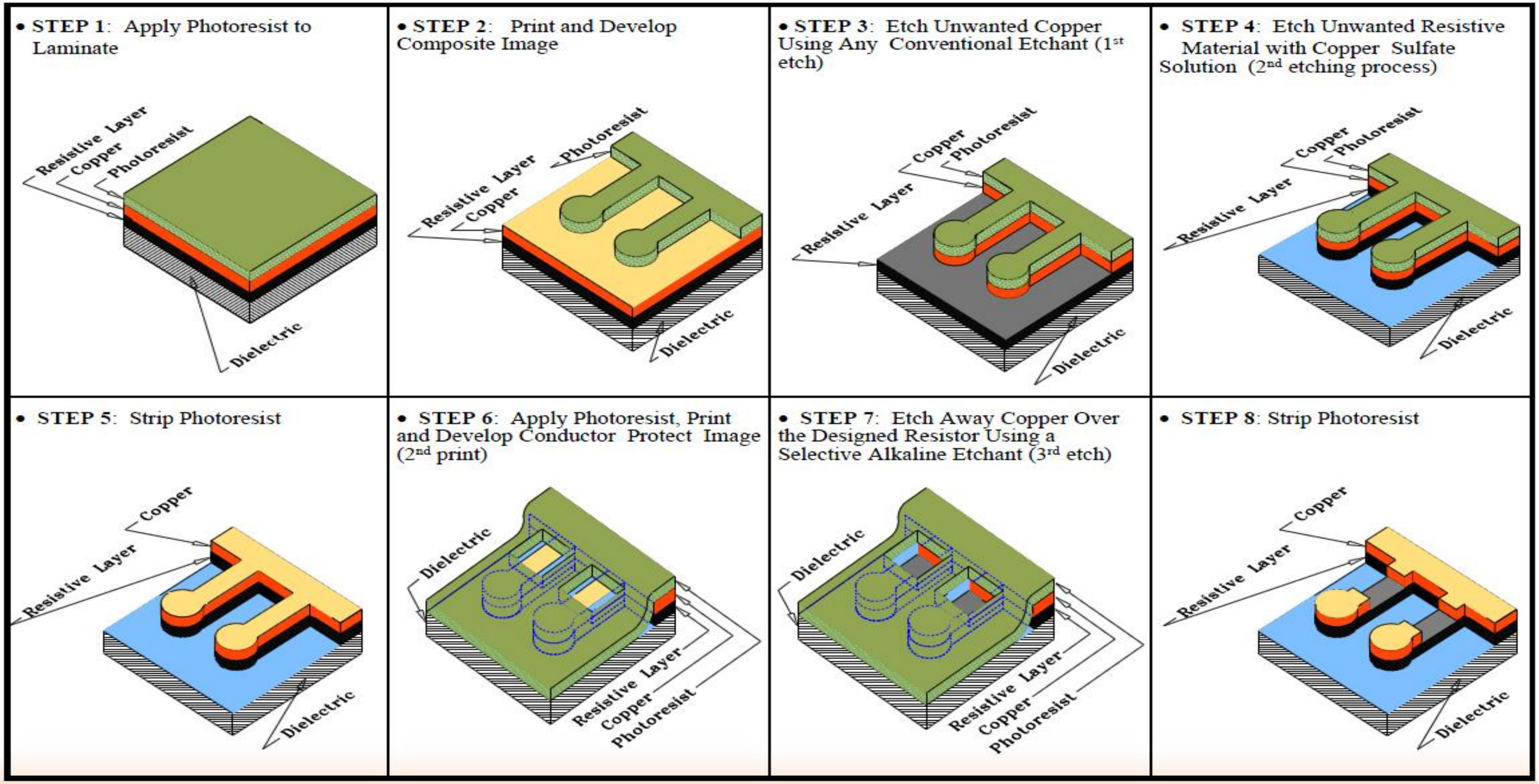


Embedded Passive Components

** **Subtractive** Fabrication Technology - Thin Film (Resistors)

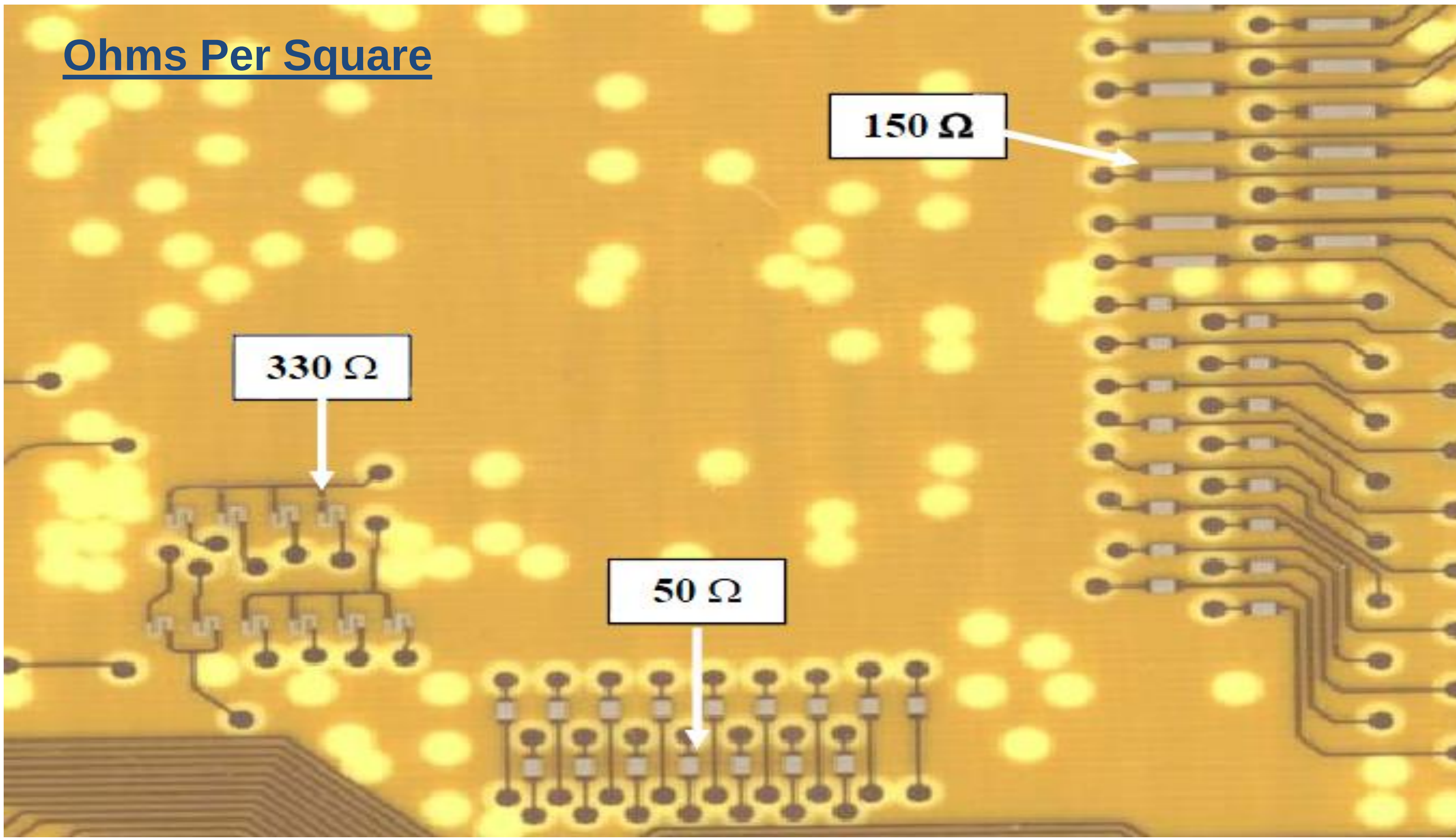
The Processes Step by Step – About 85% of copper is removed.

High of energy is needed (Long process) during the manufacturing - similar to surface PCB process.



Embedded Passive Components

** **Subtractive** Fabrication Technology - Thin Film (Resistors)



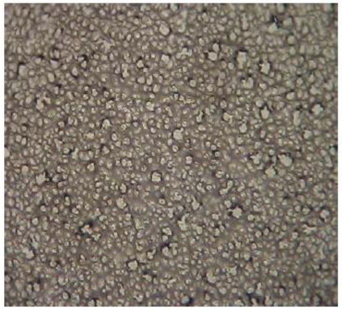
Embedded Passive Components

** **Subtractive** Fabrication Technology - Thin Film (Resistors)

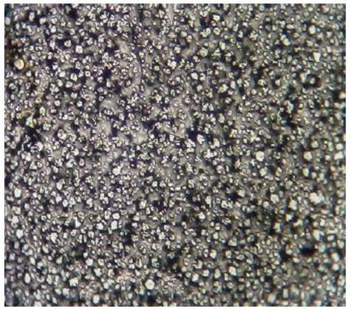
OhmegaPly® Laminate Recommended Copper Type:

Sheet Resistivity	Material Tolerance
10 Ω/□	3%
25 Ω/□	5%
50 Ω/□	5%
100 Ω/□	5%
250 Ω/□	10%

TOCIII	PT	DFF
PTFE	Hi T_g Epoxy	Ohmega/Faradflex ®
Rogers Duroid®	Polyimide	BC12
Arlon CLTE	Lead-Free	BC8
Ohmega/Faradflex ®	Rogers 4003	
BC24	Ceramic-Filled	
BC16	LCP (Rogers Ultralam 3850)	
Flex		



1R25 with TOCIII COPPER FOIL at 200X



1R25 with PT COPPER FOIL at 200X

1R25 with DFF COPPER FOIL at 200X

orbotech Be Sure™

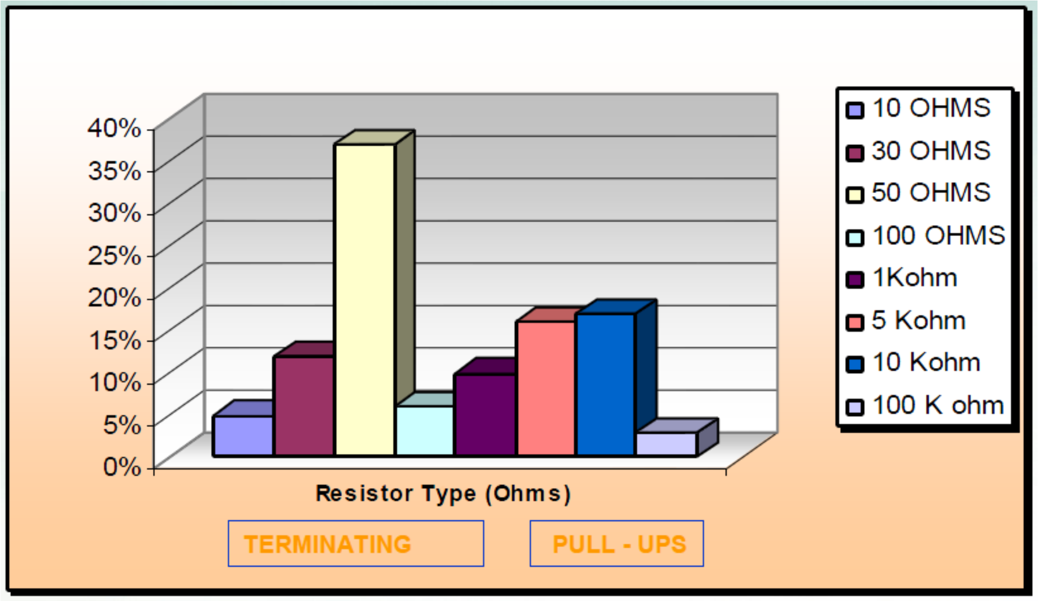
Embedded Passive Components

** **Subtractive** Fabrication Technology - Thin Film (Resistors)

Normal Values - 10 Ohm to 25K Ohm.

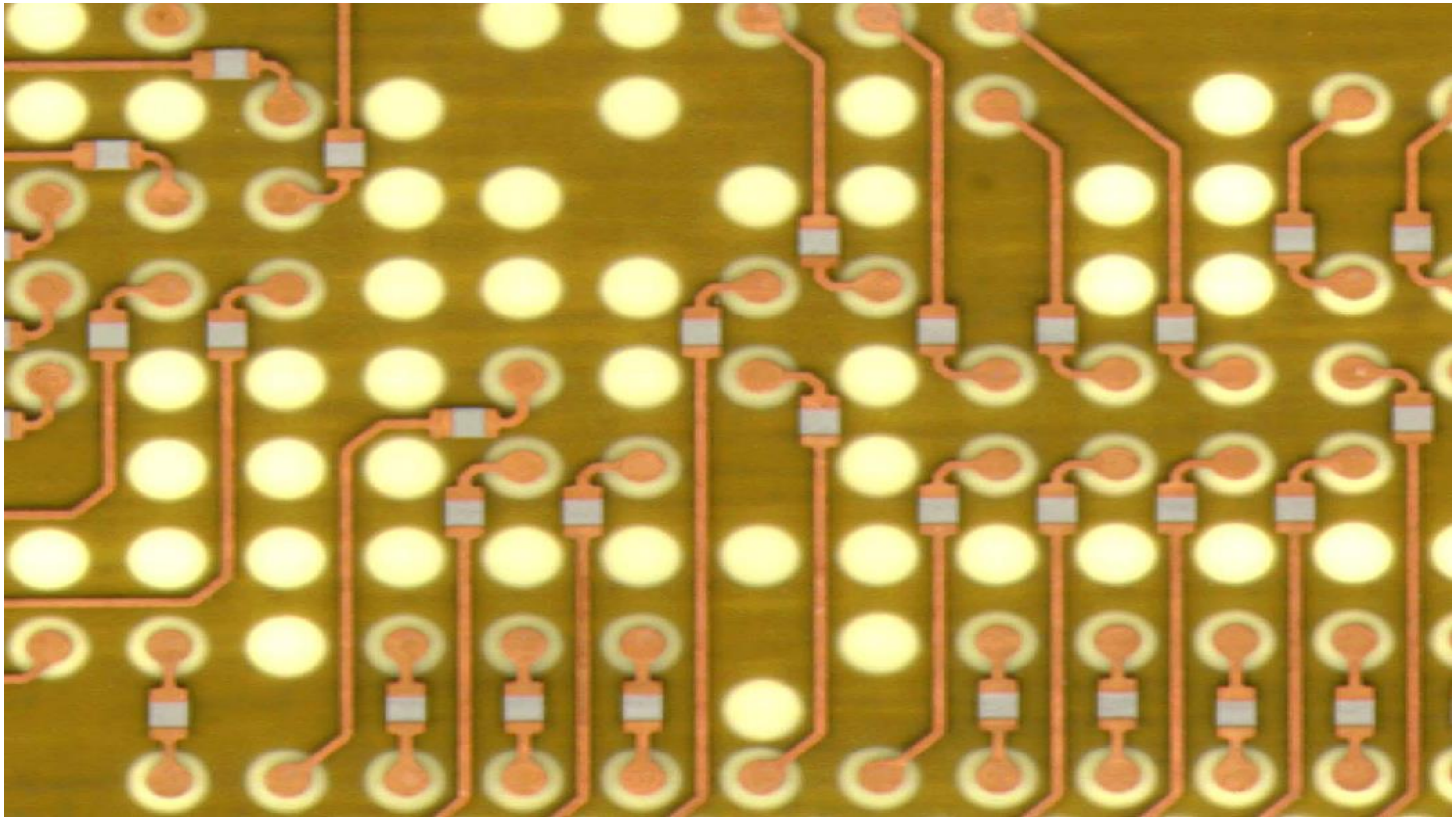
Generally for Termination and Pull-Up/Down.

Can be Excellent in Analog PCB's.



Embedded Passive Components

Series termination resistors for telecom switching card



Embedded Passive Components

** **Additive** Fabrication Technology - Thick Film (Resistors)

Screen printing is an additive technique used to apply materials:
(Conductors, Resistors, Dielectrics) in paste-form to a substrate in defined patterns.

No Imaging, electroplating and etching.

Metal is only pasted where needed; Technologies are based on Screen Printing.

Screen is made of precision woven wires, typically 200 - 400 MESH (wires/inch)

Photographic emulsion is attached to the screen and openings created.

Conductor paste contains metal powders and binders.

Leading types of materials : Ceramic-metal nanocomposites, Carbon filled polymers.

Other common metals potential for Thick - Film: NiCr, **NiCrAlSi**, CrSi, TiNxOy, TaNx. (N-Nitrogen)

Leading companies that provide the materials: Ohmega-Ply, MacDermid, DuPont Interra, Gould TCR.

This Process reduce the number of steps in PCB's manufacturing.

Embedded Passive Components

** **Additive** Fabrication Technology **-** Thick Film / **Overview of resistor process**

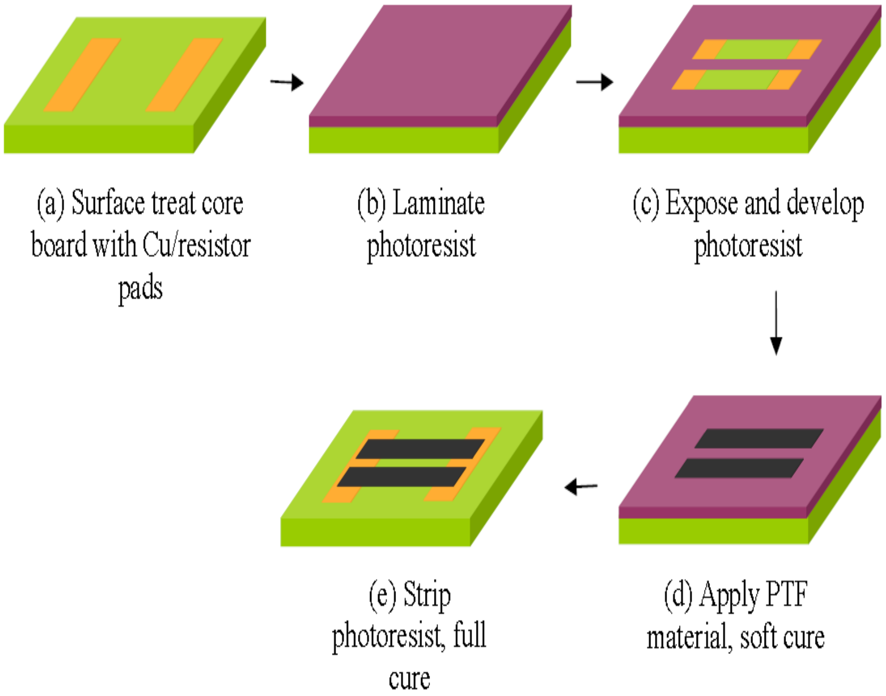
a. Laminate cleaned by (acetone), microetched for adhesion improvement.

b. Applying dry film photoresist 30 µm thickness on vacuum laminate to create a deep resist trace.

c. Resist traces are UV exposed
with a negative mask and developed.

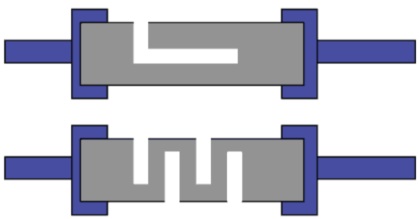
d. Apply material by screen printed
(for example Carbon ink), into developed
negative pattern of the resist trace.

e. baking 150°C for 1 hour
to complete resistor process.

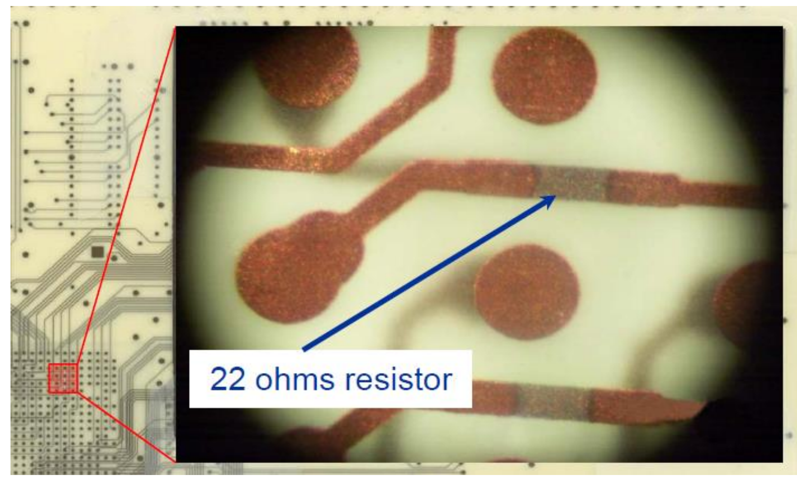


Embedded Passive Components

** **Additive** Fabrication Technology - Thick Film (Resistors)



Finally laser Trimming process is used to achieve 1% tolerance.



Quality and strength of conductors adhesion to a substrate should be wider than subtractive (8-10 pounds per inch).

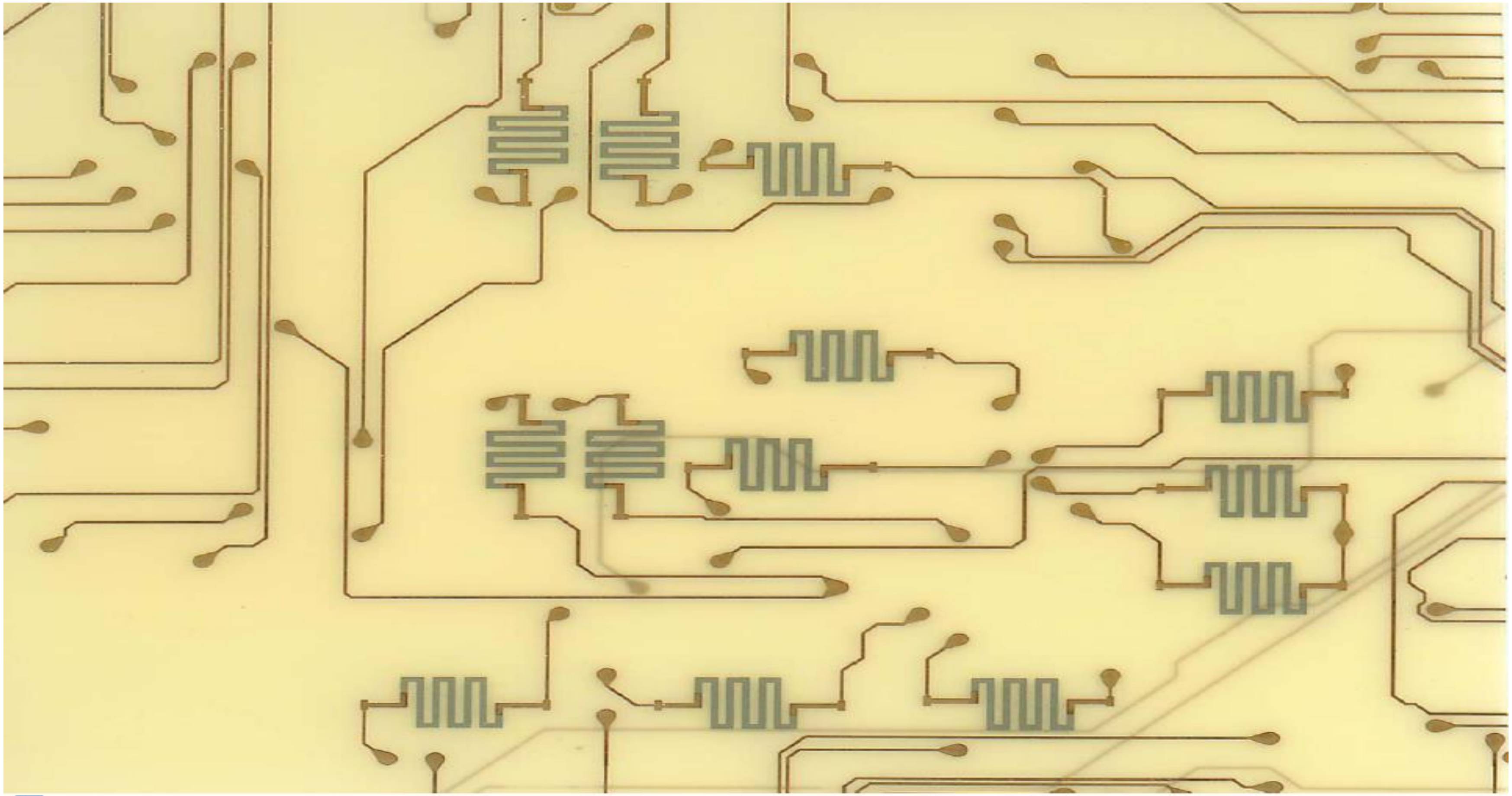
$$R = \rho * (L / A)$$

$$R = \left(\frac{ohms}{square}\right) * \left(\frac{L}{W}\right)$$

Calculation method

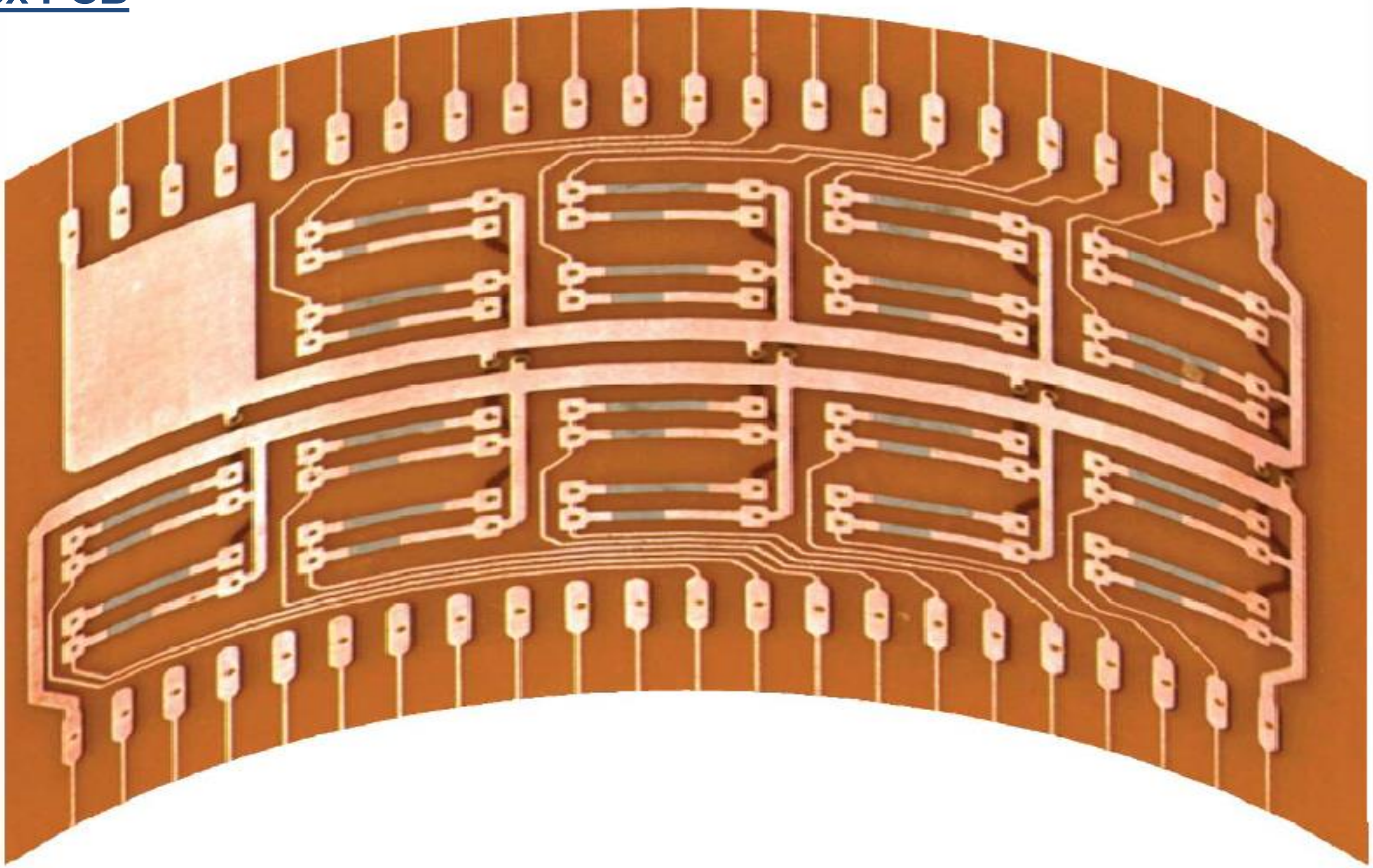
Embedded Passive Components

Pull-up Resistors



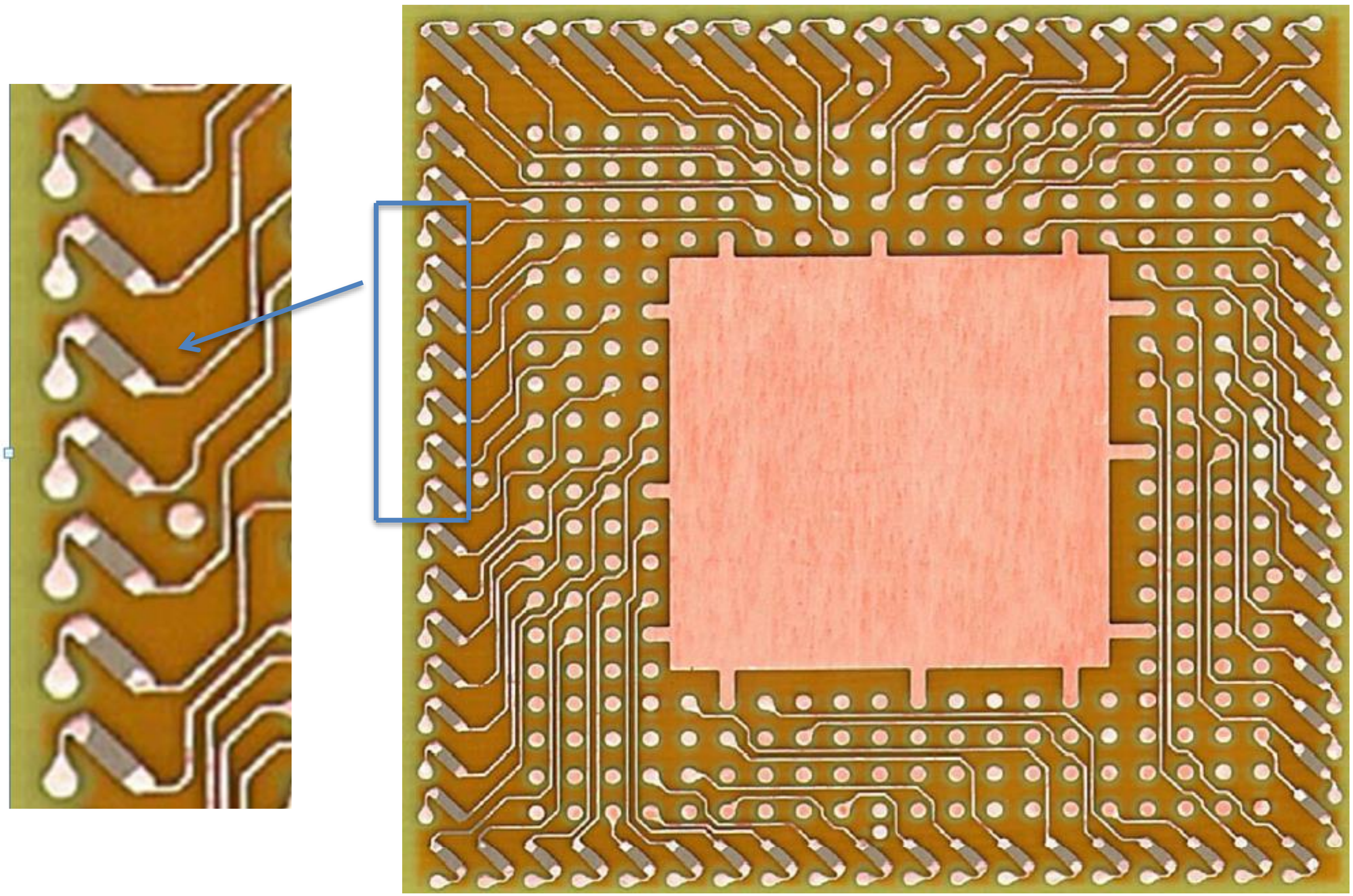
Embedded Passive Components

Resistors in Flex PCB



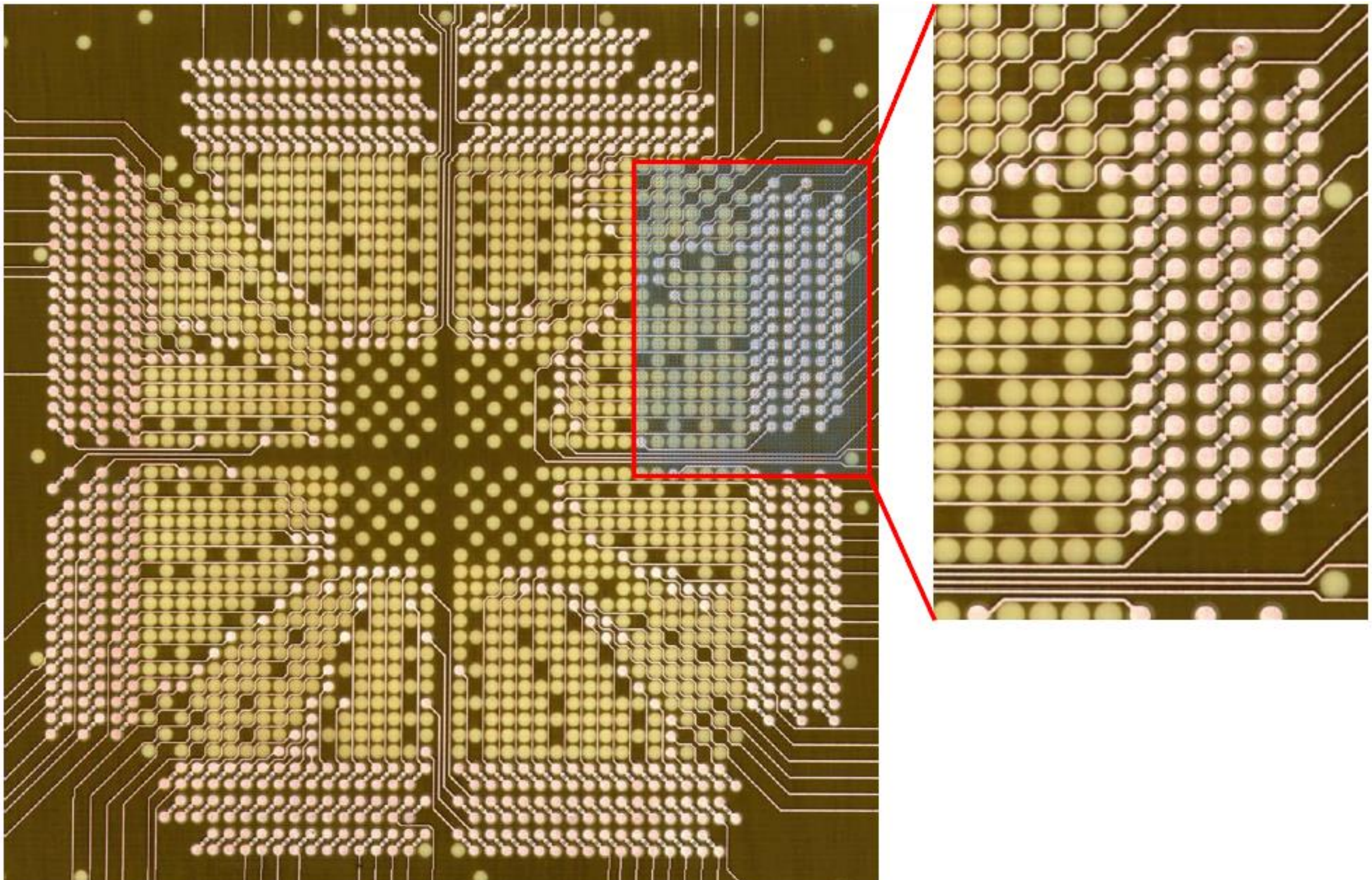
Embedded Passive Components

Fan-out layout of series termination in a BGA package



Embedded Passive Components

Fan-out of series termination resistors in a HDI layout with Micro BGA



Embedded Passive Components

Resistor footprints calculation for different type of sheet resistivity.

A - DESIGN SPECIFICATION

Please enter the resistance value ***(R)*** in Ohm, power rating ***(P)*** in milliWatt, and *maximum* tolerance ***(t)*** in percent for each desired resistor (R_1, R_2, R_3, R_4 & R_5) in table 1 below, and exit the cell to allow the program performs the calculations.

	R_1	R_2	R_3	R_4	R_5
Resistance Value ***(R)*** in Ohm	10	25	50	100	250
Power Rating ***(P)*** in mW	20	62	65	125	250
Maximum Tolerance ***(t)*** in %	7	11	15	15	20

Table 1. For designer to enter the resistance, power rating and percent tolerance values of desired resistors

B - RECOMMENDED MINIMUM WIDTH AND LENGTH OF DESIRED RESISTORS

Sheet Resistivities (Ohm/Sq.)	R_1			R_2			R_3			R_4			R_5		
	W_1 (Mil)	L_2 (Mil)		W_2 (Mil)	L_2 (Mil)		W_3 (Mil)	L_3 (Mil)		W_4 (Mil)	L_4 (Mil)		W_5 (Mil)	L_5 (Mil)	
10	35.0	35.0	t*	12.0	30.0	t*	7.0	35.0	t*	7.0	70.0	P*	7.0	175.0	P*
25	123.0	49.2	t*	23.0	23.0	t*	11.0	22.0	t*	13.0	52.0	P*	13.0	130.0	P*
50	210.0	42.0	t*	35.0	17.5	t*	16.0	16.0	P*	20.0	40.0	P*	19.0	95.0	P*
100	385.0	38.5	t*	58.0	14.5	t*	28.0	14.0	P*	35.0	35.0	P*	32.0	80.0	P*
250	607.0	24.3	P*	770.0	77.0	t*	84.0	16.8	t*	59.0	23.6	P*	53.0	53.0	P*

Table 2. The recommended minimum width and length for each desired resistor which is calculated by the program base on the given values by the designer in table 1.

C - RECOMMENDED RESISTOR FOOTPRINTS

R_s	R_1	R_2	R_3	R_4	R_5
10	Bar Type	Bar Type	Bar Type	Bar Type	Serpentine
25	Partial Square	Bar Type	Bar Type	Bar Type	Bar Type
50	Partial Square	Partial Square	Bar Type	Bar Type	Bar Type
100	Partial Square	Partial Square	Partial Square	Bar Type	Bar Type
250	Partial Square	Partial Square	Partial Square	Partial Square	Bar Type

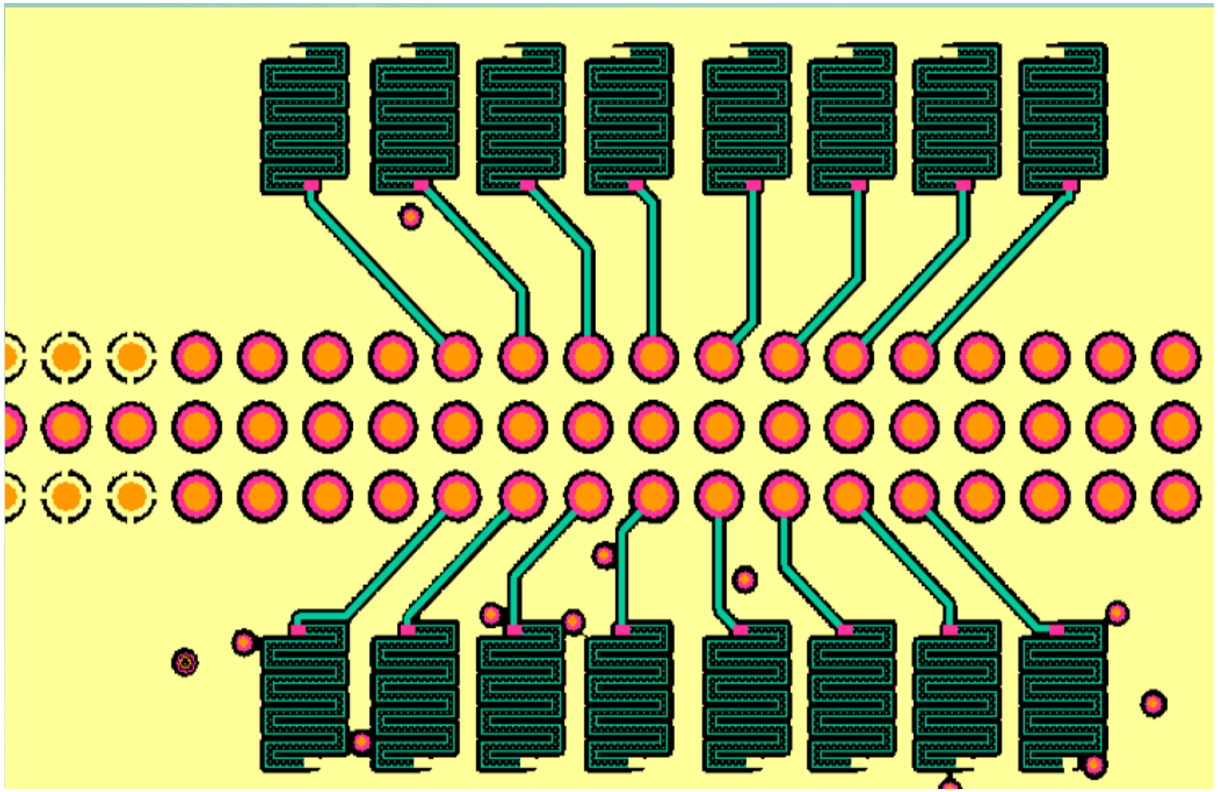
Table 3. The recommended resistor footprints for different type of sheet resistivities

Embedded Passive Components

Standard CAD Layout Tools

Instructions are available in:

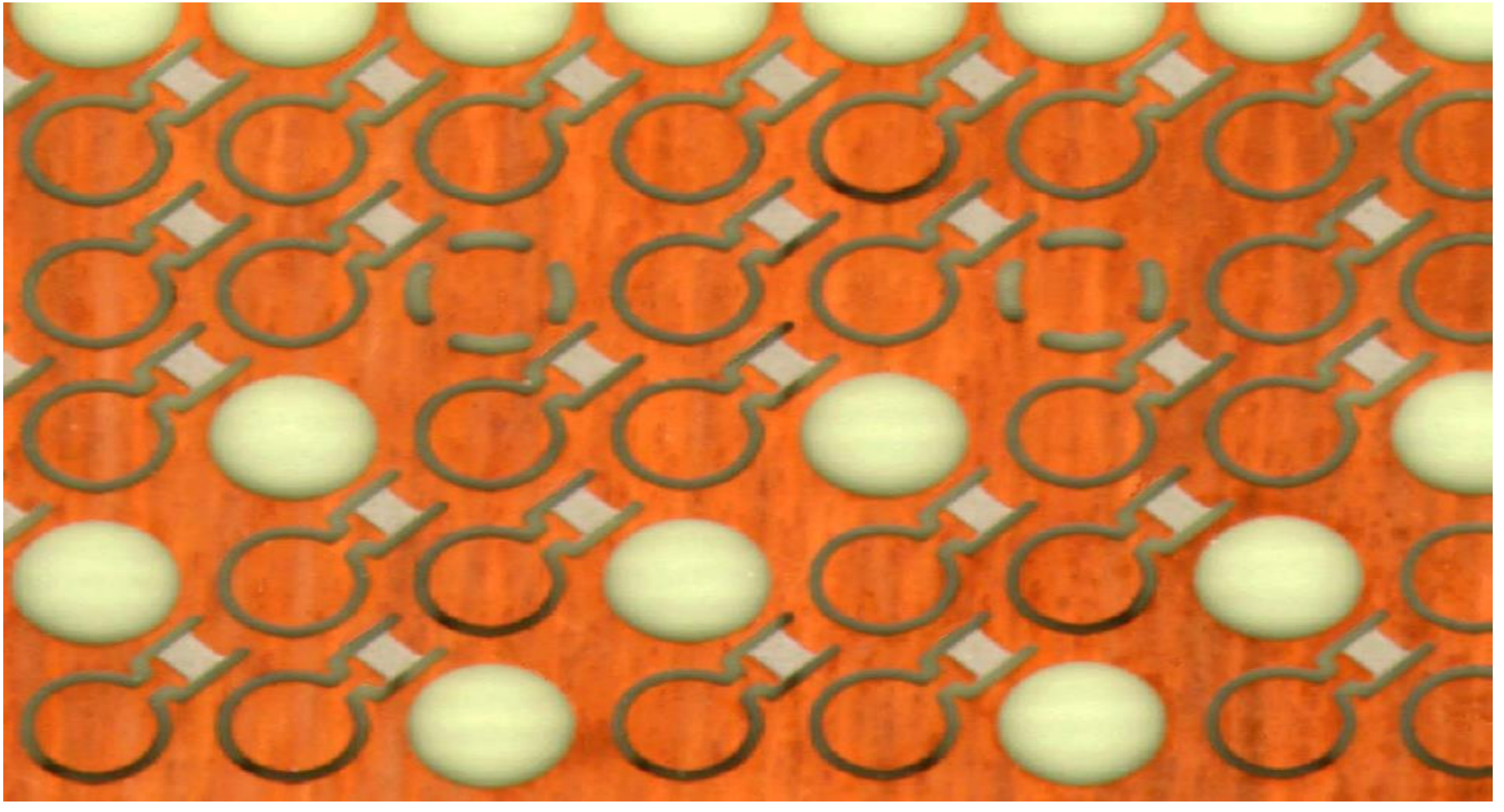
1. Mentor Graphics
2. Cadence
3. Intergraph, Classic



GND plane: Direct connection between embedded resistors and plane in design.

Embedded Passive Components

Parallel termination resistors on an inner layer of a PCB



Embedded Capacitors

Embedded Passive Components

** **Subtractive** Fabrication Technology - Thin Film (Capacitors)

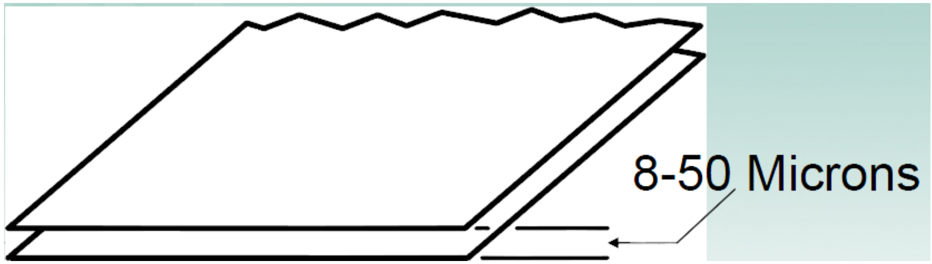
Embedded formed capacitors are generally formed by the careful selection of dielectric material, dielectric thickness, and plane area. Typically, thin laminate.

Pair of Planes, set very close together.

Normal Dielectric Materials are FR4, Polyimide and Epoxy.

Sheets of Cu-clad laminate recommended:
Thin, **Hi-DK** (laminate Dielectric Constant).

Ideal for high frequency decoupling.



Pair of Planes, set very close together

Embedded Passive Components

Embedded Capacitor Material - Key properties

Attribute	Value
Capacitance /area	6.4 nF/in^2 (1.0 nF/cm^2)
Dielectric Constant	16
Dielectric Thickness	0.55 mil (14 um)
Dielectric loss @ 1GHz	0.03
Resin system	Epoxy, ceramic filler
Freq., Voltage, Temperature	Meets X7R
Dielectric Strength	~3300 V/mil (130V/um)
Breakdown Voltage	>100V
Copper Thickness	1.4 mil (35 um)
Flammability Rating	94V-0

Embedded Passive Components

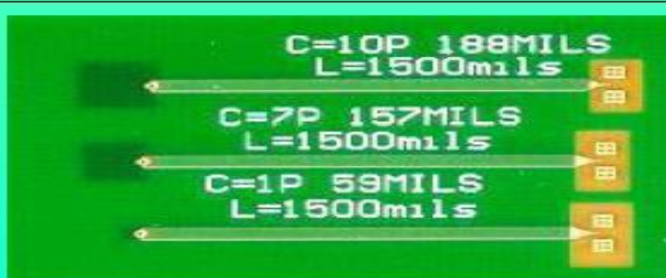
** **Subtractive** Fabrication Technology - Thin Film (Capacitors)

The different between capacitive **Hi-DK (3.5-27)** and **FR4** material:
Hi-DK required to promote capacitance of same physical dimension, and for determine the impedance.

Significantly improves performance.

Capacitor	1pF	7pF	10pF
Hi-Dk Cap. Size(mil^2)	13^2	33^2	40^2
FR-4 Cap. Size(mil^2)	59^2	157^2	188^2
Area Ratio Hi-Dk : FR-4	1:21	1:23	1:22

- Embedded Capacitors on FR4 substrate.



- Embedded Capacitors in Hi-DK substrate.

Embedded Passive Components

DK - Laminate Dielectric Constant Types

Performance	Material	Dielectric Constant	Loss Tangent / Dissipation Factor	Cost
Low	Standard FR4	4.1 - 4.4	0.019 - 0.024	Low
	Nelco N4000-6	4	0.022 @ 2.5GHz	
	Isola FR 370 HR	4.04	0.021 @ 2GHz	
Medium	GETEK	3.5	0.010 @ 10GHz	Medium
	Isola FR 408	3.75	0.012 @ 10GHz	
	Nelco 4000-13	3.6	0.009 @ 10GHz	
	Nelco 4000-13 SI	3.2	0.008 @ 10GHz	
High	Polyimide	4.2	0.006 @ 10GHz	High
	Rogers 4350 B	3.48	0.0037 @ 10GHz	
	Arlon 25N	3.38	0.0025 @ 10GHz	

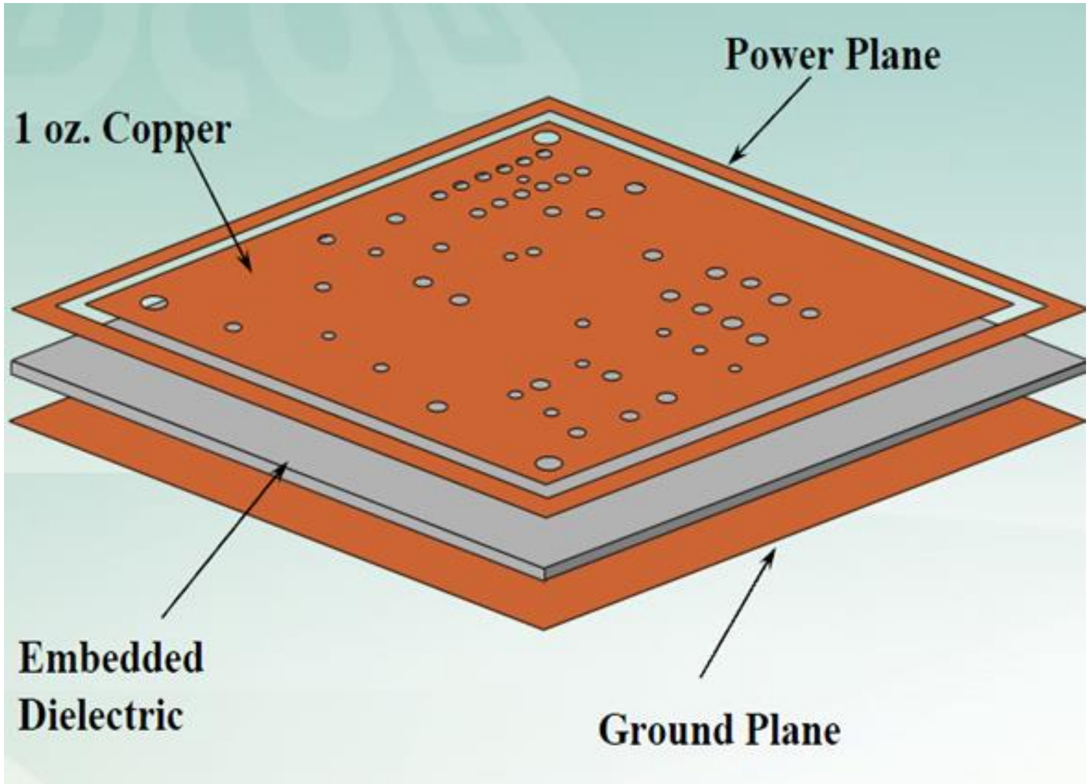
Embedded Passive Components

**** Subtractive** Fabrication Technology - Thin Film (Capacitors)

$$C = A \, x \, D_k \, x \left(\frac{K}{t} \right)$$

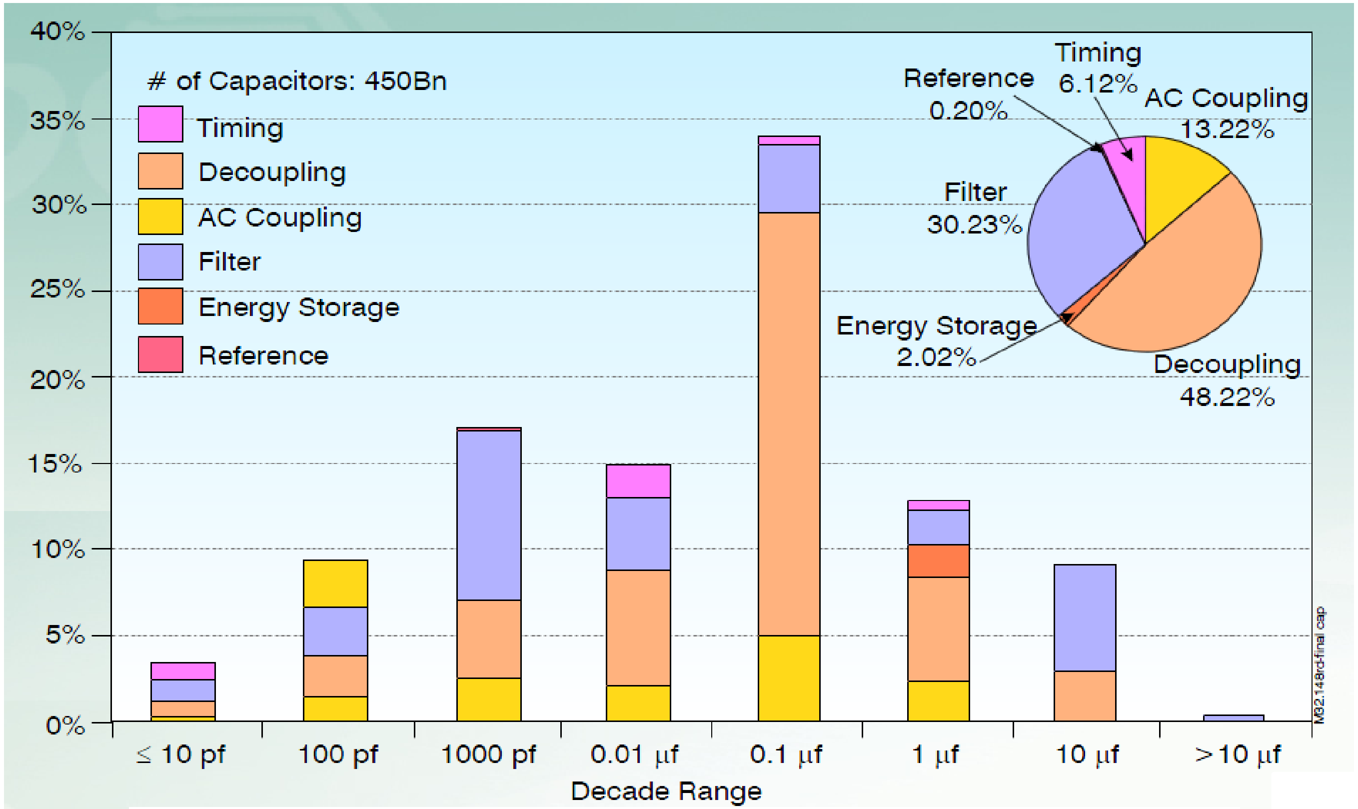
C = Value of Capacitance (F)
A = Area of the capacitor plates
D = dielectric constant
t = thickness between capacitor plates
K = conversion factor (F/cm)

$$K = 8.854 \, x \, 10^{-14} \; F/cm$$



Embedded Passive Components

Capacitors Distribution



Range of Capacitors

Embedded Passive Components

<u> Resistor & Capacitor (R-C) Laminate - 3M</u>**

** A copper clad laminate that can be used to embed:
resistors, capacitors, RC networks and copper inductors
Into a rigid or flexible PCB module or chip package.

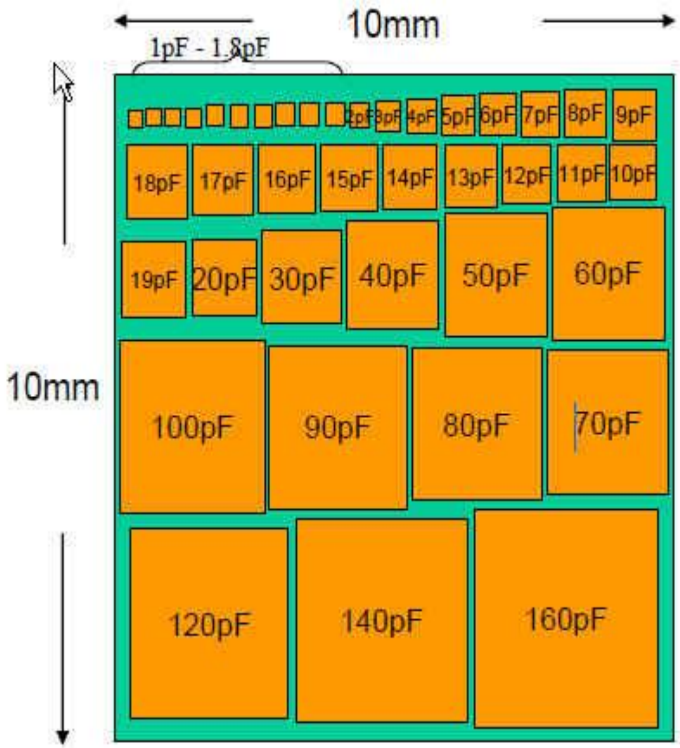
** PCB Fabrication will use 1 substrate (core) instead of 2 to pattern and embed R and C's.

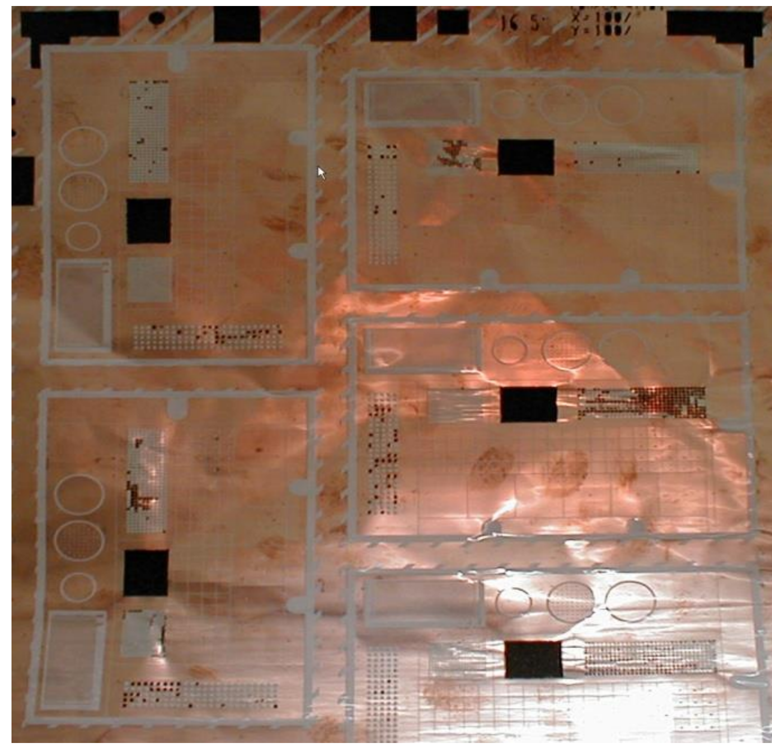
** Capacitance per unit area (C/A) is proportional to k and inversely proportional to t2

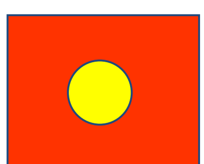
** Resistance is dependent on sheet resistivity (function of material and t1)
and resistor geometry (length and width).

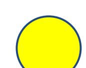
Embedded Passive Components

Single embedded capacitive layer could serve as a replacement for a larger number of decoupling and Bypass capacitors, that would otherwise be located on the outer layer.



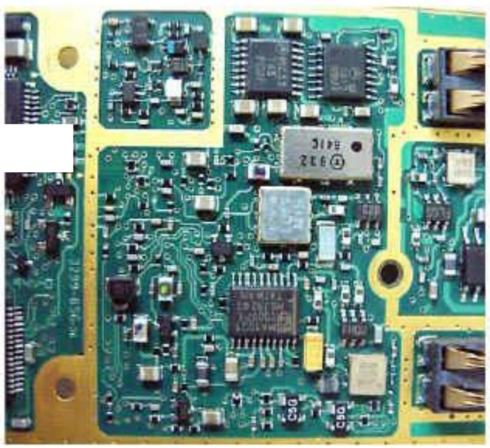


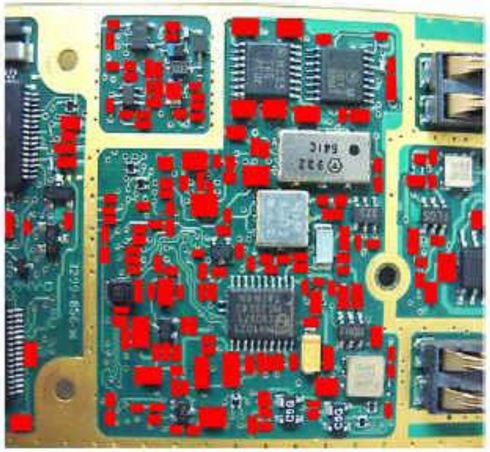
1mm  =10pf  =5.45pf

clearance  Dim=30mil=0.762mm

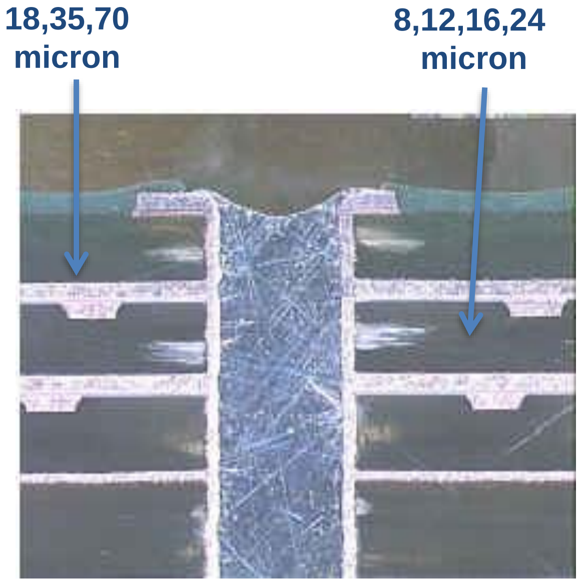
Embedded Passive Components

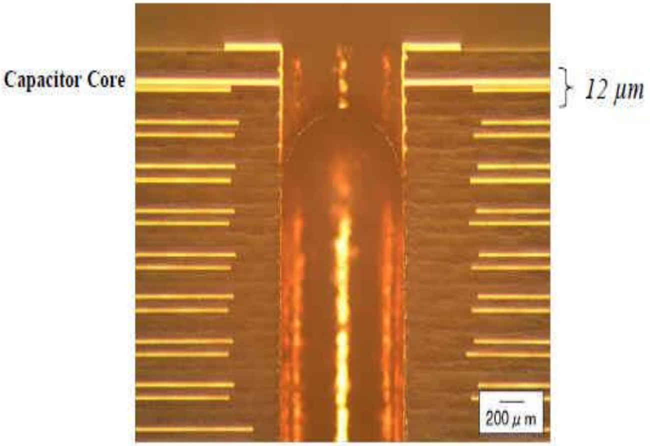
Compared to the traditional process





Substances in different copper thickness





24 Layers

Embedded Passive Components

**** Subtractive** Fabrication Technology - Thin Film (Capacitors)

Capacitor Materials

SUPPLIER	OAK-MITSUI	SANMINA	3M	DUPONT	Gould
Trade Name	**FaradFlex**	**BC2000**	**C-Ply**	**Interra HK**	**TCC**
Dielectric	Epoxy/Y5V ceramic	Epoxy FR-4	**Epoxy/Barium Titanate**	Polyimide	Polyimide
Capacitance Range (nF/in2)	0.9-4.5 (11)	0.5	**10-30**	0.8-3.4	0.78 - 1.45
Thickness (um)	8, 12, 16, 24	50	**7-25**	25	12.5, 25
Dissipation Factor @ 1 MHz [GHz]	0.015-.019,[0.06]	0.02	**0.1**	0.01	0.009
Dielectric Constant @ 1 MHz	4.4-10 (30)	3.9	**22**	3.5, 10	3.2

Embedded Passive Components

** Overview of capacitor process - organic material based on **Polymer Thick Film**

a. Polymer/ceramic dielectric cleaned (acetone), microetched and bond film applied for adhesion improvement.

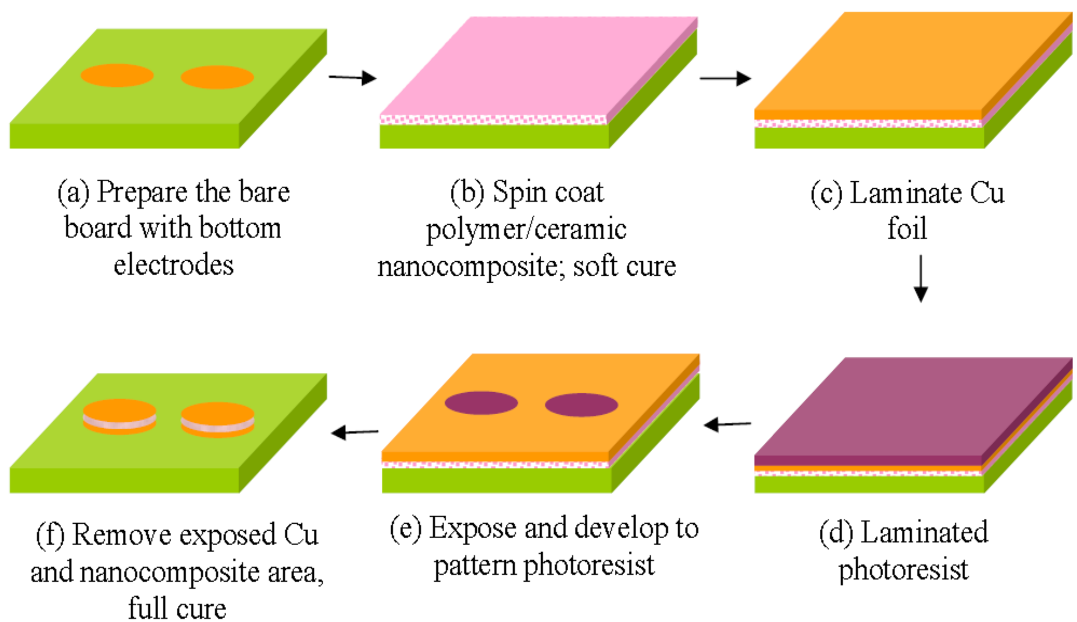
b. Mixing barium titanium based polymeric resin, coating on board to achieve 20μm thickness, and oven in 65C° for 45 minutes.

c. Top copper electrode15 μm vacuum and heat press to strengthen the lamination.

d. Liquid photoresist coated on board.

e. UV exposed with positive mask and developed.

f. The result: exposed copper Nanocomposite materials were removed; baking 150°C for 1 hour.



Embedded Passive Components

** Embedded Capacitors Additive Technology Thick Film -The next step of DuPont

The market request: High capacitance in low cost.

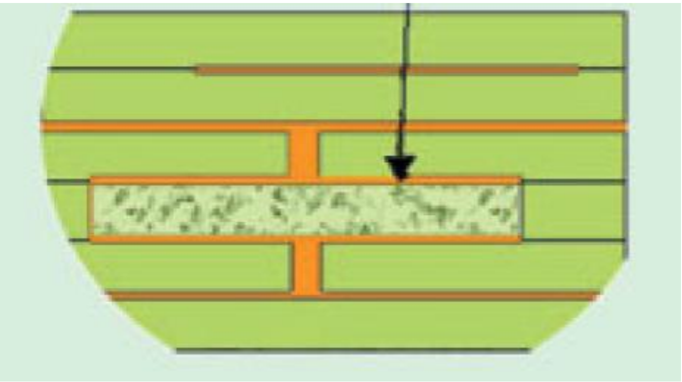
Ceramic Thick - Film Organic substrates can be using in simply manufacturing processes.

The dielectric paste is based on Barium Titanium composition and compatible glass works together with a copper electrode paste.

The capacitors system designed to be screen print on copper foil in locations desired.

After print the paste dried and fired in nitrogen at 900°C to form the ceramic components.
Compared to Polymer Thick Film that dried at 80 - 280°C.

Embedded Capacitor



Barium Titanium Glass and Copper

Hi capacitance density
~ 1.5 nF/mm^2 per dielectric layer - in 25 to 85C temp. Range.
we can combine between layers.

Dielectric Constance ~4000 @ 10kHz

Total thickness 28-34 µm which fires to ~18-24 µm.

Enable to remove from surface capacitors with values between 100pF to 60nF.

Embedded Passive Components

** Embedded Capacitors - The next step of Thick Film - DuPont

When Copper foil with screen printing paste go to 900°C peak temperature

The process presents three reactions:

- Burnout of organics materials.
- Densification of the ceramics.
- Reactive bonding to the copper foil.

Process of firing atmosphere should be controlled and monitored.
Capacitance can change due to past properties, screen print thickness.

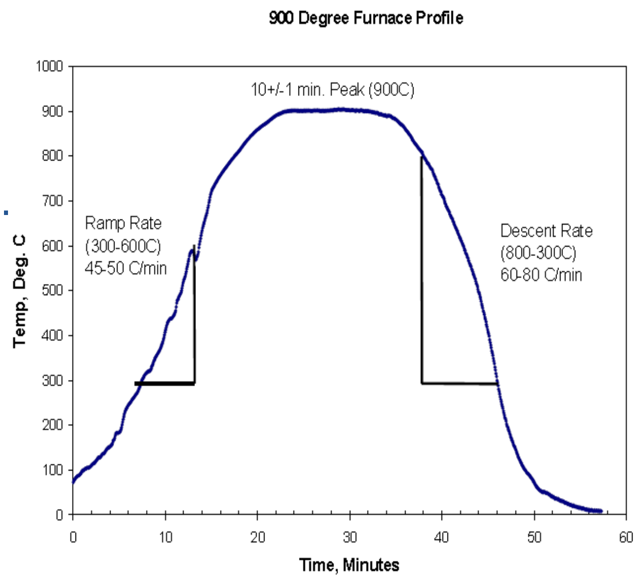
Oxygen is necessary to burn off the organics in the paste completely, but it has negative effect on copper.

Opposite - Insufficient oxidize can leave carbon remnants which has negative impacts on ceramic properties.

Fired dielectric thickness ~ 10-40 microns.
Typical concentration of oxygen nitrogen is ~1-2 ppm.

Test of 4 firing steps show that copper foil shrank with no significant changes.

Prepreg thickness of 60 microns can adapt two-layer capacitor structure



Embedded Passive Components

** Embedded Capacitors - The next step of Thick Film - DuPont

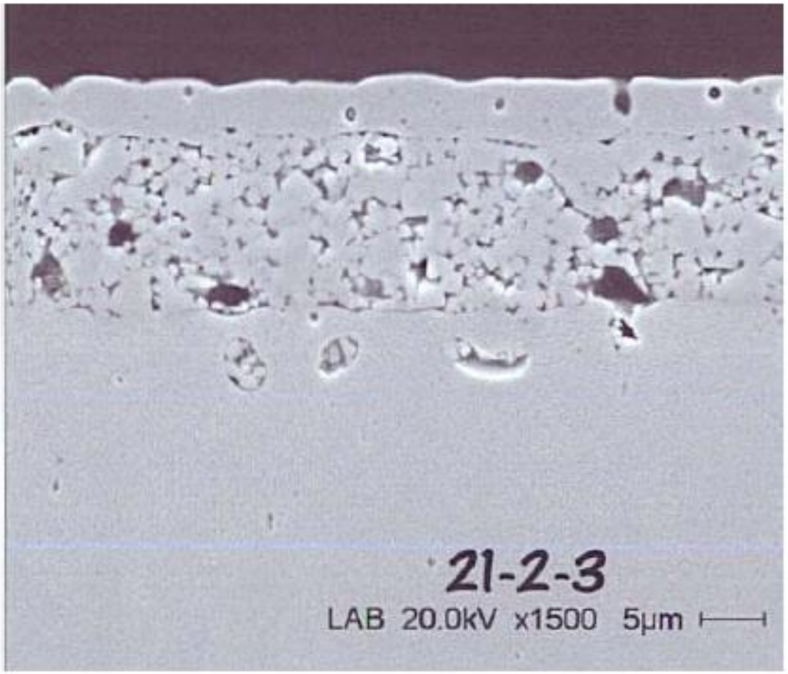
Processing factors

Electrode size for small capacitor area: 10-180 mils.

For screen printing tolerances and keeping the capacitor size small enough to minimize distortion of the underlying copper foil after firing.

Firing condition: 1-2 ppm oxygen give
3-5 micron size barium titanium developed grain.

Up to 50 ppm not recommended:
- Gives a continual reduction in peak K value;
- Reduces barium titanium grain size;
- Lowering of dissipation factor.



Typical barium titanium
2-5 microns grain size

Embedded Passive Components

** Embedded Capacitors - The next step of Thick Film - DuPont

Reliability tests:

Different sizes of capacitors were tested:
50x60 mil^2 ; 188x188mil^2 ; 84x84 mil^2 ; 19x19 mil^2

Thermal cycling: between -40°C to +125°C for 500 cycles.

HAST (highly accelerated stress test) : 110°C and 85% RH (Humidity stress) for 264 hours.

Changes were around 4% after 264 hours and 5% after 1000 hours.

Embedded Passive Components

** Embedded Capacitors - The next step of Thin Film - Endicott

$BaTiO_3$ - Barium Titanium with epoxy polymer Nanocomposite.

2 - 25 microns thick processed on substrate by liquid coating or printing process.

Hi capacitance density in large area.
~10 - 100 nF/inch^2 per dielectric layer, DK min.- 3.7 , Loss 0.017.

Stable capacitance density in 40-80 nf/Inch^2 , stable over a frequency range 1MHz - 10MHz.

New dielectric material that integrated into PCB (laminate chip carrier or roll to roll manufacturing process).

Mixing $BaTiO_3$, nano powders and epoxy resin in organic solvent.

Thin film of Nanocomposite deposited on copper substrate and cured.

In case of laminates, two thin films were prepared, dried and laminated together.

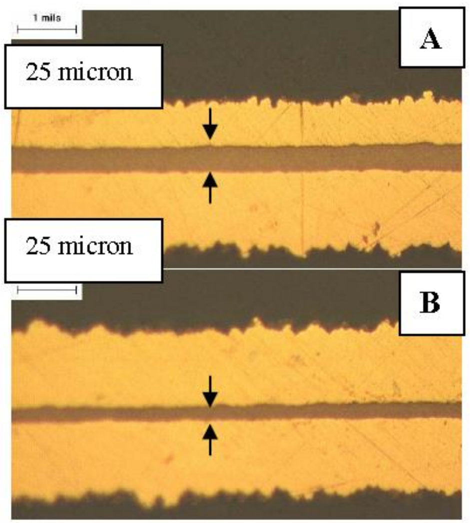
<u>The challenge</u>: creating large area of Nanocomposite, with compatibility between hydrophilic nanoparticles and hydrophobic polymer matrix.

As a result nanoparticle agglomeration which lead coatings with poor performance.

Embedded Passive Components

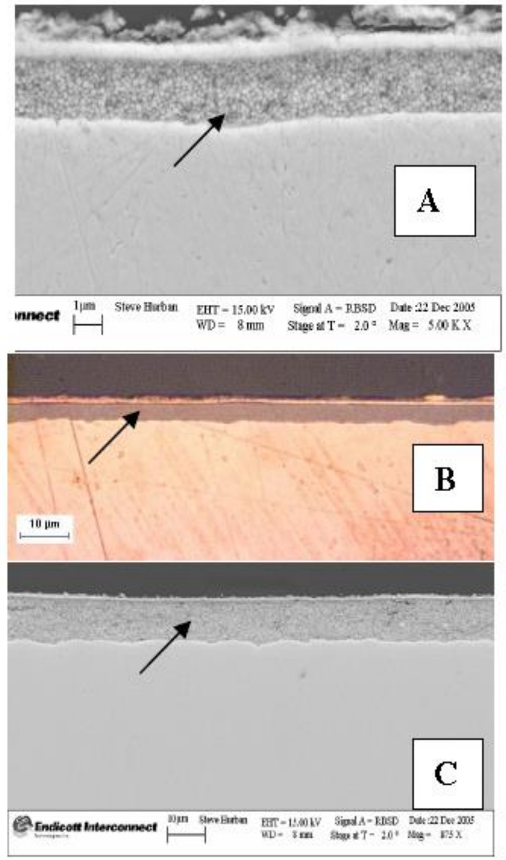
** Embedded Capacitors - The next step of Thin Film - Endicott

Desired thickness of the film
can be achieved by controlling
the viscosity of the coatings,
composition and
the number of layers deposited.

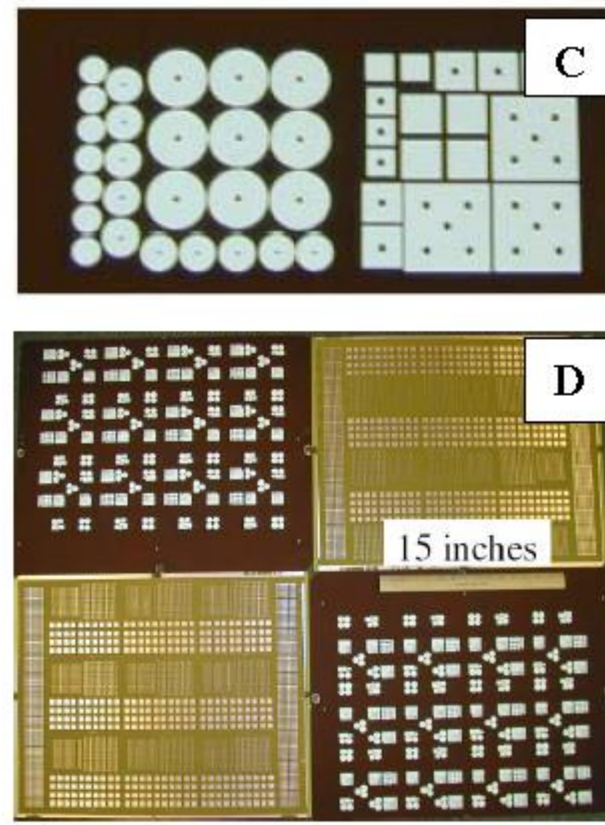


Cross sections of thin films laminated with each other

(A) 10 micron laminates
(B) (B) 5 micron laminates



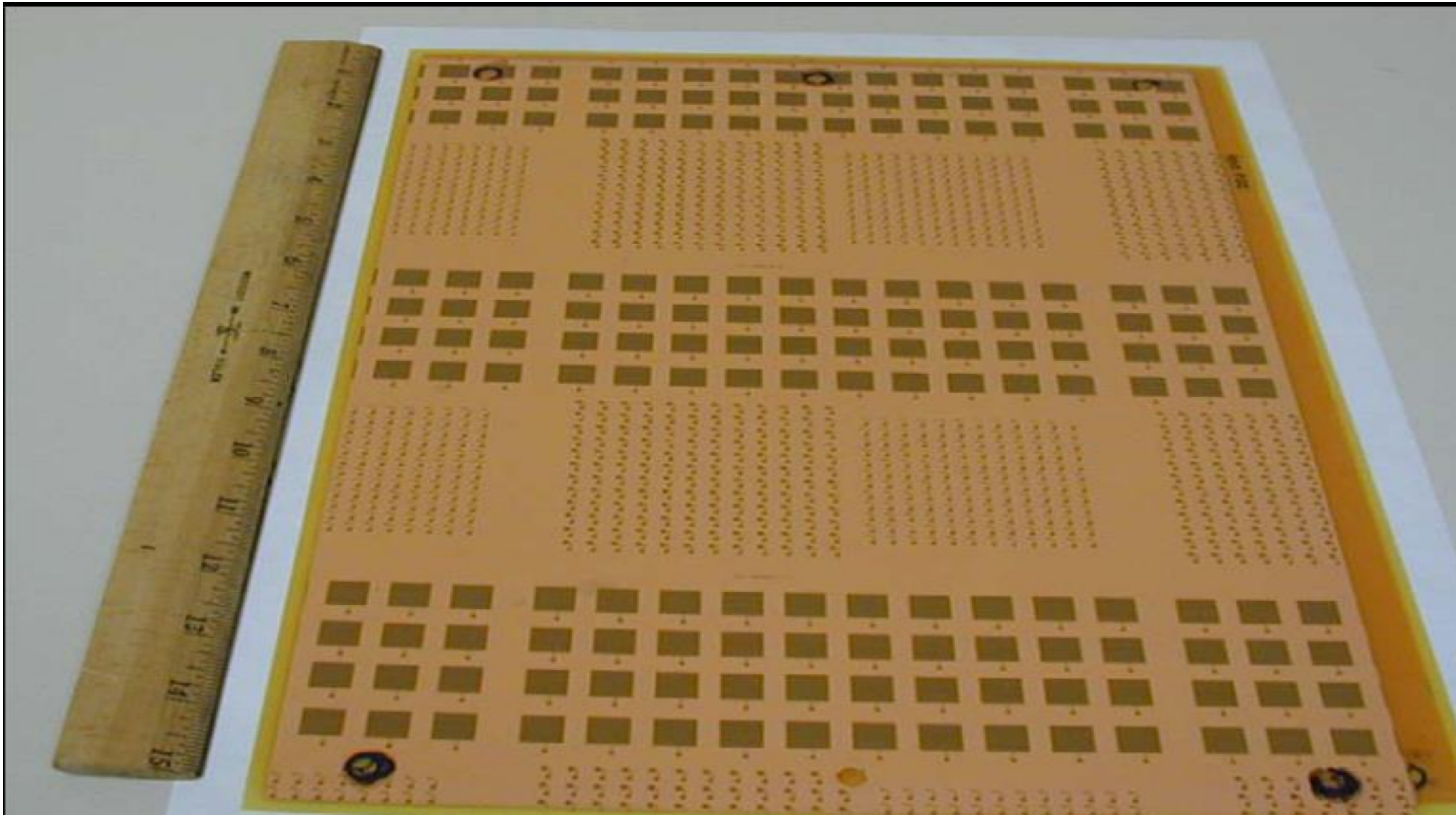
Cross sections of thin films sandwiched between two metal electrodes.
(A) 2 micron, (B) 3 micron and (C) 8.5 microns.



(BaTiO3)-epoxy polymer nanocomposites film.

Embedded Passive Components

Endicott Thin Film embedded capacitors – 13”x18”, 19.5”x 24”



Embedded Passive Components

** Embedded Capacitors - The next step of Thin Film - Endicott

Reliability tests:

Capacitors were exposed to PCT (Pressure Cooker Test) 4 hrs followed by 15 seconds solder dip at 260 ^{0}C there was no delamination.

Stable capacitance and low loss capacitance : change was less than 10% over a temperature range of 25 ^{0} C to 100 ^{0} C.

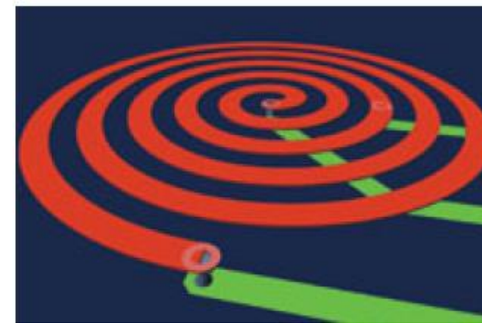
1400 cycles DTC (Deep Thermal Cycle) -55^{0}C to 125^{0}C.

Baking 140^{0}C 4 hrs or reflow (3X, 245^{0}C) indicates copper annealing that could possibly stabilize.

Samples were exposed to 100 % humidity with a constant pressure 19 PSI at 121^0 C. The results showed capacitance decrease but simple drying reverse the capacitance.

Embedded Passive Components

** Embedded Inductors



Embedded inductors do not require special fabrication processes.

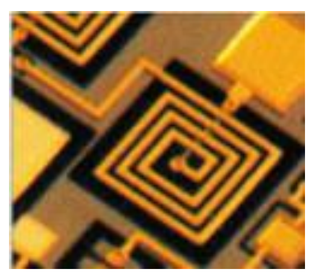
Standard copper traces in a spiraled configuration.

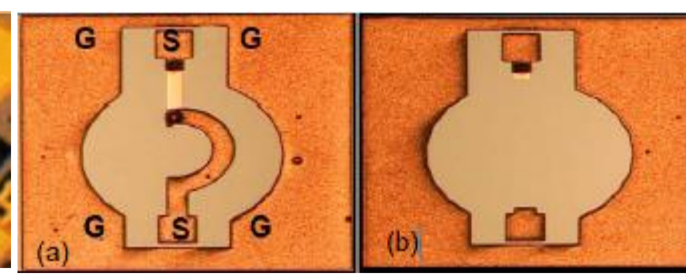
Inductance is defined by the geometries of the copper traces.

Design and analysis of embedded inductor on low cost multilayer laminate.

Copper circuit traces are etched around the embedded Ferrite cores to form windings.

Size of inductors dependents on:
Metal line width
Spacing
Diameter of any circular geometries





Inductors can be applied by additive technology too: Adding iron powder on substrate.

Embedded Passive Components

Embedded passives advantages

- Improving the packaging efficiency
- Reducing size, components on the same layer could be fabricated simultaneously.
- Eliminating substrate assembly.
- Minimizing solder joint failure and Increase reliability.
- Better MTBF (Mean Time Between Failures).
- Reduced power bus noise.
- Faster and cleaner electric signals – EMI reduction.
- More Functionality.
- Cost Saving (cost of adding one more passive is nearly zero).
- Reduction weight.

Embedded Passive Components

<u>Embedded passives disadvantages</u>

- Defective parts can’t be replaced, for embedded passives.

- Cost per square inch will increase - Embedded need extra layer

  <u>But overall cost of the board will be less.</u>

- If embedded components failed, we can't repair or replace, PCB is scrap.

Embedded Passive Components

Summary

Now manufacturers required to fabricate the passives instead of simply purchasing them.

Lack of expertise could cause hesitations or resistance to implementation.

The consortium’s confirmed that embedded materials were compatible with all facets
of the PCB manufacturing including design, fabrication and reliability testing,
But substrate must be able to withstand of all processing conditions: chemical and mechanical exposures.

The challenge for embedded components are:
to increase the specific values - for resistors Ω/square, more capacitance for capacitors,
And achieve accurate tolerance.

Thank You