**NCAB Group |** Seminar no. 7

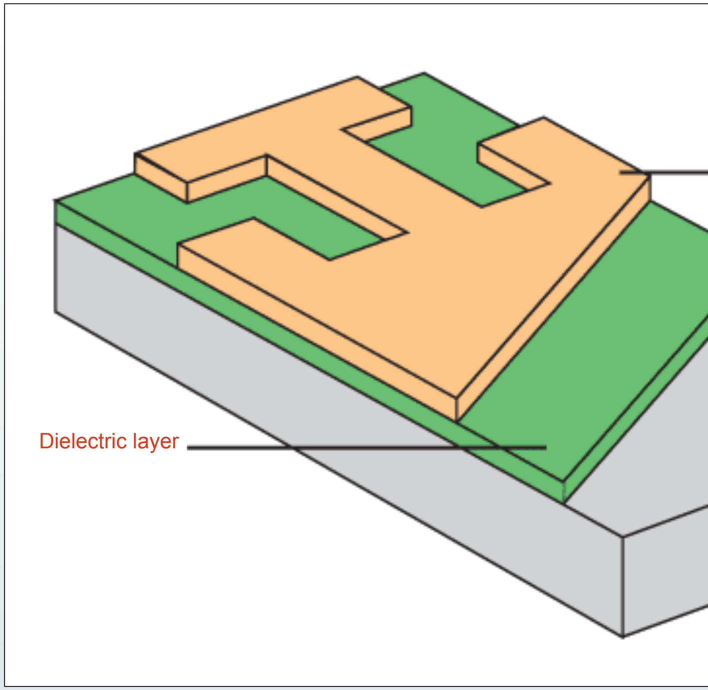
# Insulated Metal Substrate

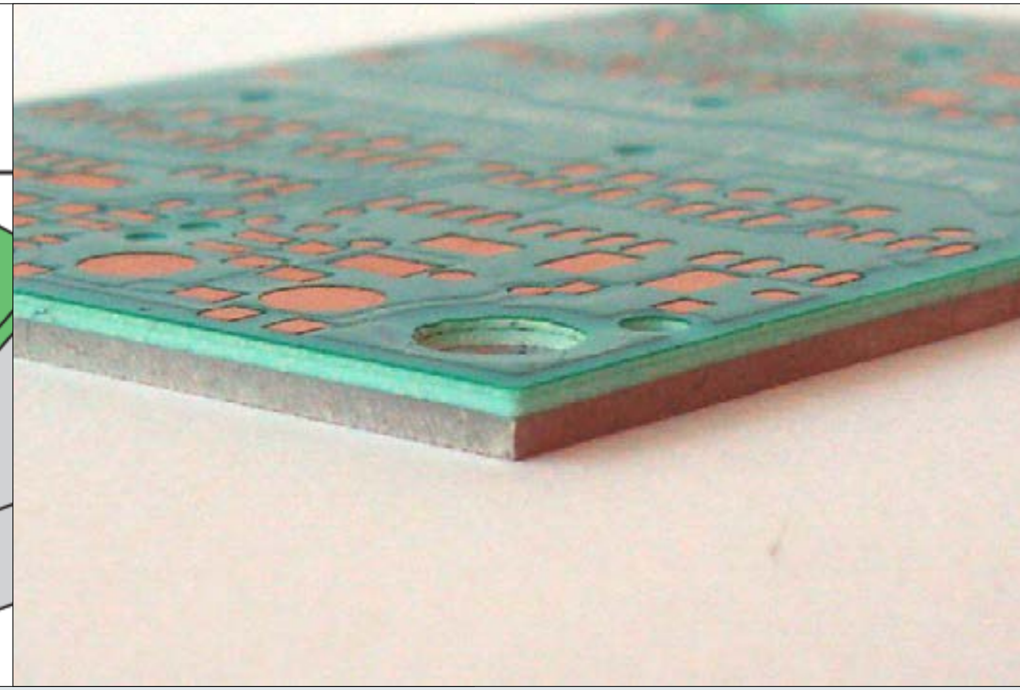
NCAB GROUP

# Introduction to IMS

INTRODUCTION TO IMS

# What is an IMS PCB?



**IMS** = Insulated Metal Substrate

Copper circuitry bonded onto an electrically insulated thermal dielectric layer, that is bonded to a metallic substrate.

# What is an IMS PCB?

- The insulating thermal dielectric is a special material, with good thermal conductivity; normally it is 8 to 10 times more thermally conductive than FR4.
- The dielectric is normally is made using a filling material that normally used aluminium oxide, aluminium nitride, boron nitride, magnesium oxide or silicon oxide.
- An aluminium metal base is perhaps the most common metallic base. It is suitable for drilling, punching and cutting.
- In most cases and IMS board reduced the need for heat sinks.

## INTRODUCTION TO IMS

# Benefits of IMS PCB´s

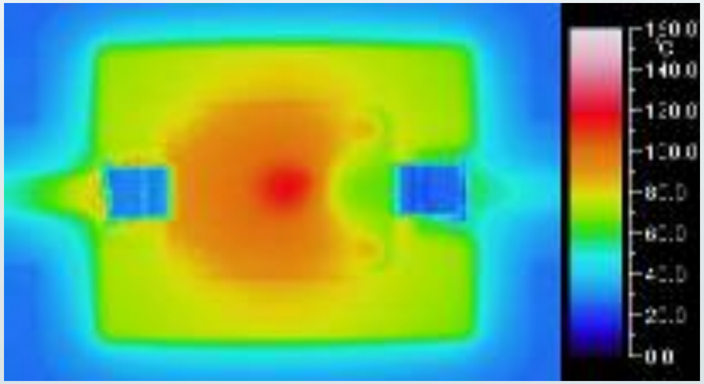
- Increased thermal conductivity
- Reduces working temperature of PCB
- Enables better use of surface mount technology $cm^2$ / $in^2$
- Maintains management of physical size of PCB
- Reduces need for heat sinks and other mounting hardware including thermal interface material
- Enables high current applications
- Replaces fragile ceramic substrates with greater mechanical durability

# Benefits of IMS PCB´s

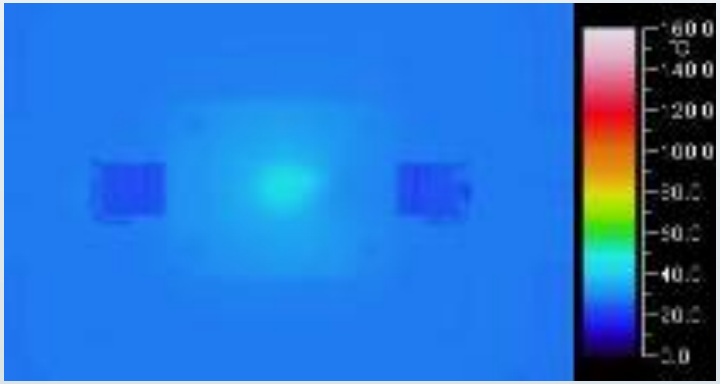
Below we can see thermal imaging of an LED under load conditions.

Left image uses FR4 PCB - 1.60mm with 35um Cu.

Right images uses IMS PCB - 1.00mm Al /100um dielectric also with 35um Cu.

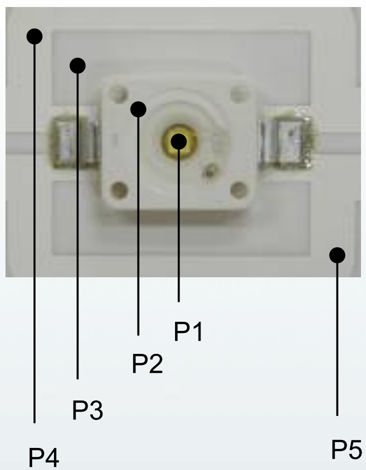


Maximum temp = 129.1℃



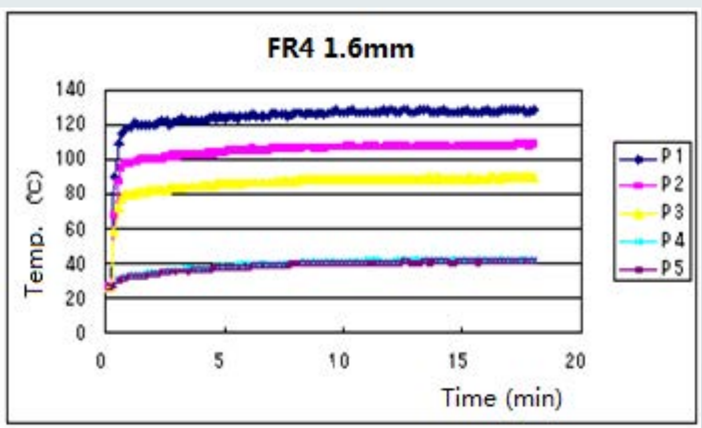
Maximum temp = 61.9℃

# Benefits of IMS PCB´s



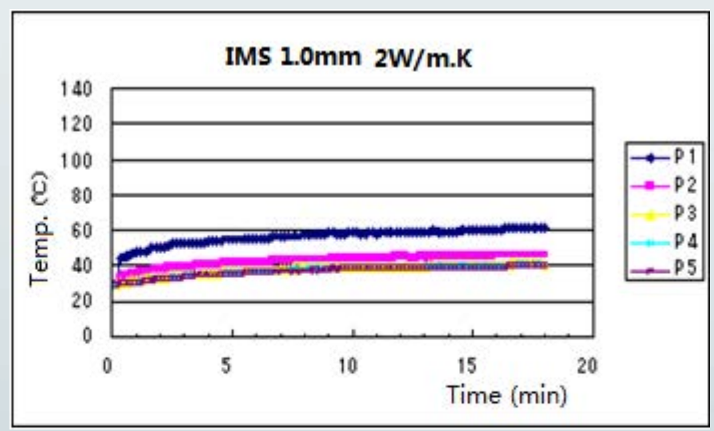

**FR-4 0.2W/mK**

1.6mm thickness with 35um Cu



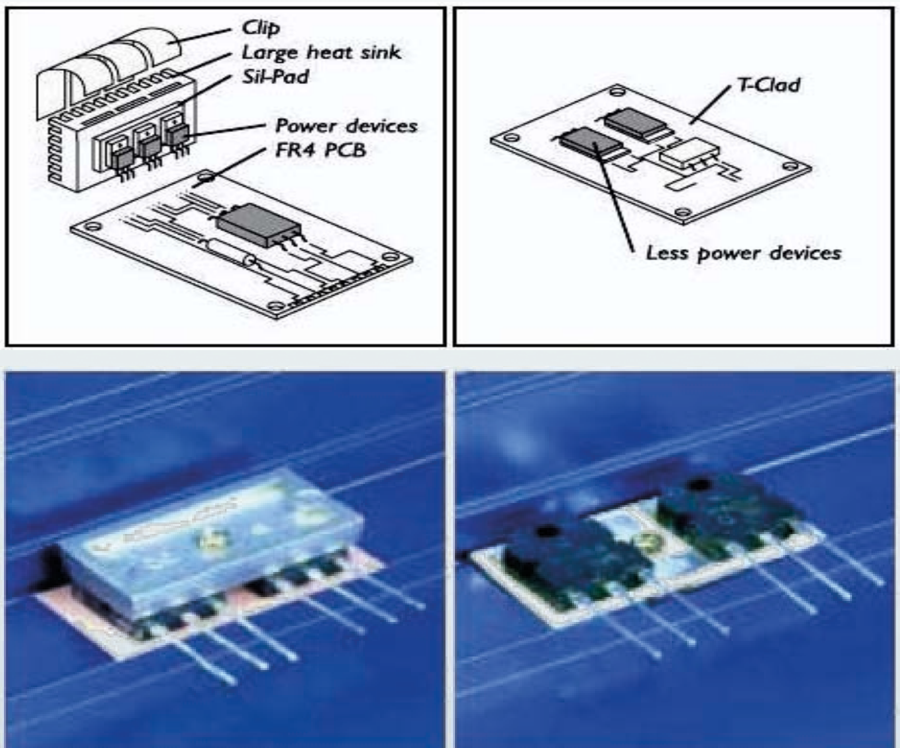

**IMS 2W/mK**

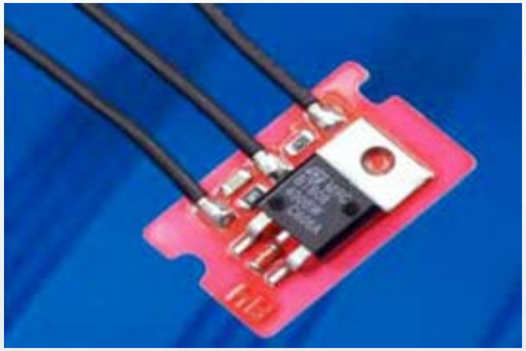
（Al 1.0mm／100um／Cu 35μm）

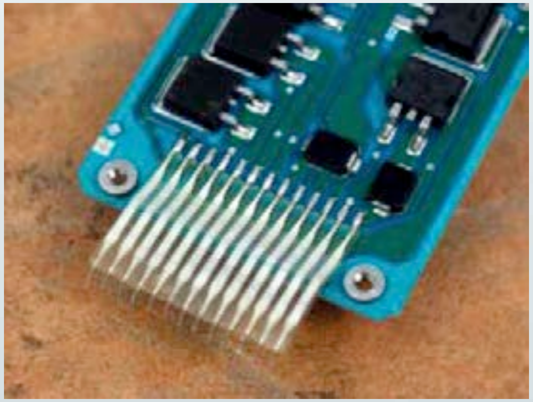


# Benefits of IMS PCB´s

## Can reduce the size of components.



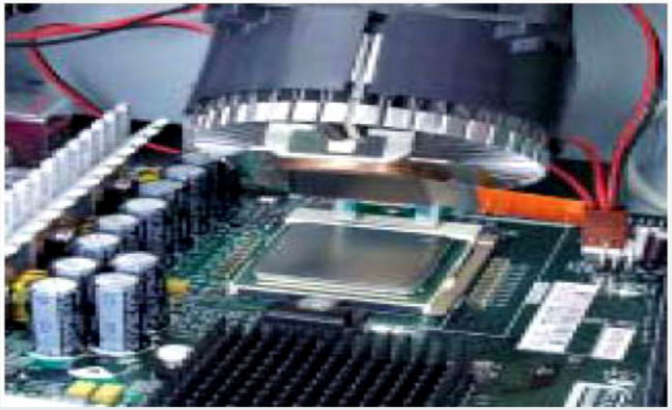



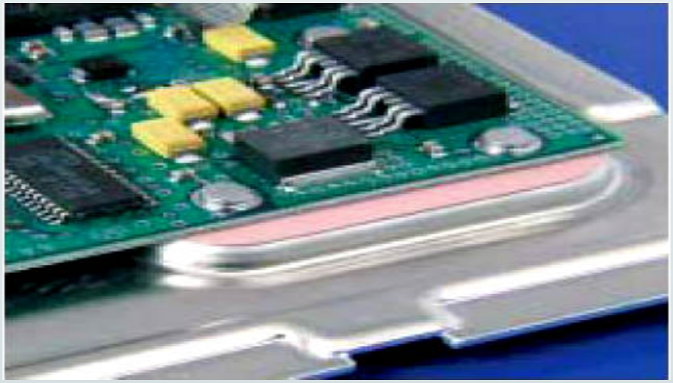
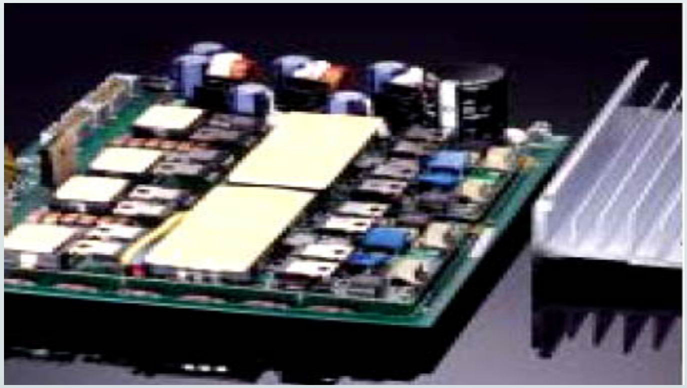


NCAB GROUP

# Benefits of IMS PCB´s

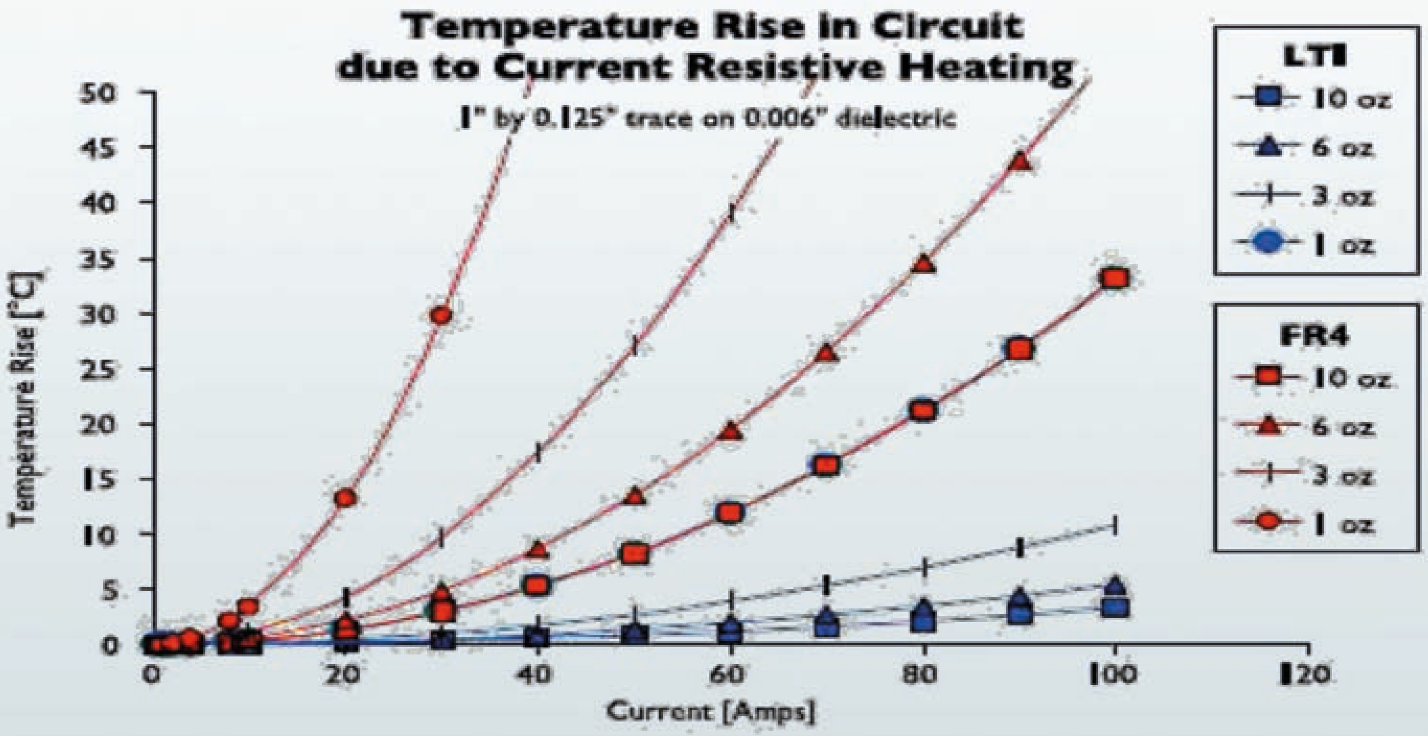
## Reduce using more material for heat sink



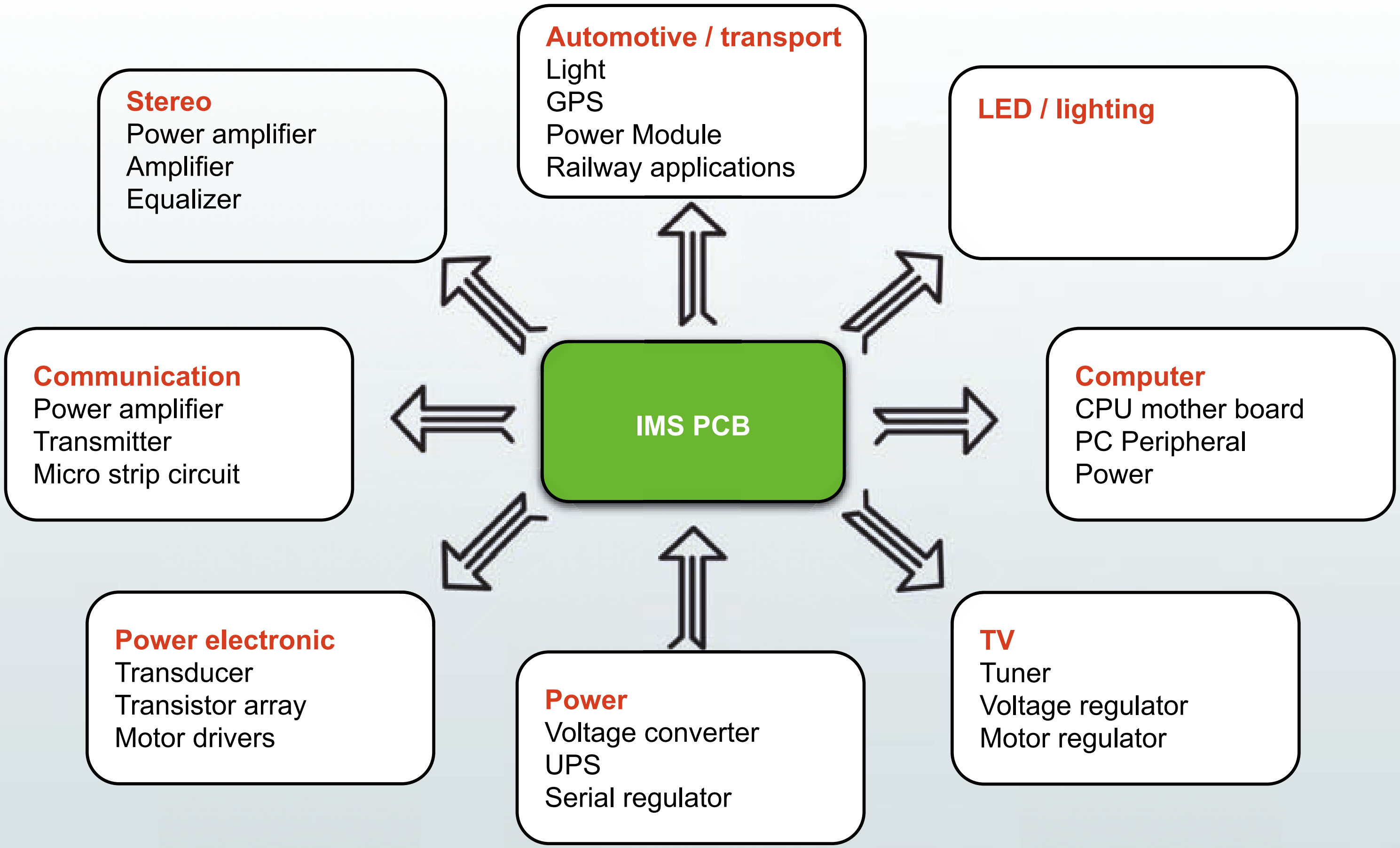



# Benefits of IMS PCB´s

## Can withstand the affects of higher current.



# Applications for IMS boards




NCAB GROUP

# How do IMS PCB´s work?

An IMS PCB uses **thermal conductivity** to transfer the heat - from the warmer to the cooler part of the PCB.

HOT → COLD

Thermal conductivity relates to the ability of the **material** to transfer heat, and is measured using W/m/K. All materials transfer heat, with some better than others:

| | |
|---|---|
| **ALUMINUM** | 205 W/m/K |
| **WATER** | 0.56 W/m/K |
| **FR4** | 0.20 - 0.25 W/m/K |
| **THERMAL PRE-PREG** | 1.00 – 5.00 W/m/K |
| **AIR** | 0.024 W/m/K |

# How do IMS PCB´s work?

**Thermal Resistance** (Tr) is the resistance that the heat will encounter as it tries to transfer through the substrate (hot to cold).

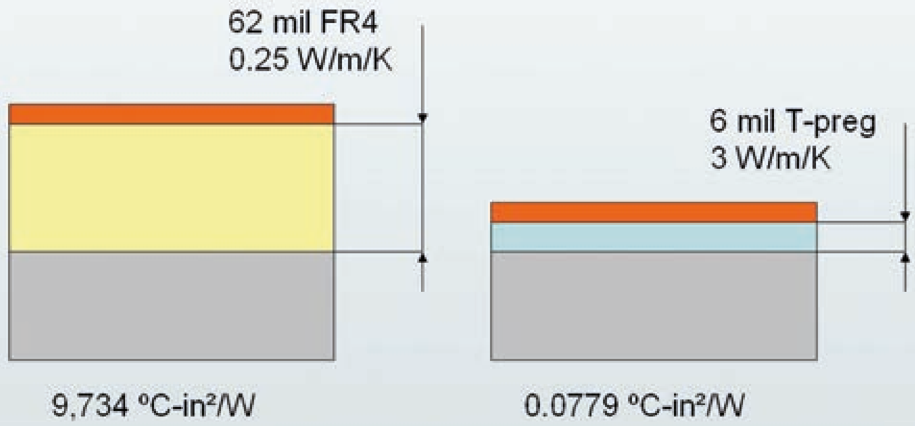
It's measured in the term ºC-m²/W or ºC-in²/W

**Tr** shall be as low as possible and is linked to the **thermal conductivity** of the material.

**d** = Thickness in meter

**ʎ** = Thermal conductivity

**Tr** = d / ʎ




The IMS concept is to have a thin material with high thermal conductivity.

# Thermal management

**How much heat can be transferred away?**

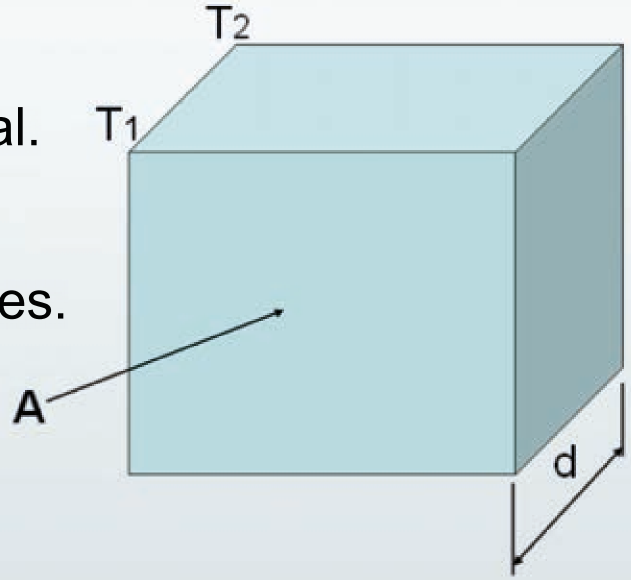
It depends of these factors:

**ʎ** = The thermal conductivity of the material.

**d** = The thickness of the substrate.

**ΔT** = Difference in temperature between sides.

**A** = The area that will transfer the heat




Heat transfer **(W) = ʎ *A * ΔT / d**

# Thermal management

Examples below show the difference in insulation material, using the formula **W = ʎ * A * ΔT / d**, where:

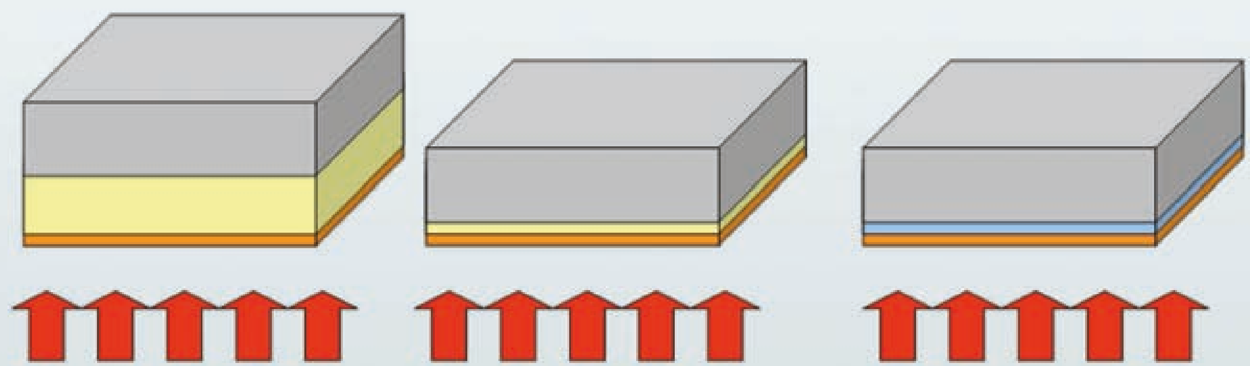
**A =** 1cm²

**ΔT =** 20 ºC

**d =** Thickness of material as shown below

**ʎ =** FR4 0.25 W/m/K

**ʎ =** T-Preg 3 W/m/K



FR4 1.60mm
0,31 Watt

FR4 0.15mm
3,33 Watt

T-Preg 0.15mm
40 Watt

# Thermal management

Readjusting the formula, we can define the necessary thickness of dielectric needed for a specific reduction in temperature:

**d = ʎ * A * ΔT / w**, where:

**d =** Thickness of material as trying to calculate below

**ʎ =** T-Preg 3 W/m/K = 0.003 W/mm/K

**A =** 1cm² = 100mm²

**ΔT =** 20 ºC

**W =** 40 watt (T-Preg)

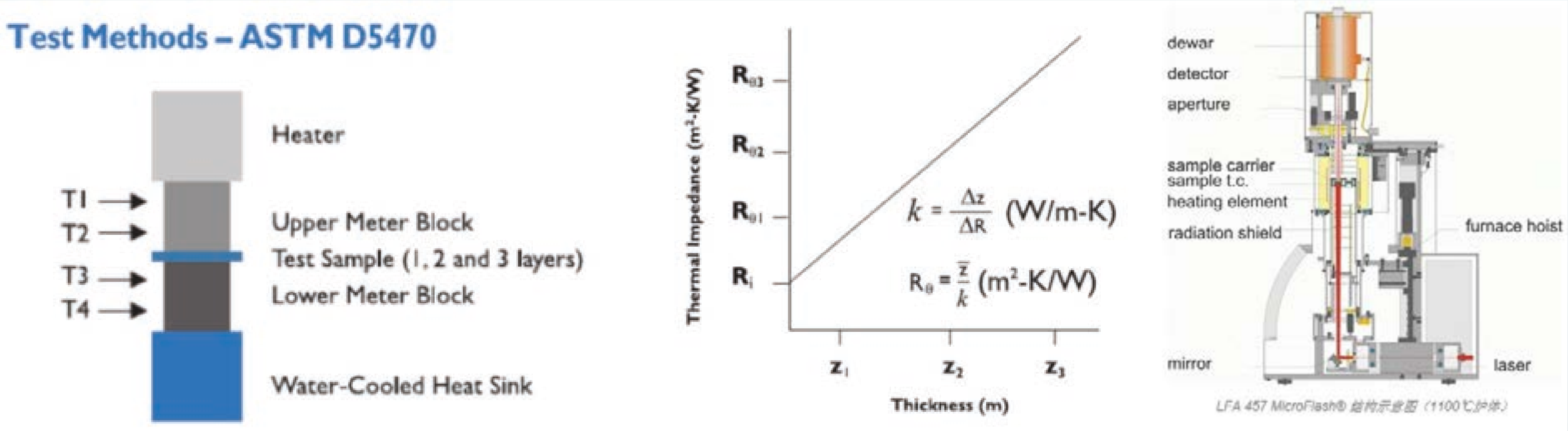
**d** = 0.003 x 100 x 20 / 40 = **0.15mm**

# Thermal management

ASTM D5470 (ASTM: American Society for Testing Material) used to measure the conductivity of thermal material.

Measure Thermal impedance ( $R_0$) of 3 samples with different thickness ($Z_0$), base on this data to calculate conductivity k.

LFA 457

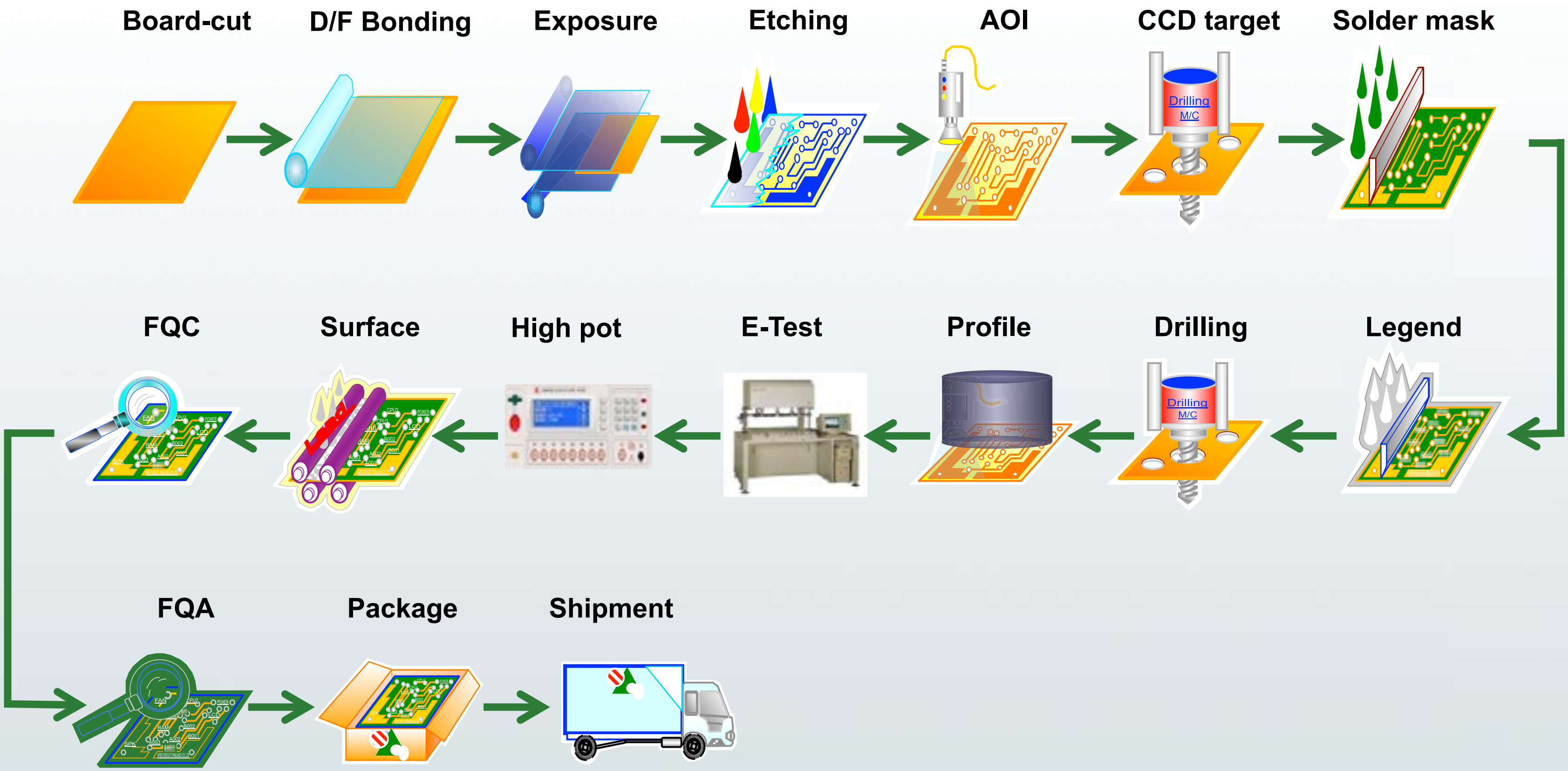



2 in. diameter stack (ref. 3.14 in2) – 10-500 psi, 1 hour per layer


Manufacturing
process

MANUFACTURING PROCESS

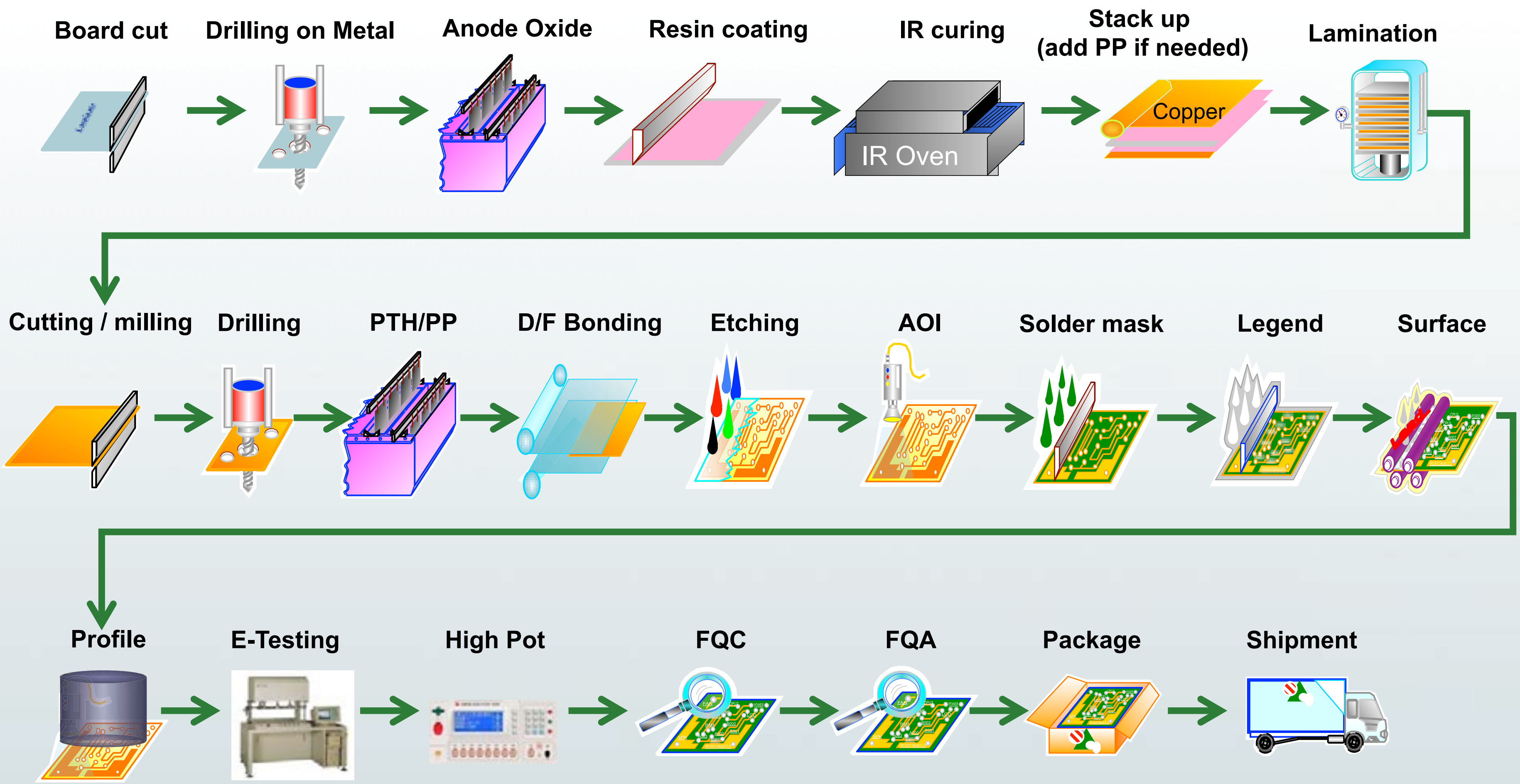
# Overview – single sided




NCAB GROUP

MANUFACTURING PROCESS

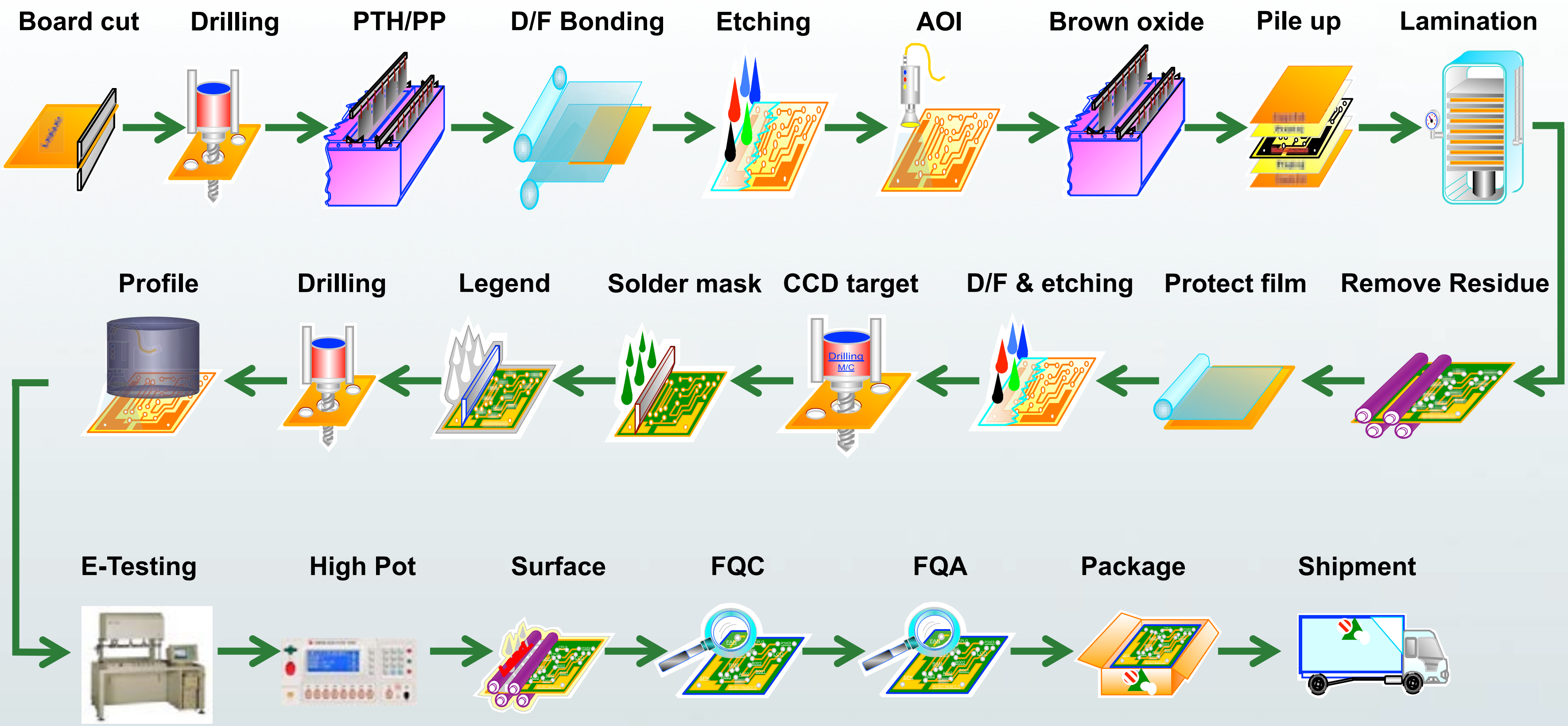
# Overview – Double layer




NCAB GROUP

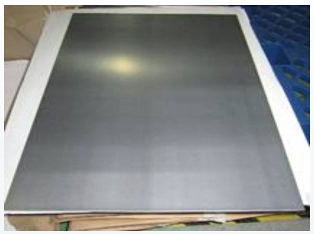
## MANUFACTURING PROCESS

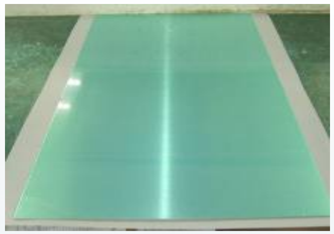
# Overview – Double side FR4 + Metal base



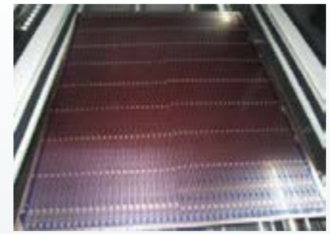
MANUFACTURING PROCESS

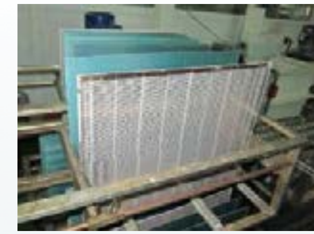
# Overview – Pictures of boards in process


IMS bare board


PET film coating


Drilling


Dry film


Etching


AOI


Solder mask


Legend


OSP


Protective film coating


After punching


Leveling


Inspection


Packaging

MANUFACTURING PROCESS

# Material Cutting

Material stores

Cutting material

NCAB GROUP

MANUFACTURING PROCESS

# Material issue – critical to quality

- KW:Thermal conductivity and high-pot test will be taken to check the reliability every 2 days / every 10000 panels.
- KW: Other testing is similar to normal FR4 controls such as Tg, thermal shock etc. Dielectric thickness will be checked by thickness machine (peel off at the board edge). During coating the factory will check the first and last board for dielectric coating thickness.
- The Al base side will be covered by a protective film. Normally, this is PET material with adhesive and there are different types of adhesive with different heat resistance so also depends upon surface finish (HASL / LF-HASL).
- Laminates should be stored in a cool, dry, ventilated environment (<80%, ≤30 deg C) and always be stored flatly.
- Shelf time of IMS material is normally 2 years.

MANUFACTURING PROCESS

# Drilling


# Drilling – Critical controls

- UC drill bit (<=0.5mm; others same to FR4);
- Hole size >= ¾ board thickness; Minimum 0.2mm drill bit
- Stack up: lower than FR4, and according to board thickness and length of drill bit – typically 2 high.

**Critical to quality**

Wrong hole size, burr, not drill through, ring damage, mis-registration, more holes, hole missing.

**Main Control Items**

Spindle speed: 20%～40% FR4 | Feed rate: 20%～40% FR4

Retract rate: equivalent FR4 | Hits: 200 holes～500 holes

Only 1 time re-sharpen due to impact from drilling through aluminum.

MANUFACTURING PROCESS

# PTH + Panel Plating

PTH

Panel Plating

Metal Oxide

(conductive or non-conductive)

MANUFACTURING PROCESS

# Dry film / Imaging

D/F pretreatment line

Auto D/F laminator

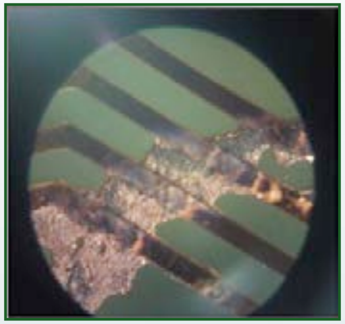
Automatic exposure machine

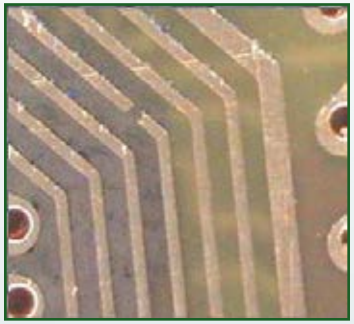
# Dry film / Imaging – critical controls

- For single layer, normally only cover dry film on one side
- For boards etching, normally use Alkaline ($NH_4Cl + NH_3 \cdot H_2O$) serial chemical,  that will be no attack to the Al base
- Al metal base has no effect to the temp controls of chemistry.

# Dry film / Imaging – critical to quality

Nick in track, open, short, line out of spec., residue, under developing, dry film debris.





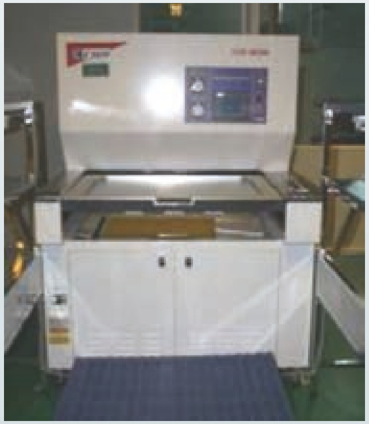
**Main Control Items (typically similar to FR4)**

- Grinding check
- D/F bonding temp. speed
- Exposure energy
- Concentration of chemical
- Uniformity of etching

# Soldermask / Legend

S/M pretreatment line

Semi-auto silk screening machine



Manual exposure machine

Solder mask baking oven

MANUFACTURING PROCESS

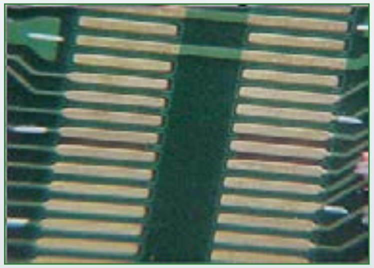
# Soldermask / Legend – critical controls

- 90% of products use white color soldermask and common material is Taiyo PSR 4000 WT02.
- We can also support PSR 4000 LEW1, and also run samples using LEW 3, but there is no UL.
- UV intensity during exposure has no difference when compared to processing FR4 boards.
- Vacuum on artwork will not be changed because of Al base and its thickness.
- For automotive or if opening smaller than 0.05mm, use CCD exposure machine to get better registration precision.
- Baking time after developing should be controlled (same to FR4), to control the adhesion, contamination and potential discoloration of white soldermask surface.
- Only rework one time.

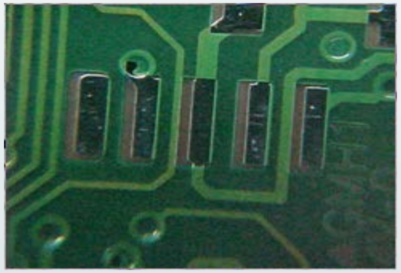
MANUFACTURING PROCESS

# Soldermask / Legend – critical to quality

Extreme soldermask thickness, pin holes and bubbles, under exposure, over developing, soldermask adhesion problems and misregistration.



Web breakdown



Misregistration

**Key controls point**

- Surface pre-treatment
- Viscosity of ink
- Exposure energy
- Film registration
- Concentration of chemical
- Parameter of developing

NCAB GROUP

MANUFACTURING PROCESS

# Profile - Routing / V-Score / Punching

Routing machine

Laser cutting
(FP only)

Punching machine

V-Cut machine

Water cooled machining

# Profile – critical controls

According to the metal base to choose suitable profile type.

**Routing - Water cooling vs. 'dry' routing**

- Speed (rotational): 15 - 30krpm    Feed (penetration) : 0.2 - 0.3m/min
- Cutting speed: 6 - 12mm/sec
- Low efficiency option, higher cost, longer LT and greater tolerances (#2)

**V-Score**

- Speed (rotational): 8～12krpm    Run speed: 20～40m/min
- Length of score/ cut: 40000 - 50000m and 5 times re-sharpened
- Spindle hits after re-sharpened = New hits * (1-(10%+2%* re-sharped times))
- Leaves burrs and some manual work needed to keep edges smooth (#3)

# Profile – critical controls

## Punching

- Hydraulic punching machine = 160T and 300T
- Mechanical press : 20T, 40T
- Hits: 60,000 - 80,000 hits/ panels
- Re-sharpen frequency = every 3,000 – 6,000 hits
- Still some edge deformation, but high eficiency option = faster. (#1)

# Profile – critical to quality

Wrong profile dimensions / size, burr, mis-registration, missing out-line

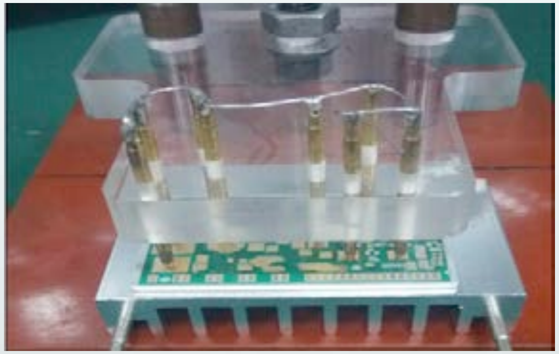
**Key control point (Parameter)**

- For outline normally use calipers to measure the outline dimension. For special dimension such as irregular shape and positional tolerance requirements the PCB will be checked by 3D machine;
- Preferred to use water cool during routing for IMS.
- The tolerances of out line = +/- 0.1mm
- Heavier punch tools on hardness and thickness of material and perimeter of outline

MANUFACTURING PROCESS

# Final processes

Electrical test machine



Hi-Pot test machine

Packaging machine

MANUFACTURING PROCESS

# Surface treatement – critical controls

- HASL process with heat sink will reduce temp of solder pot, so tight controls on temp are needed and will stop producing once the temp has dropped lower than requirement (wait until back up to temperature).
- When surface treatment is immersion tin, silver OSP then Hi pot testing will be done before surface finish.

**Critical to quality**
Similar to standard PCB's

NOTE: IMS / heatsink has no affect for ENIG processes.

## MANUFACTURING PROCESS

# Test equipment

IR reflow


CMI copper thickness

3D 1000x magnifier

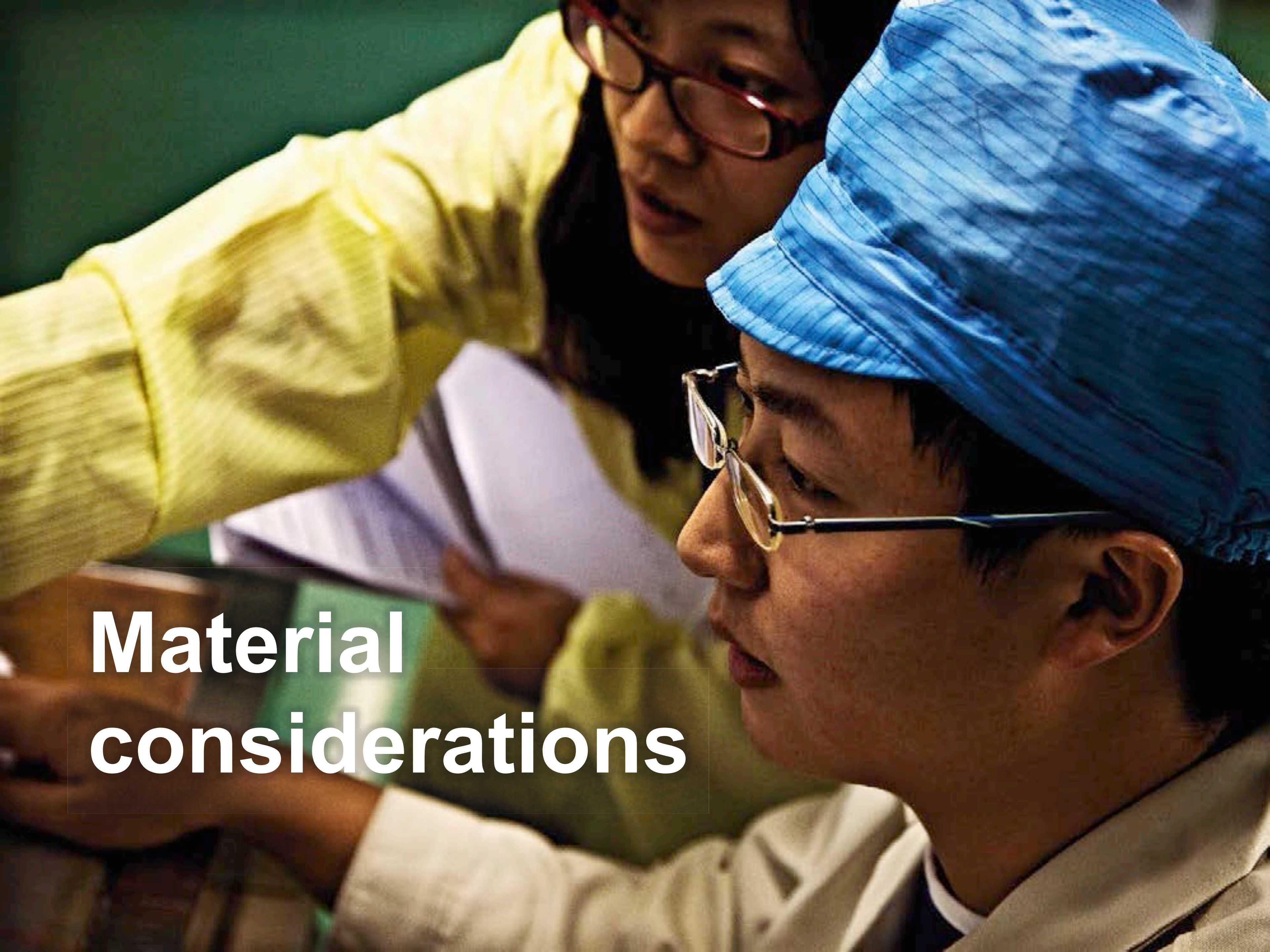
Thermal  Cycling

Hot oil testing

2D measurement

Salt humidity chamber

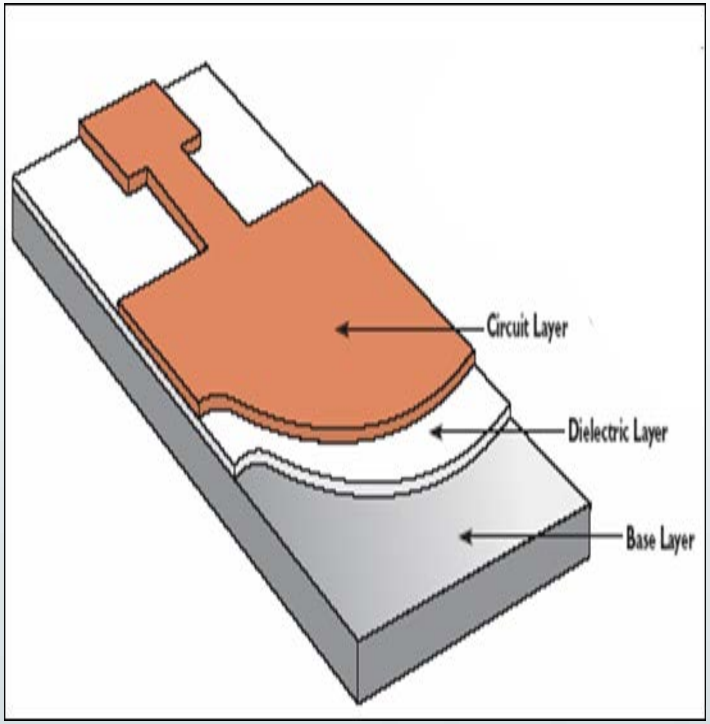
NCAB GROUP


Material
considerations

MATERIAL CONSIDERATIONS

# Material choices

Simple to IMS base copper, it is combined by copper layer, Dielectric layer and metal base layer, how to choose the suitable material for your application?



# Material choices

## Copper foil

- Current carrying demands is the key drived when selecting the suitable copper thickness.
- Cost is also influenced with heavier copper weights being more costly.
- Standard copper foil, normally H-4oz with UL approval, yet beyond this and up to 6oz can be supported as special projects without UL approval.

# Material choices

Thermal dielectric thickness can be **50 – 200um**, and there are numerous brands on offer:

- Bergquist
- Laird T-LAM
- Arlon
- KW
- Ventec
- Polytronics
- ………….

MATERIAL CONSIDERATIONS

# Material choices – key element for dielectric

The **thermal dielectric / thermal pre-preg** is the key element in the construction of an IMS PCB.

Through its high thermal conductivity (W/m/K), it defines the ability to transfer of heat from the circuit side, dissipating it through to the metal core. Therefore, this property defines the thermal performance of the PCB, while still ensuring electrical good insulation.

**Thickness of the dielectric** would affect the Thermal Resistance. The thinner dielectric the smaller Thermal Resistance;

**High-pot resist property**: Dielectric Strength / Breakdown voltage ;Unit of Dielectric Strength is “V / mil” ; of Breakdown voltage is “KV”;

**MOT** – Max. operation temperature, higher is better to support high temperature component;

MATERIAL CONSIDERATIONS

# Material selection

**MOT** is one of the key elements when selecting materials – refer to UL796 file.

A higher MOT can be helpful for higher temperature of components

**23.3 Oven conditioning**

23.3.1 Following the test described in Sections 23.1 and 23.2, two of the four test samples are to be placed for 240 consecutive hours (10 days) in a full-draft circulating-air oven that complies with the Standard Specification for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation, ASTM D 5423, maintained at a temperature determined by the following formula:

$$t_2 = 1.076\ (t_1 + 288) - 273$$

*in which:*

*$t_2$ is the 240-hour (10-day) oven temperature in °C, and*

*$t_1$ is the assigned temperature rating of the printed-wiring board in °C.*

See Table 23.1 for the 240-hour (10-day) oven conditioning temperatures.

23.3.1 revised April 17, 2006

**Table 23.1**
**Oven conditioning temperatures for the desired (or established) MOT**

Table 23.1 revised June 18, 2007

| $t_1$, Desired (or established) MOT (°C) | $t_2$, Oven temperature (°C) for 240-hour (10-day) oven conditioning | $t_3$, Oven temperature (°C) for 1344-hour (56-day) oven conditioning |
|---|---|---|
| 75 | 118 | 98 |
| 80 | 123 | 103 |
| 85 | 129 | 108 |
| 90 | 134 | 113 |
| 105 | 150 | 128 |
| 120 | 167 | 144 |
| 125 | 172 | 149 |
| 130 | 177 | 154 |
| 150 | 199 | 174 |
| 155 | 204 | 179 |
| 160 | 210 | 184 |
| 170 | 220 | 195 |
| 175 | 226 | 200 |
| 180 | 231 | 205 |

NOTE – The temperatures represented by $t_2$ and $t_3$ are calculated based on the formulas in Clauses 23.3.1 and 23.3.2 respectively, with the conditioning values rounded up to the next whole integer.

23.3.2 An alternate 1344-hour (56-day) oven conditioning temperature may be used if the fabricator anticipates that the higher test temperature and increased Bond Strength test requirements of the 240-hour (10-day) oven conditioning program will be too severe for the printed-wiring board. Following the test described in 23.2.1, the two remaining (of the four) test samples are to be placed for 1344 consecutive hours (56 days) in a full-draft circulating-air oven that complies with the Standard Specifications for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation, ASTM D 5423, maintained at a temperature determined by the following formula:

$$t_3 = 1.02\ (t_1 + 288) - 273$$

NCAB GROUP

## MATERIAL CONSIDERATIONS

# Material selection

Some most popular materials are listed below, detail can refer to the data sheets.

| Material vendor | Type | MOT | Thermal conductive (W/m K ) | Tg | Dielectric thickness (um) | Copper Thickness | Mark |
|---|---|---|---|---|---|---|---|
| Arlon | 92ML | 140 | 2 | 170 | 75-152 | E:17-102<br>I:77 | Single and double side Al / Cu base |
| Arlon | 92ML | 90 | 2 | 170 | 75-152 | 17-102um | Single side Cu / AL base |
| Bergquist | HT | 140 | 2.2 | 150 | 76±5 | 34-204um | Single side Cu / AL base |
| Bergquist | HIGHROAD® T30.20 | 130 | 1.1 | 90 | 76 | 34-102um | Single side AL base |
| Bergquist | HPL-03015 | 140 | 3 | 185 | 38±5 | 34-102um | Single side Cu / AL base |
| Bergquist | MP | 130 | 1.3 | 90 | 76±5 | 34-204um | Single Cu / Al base |
| Kinwong | KW-ALS | 90 | 2 | 110 | 80-200 | 17-140um | Single side stainless steel / Cu / AL base |
| Kinwong | KW-ALG | 90 | 1.5 | 120 | 80-200 | 34-102um | Single Al base |
| Ventec | VT-4A2 | 90 | 2.2 | 130 | 75-200 | 17-204um | Single side AL base |
| Ventec | VT-4B | 130 | 3 | 130 | 75-200 | 34-204um | Single side AL base |
| Laird | T-Lam DSL 1KA | 110 | 3 | 105 | 100-305 | 34-136um | Single side Cu / AL base |
| Laird | T-Lam DSL | 110 | 3 | 105 | 102-305 | E:17-102<br>I:102 | Single and double side Cu base |
| Laird | T-Lam DSL | 110 | 3 | 105 | 102-305 | E:17-102<br>I:76 | Single and double side Cu / AL base |
| Laird | T-lam SS HTD | 150 | 2.2 | 168 | 102-152 | 17-102um | Single side Cu / AL /Cu alloy base |

MATERIAL CONSIDERATIONS

# Material selection

| Material vendor | Type | MOT | Thermal conductive (W/m K ) | Tg | Dielectric thickness(um) | Copper Thickness | Mark |
|---|---|---|---|---|---|---|---|
| PTTC | PTTC(TCP-2L) | 90 | 2 | 130 | 80-150 | E:34-102<br>I:67 | Single and double side AL base |
| PTTC | TCB-2AL | 110 | 2.7 | 130 | 80-150 | 17-102um | Single Al base |
| PTTC | TCB-2L | 90 | 2 | 130 | 80-150 | 34-102um | Single Al base |
| Qingxi | CS-AL-88,CS-AL-89 | 130 | 2 | 100 | 60-200 | 34-102um | Single side Cu / AL base |
| Dongli | EPA-M2CTI | 90 | 2 | 145 | 75-150 | 34-102um | Single Al base |
| DOOSAN | DST-5000 | 110 | 2 | 110 | 95-200 | 34-102um | Single side AL base |

# Material choices

## Base metal

- Consider the application to choose suitable metal base
  - For normal lighting application, can choose 1K (1100) and 3K (3003)serial Aluminium;
  - For Power application, can choose 5K (5052) serial Aluminium;
  - For Rectification application (shaking environment), can choose 6K (6061)serial Aluminium;
  - Postfix name “H” means**;** Work hardening state to increase strength; “T” means after heat treatment;  the first digital after “H” &”T” means degree; see next slide.
- Copper base, much better for heat sink;
- Stainless steel, good for electromagnetism shielding;

# Material choices

| Metal (Alloy) | Thermal conductivity (W/m*K) | CTE (PPM / K) | Density (g/cm3) | Elasticity modulus (Gpa) | Mark |
|---|---|---|---|---|---|
| C1100 Cu | 391.1 | 16.9 | 8.94 | 117 | Low CTE, high thermal conductivity; high cost |
| 1060 H18 Al | 203 | 23.5 | 2.7 | 25.8 | Pure Al, good thermal conductivity but hard for mechanical making, low cost |
| 5052 H34 Al | 150 | 25 | 2.7 | 25.9 | Al-Mg alloy, good bending property, suitable for punch; middle cost |
| 6061 T6 Al | 150 | 25 | 2.7 | 26 | Al-Mg-Si alloy, suitable for CNC, V-cut; high cost; |
| 304 stainless steel | 16 | 16 | 7.9 | 200 | |
| Cool Roll steel | 50 | 13 | 7.9 | 200 | |

# Thermal management – Material conclusions

Use thermal dielectric material with high thermal conductivity.

Keep the thermal resistance as low as possible through using thin dielectric material in the construction.

Consider the MOT, Dielectric Strength to get suitable material according to application;

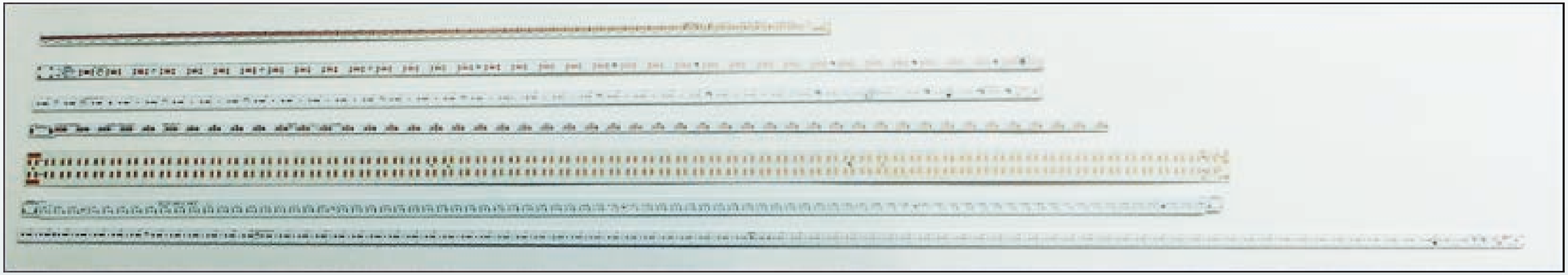
Additional:

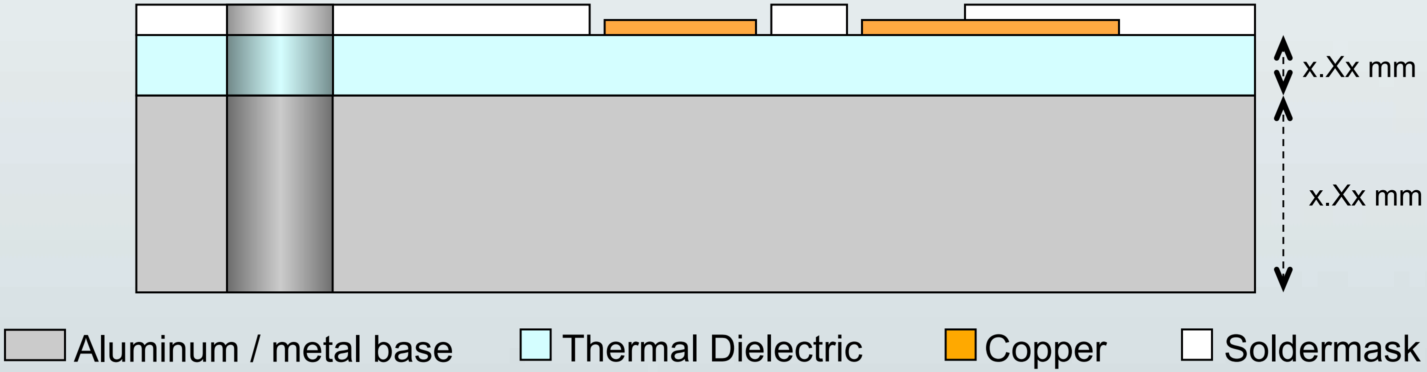
- Design the tracks with a proper width so they do not heat up the construction.
- Consider thermal vias in builds if you need more than one layer.

MATERIAL SELECTIONS

# Standard builds

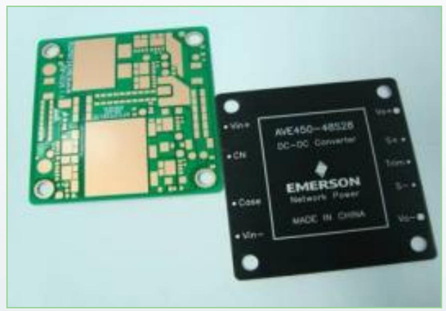
## Single layer IMS (maximum length of 1200mm)

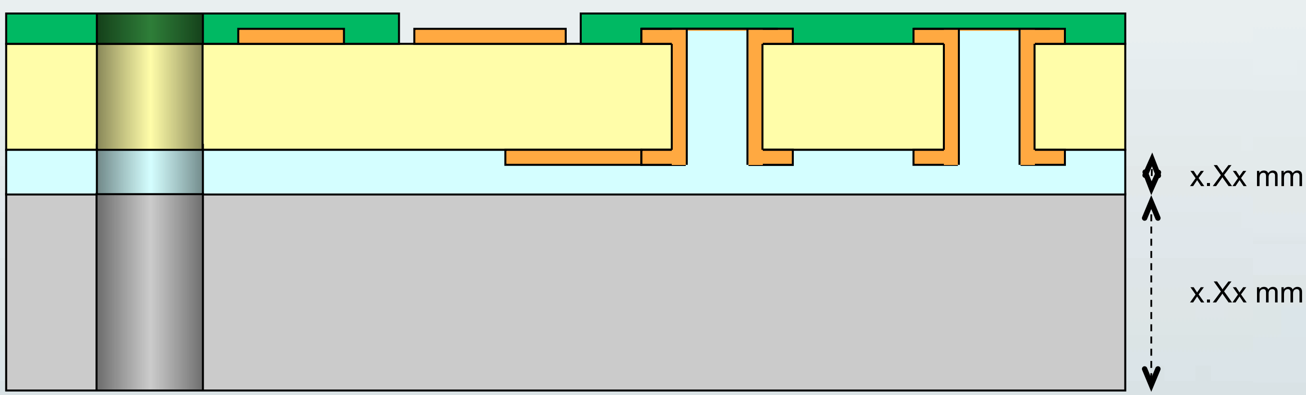




# Standard builds

## Double sided PCB with metal base




Aluminum / metal base   Thermal Dielectric   Copper   FR4   Soldermask

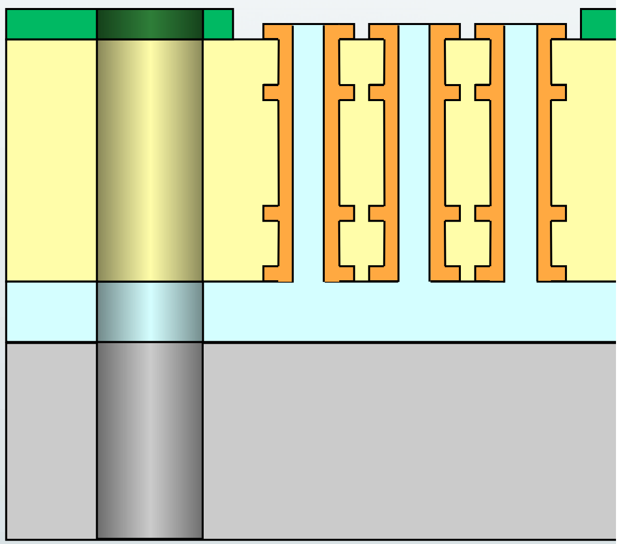
MATERIAL SELECTIONS

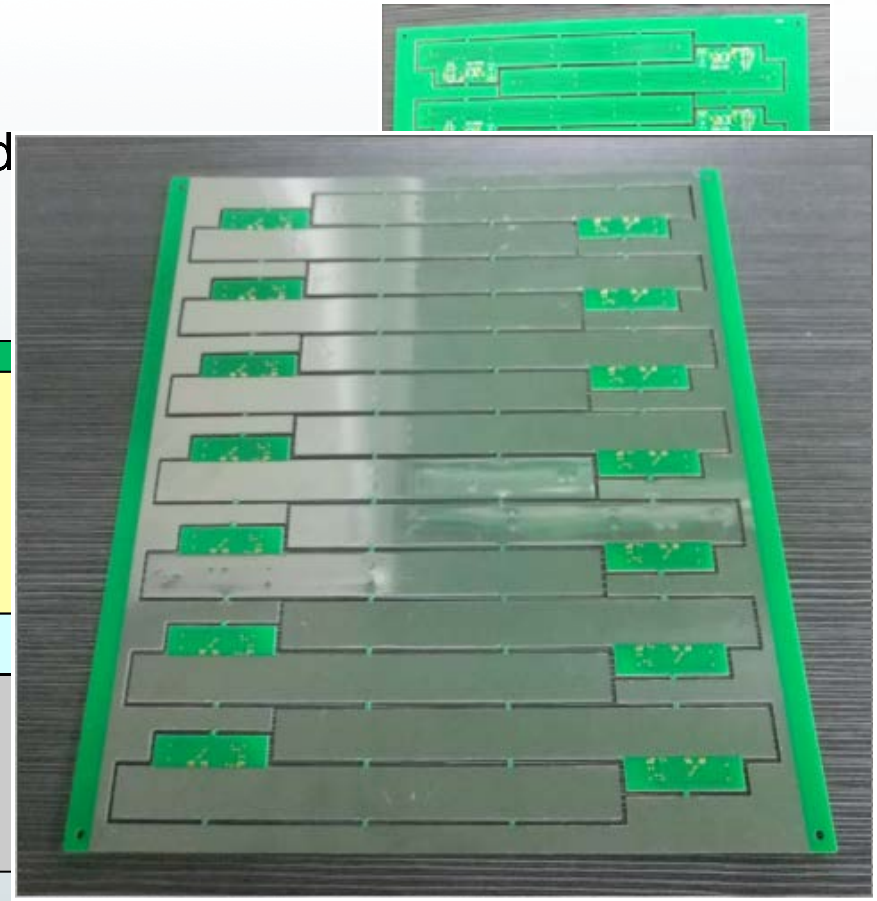
# Standard builds

## Multi layer PCB with metal base

Change the Al core for Ni/Fe alloy and

PCB with high magnetic conductivity.





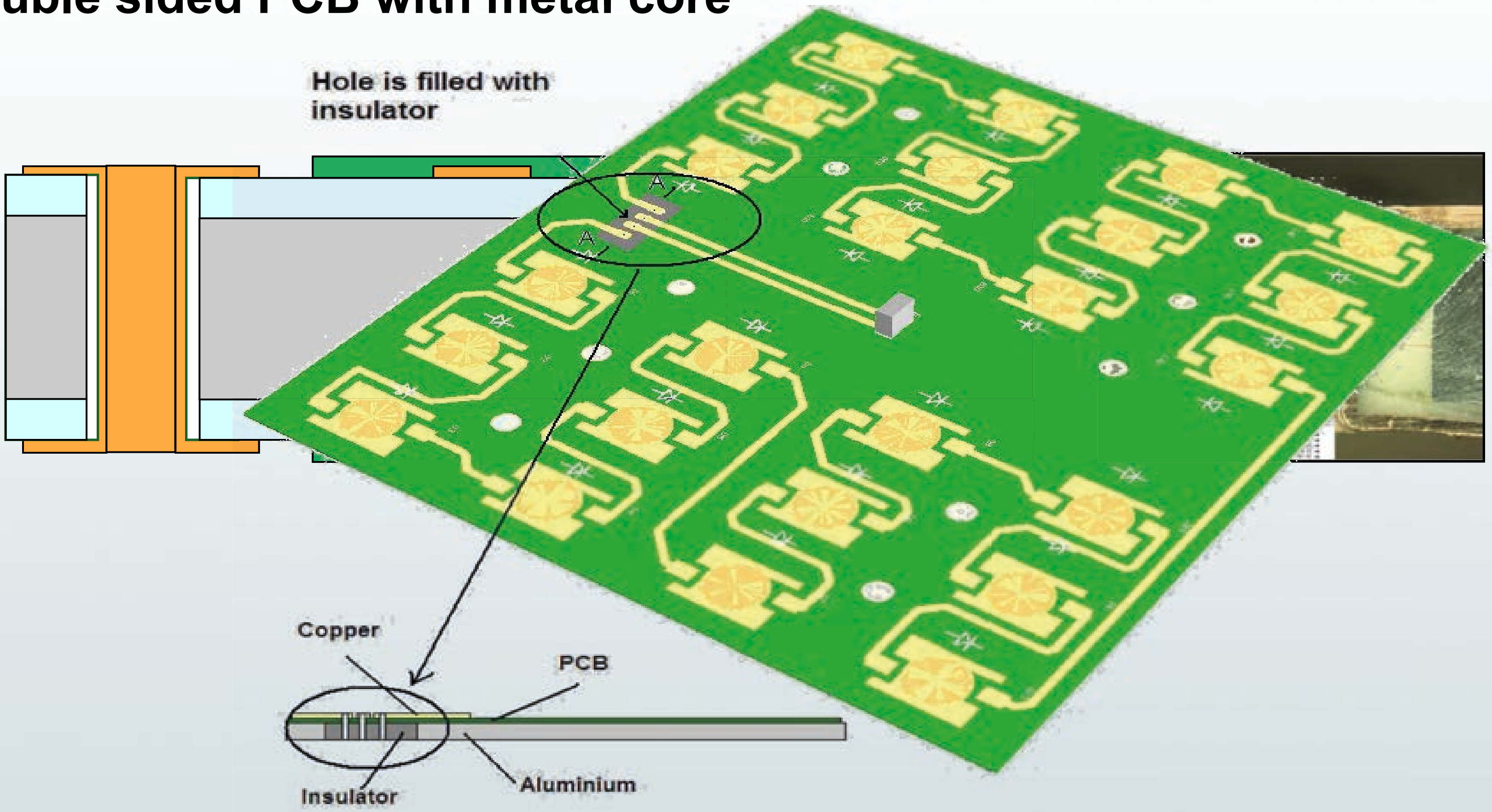
Aluminum / metal base   Thermal Dielectric   Copper   FR4   Ni/Fe alloy metal base

NCAB GROUP

MATERIAL SELECTIONS

# Standard builds

## Double sided PCB with metal core

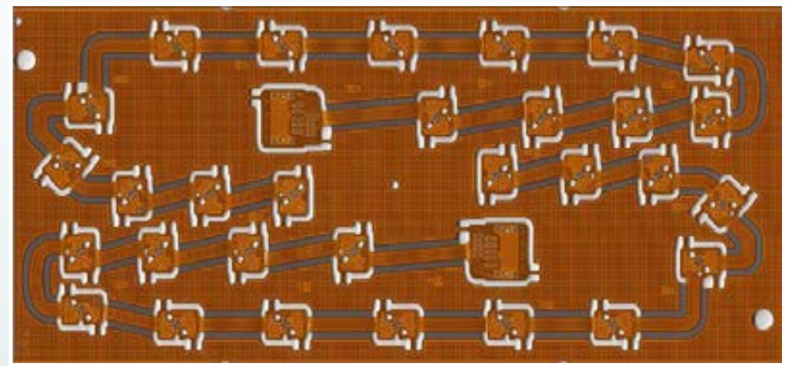


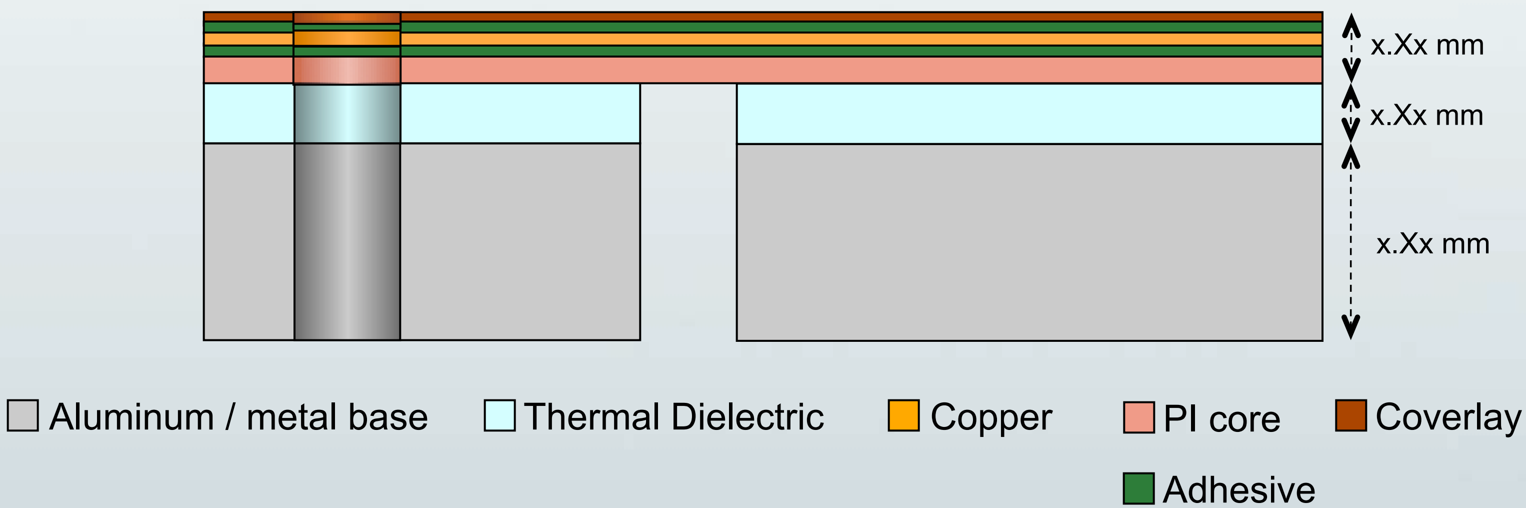

☐ Aluminum / metal base ☐ Thermal Dielectric ☐ Copper ☐ Resin ☐

MATERIAL SELECTIONS

# Standard builds

## Flexible PCB with metal base

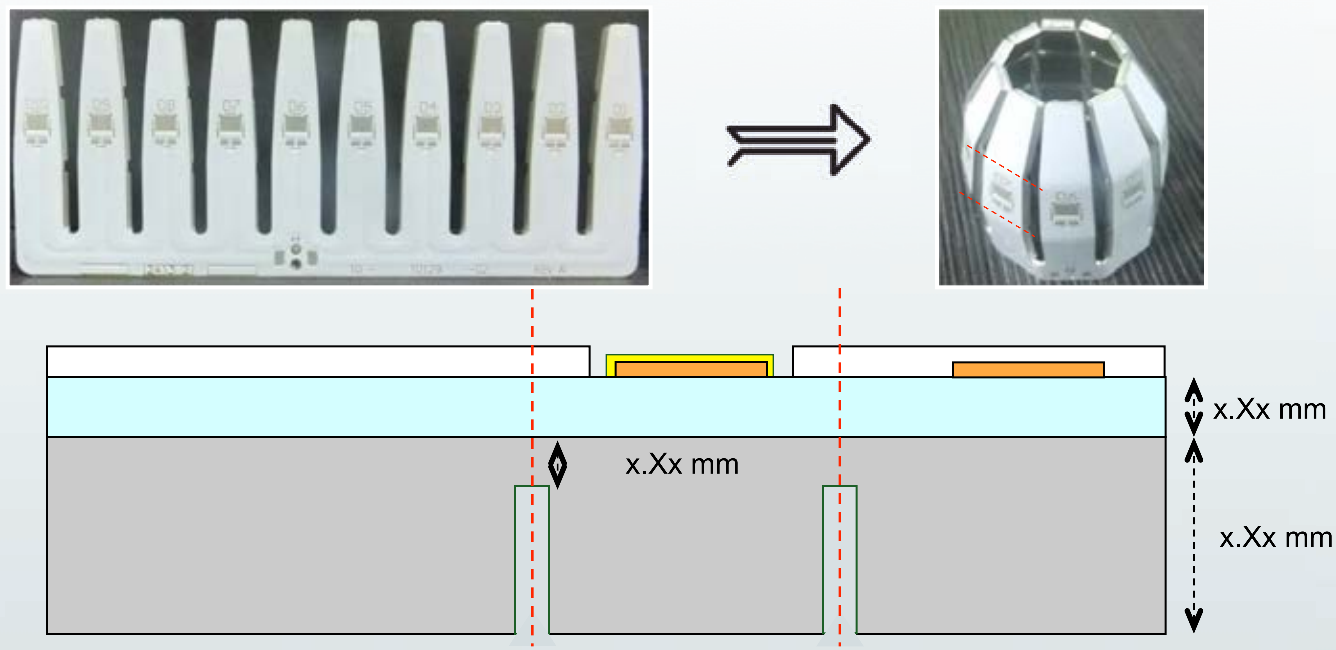




MATERIAL SELECTIONS

# Other builds

## 3D Semi-flex IMS PCB

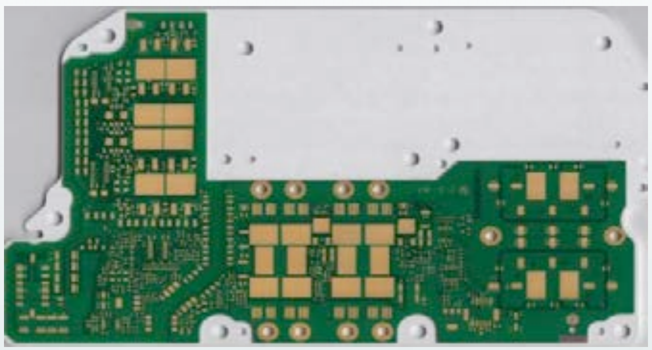


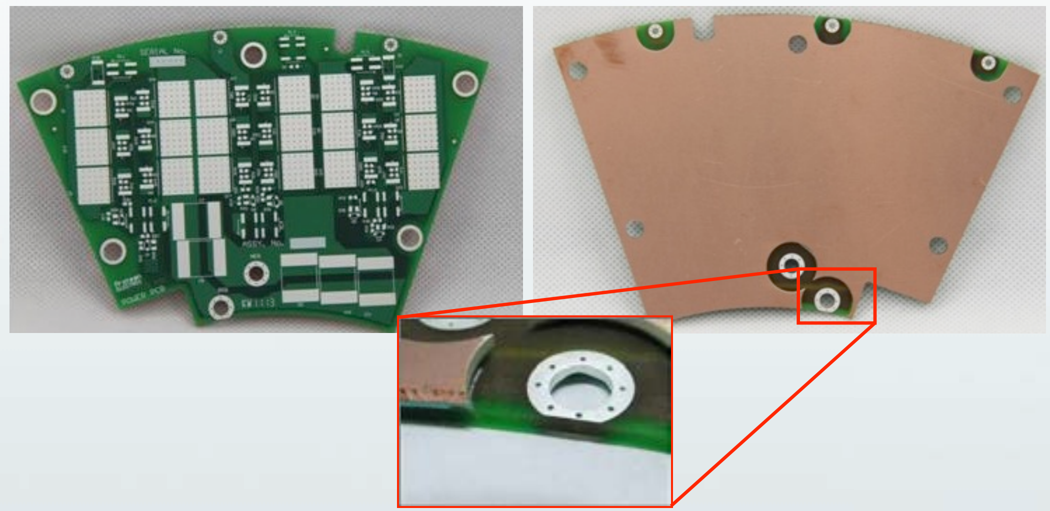

Aluminum / metal base
Thermal Dielectric
Copper
Soldermask
ENIG / OSP / other

## MATERIAL SELECTIONS

# Other builds

**Mismatch between PCB and metal base size.**



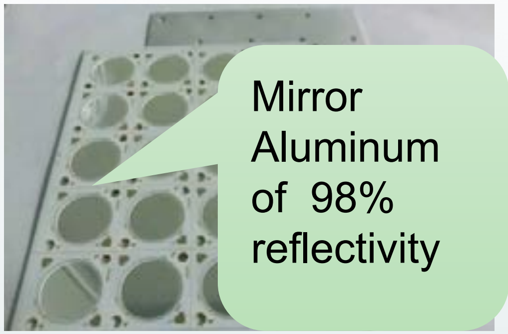


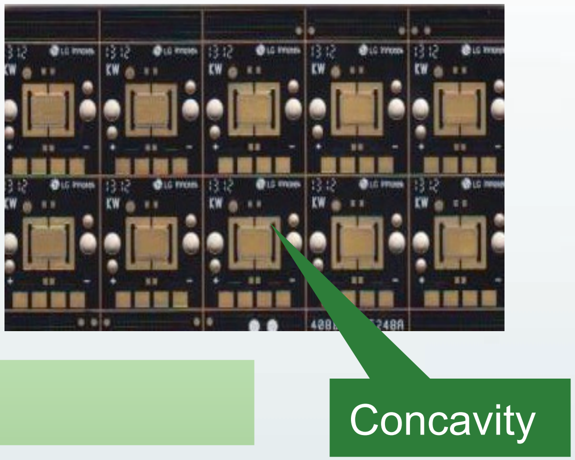
**Metal base > PCB**
(larger fixing plate)

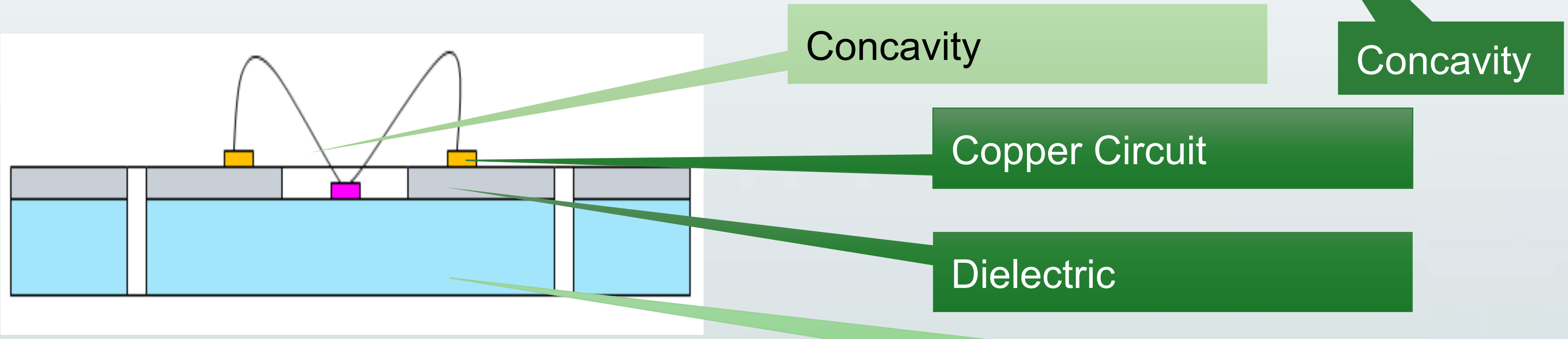
**Metal base < PCB**
(cavity within the area of the PCB)

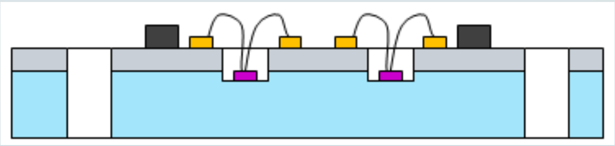
# Other builds

## COB PCB with mirror aluminum of 98% reflectivity



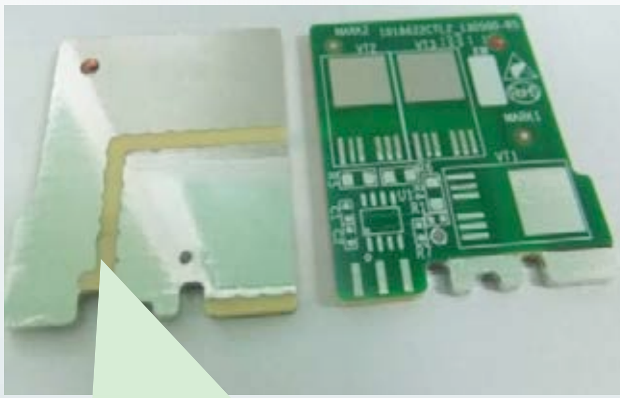



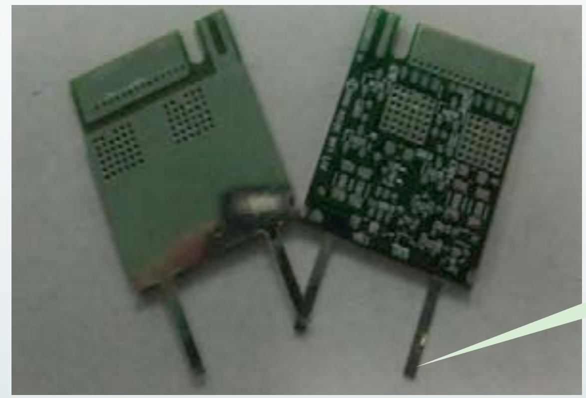



MATERIAL SELECTIONS

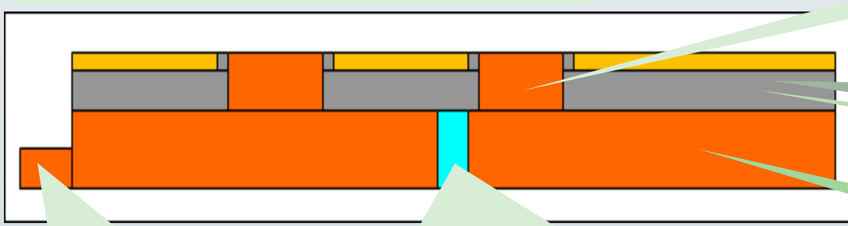
# Other builds

## Copper base PCB with copper protruding, blind slot and copper pin






Blind Slot and Resin filling



# Design for Manufacture

DESIGN FOR MANUFACTURE

# Design consideration

In most aspects, the design rules **by IPC-2221A** can be used.

**Drilling / Routing**, this can be done on prototypes / low volumes. It is not cost effective in volume since the aluminum is rather ‘nasty’ to drill / rout mechanically.

**V-cut method** is good for both low and high volumes.

**Punching of holes / outline**. This is the recommended method to produce these board and it requires that the design is optimized for punching.

**Flatness** since this design contains 3 different material. The different CTE values needs to be taken under consideration. The aluminum will dominate if the copper thickness is below 10% of the total thickness.

# Design consideration

**Standard routing thickness:** 0.51mm-3.2mm (Max. 5.0mm)

**V score depth:**

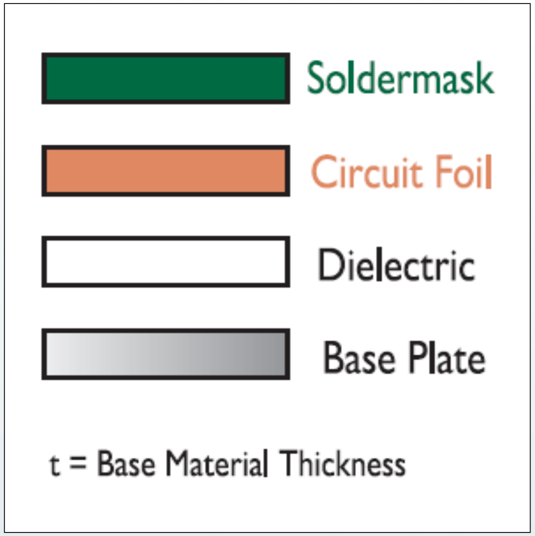
- TV light bar with board thickness <1.5mm left thickness>=0.15mm (unit separate between us but connect by one nail with V-cut at the end)
- For daylight lamp>0.1mm (unit close to unit)
- Other normal Light>1/5board thickness

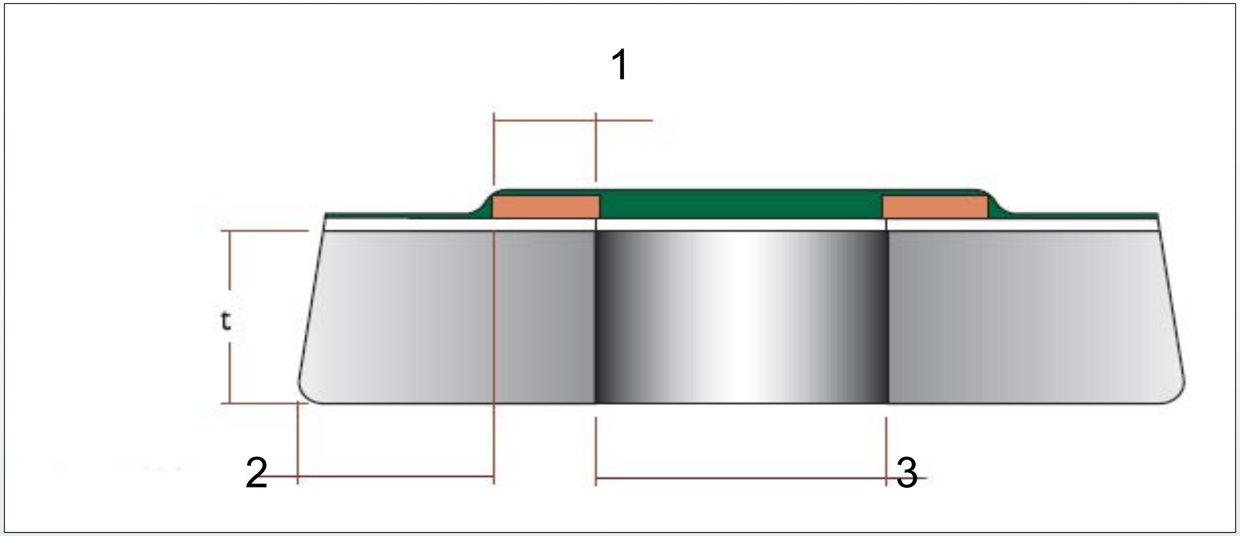
**Clearances from edge of metal / holes / circuitry:**
Same to FR4

**Min spacing between circuits**: track / gap: 4mil /4mil

DESIGN FOR MANUFACTURE

# Design consideration

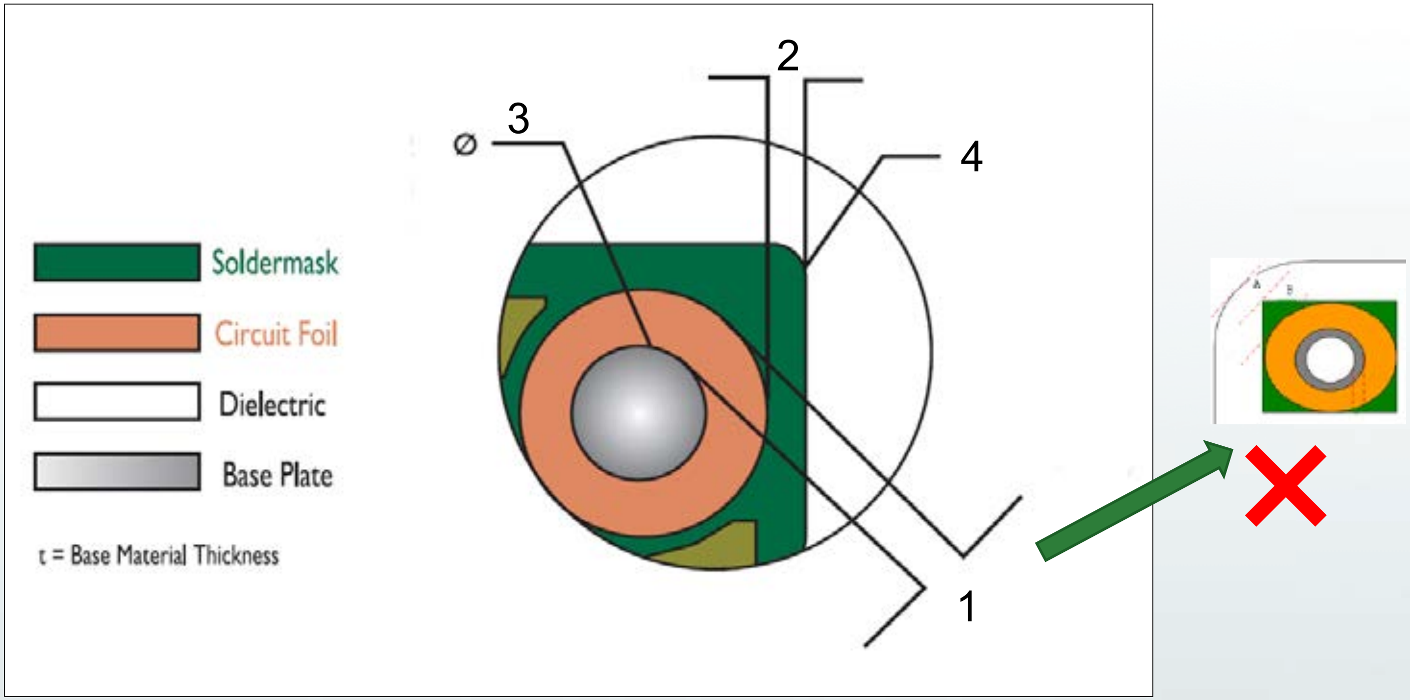



1. Clearance 0.15mm for drilling / 0.45mm for punching
2. For 1oz and 2oz, copper to outline ≥0.35mm for punching (not consider high pot voltage, for high-pot, should add 0.1mm more)
3. Min drilled diameter >= ¾ t
4. Min Punching hole diameter >=1.0 t and must >=1.5mm

DESIGN FOR MANUFACTURE

# Design consideration

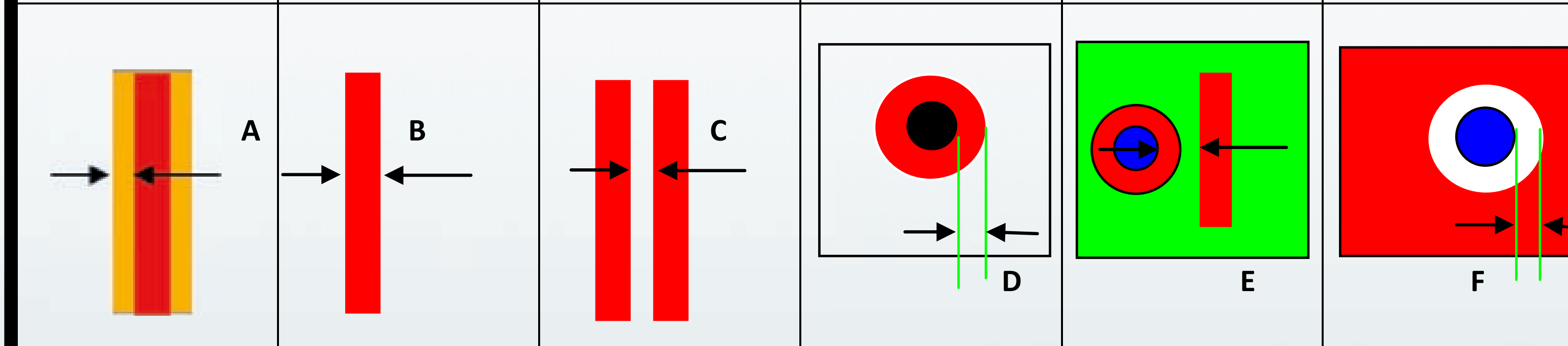



1. For ring of hole, don’t make it to be as square
2. Refer to “2” in last slide
3. Min punched hole >= material thickness * 1 and >= 1.5mm
4. Min radius :0.5mm

DESIGN FOR MANUFACTURE

# Design consideration

| Etch Compensation | Min. Track width | Min. Space ( feature to feature ) | Min. Annular Ring | Min. Space: PTH hole to copper | Min. Space: NPTH hole to copper |
|---|---|---|---|---|---|

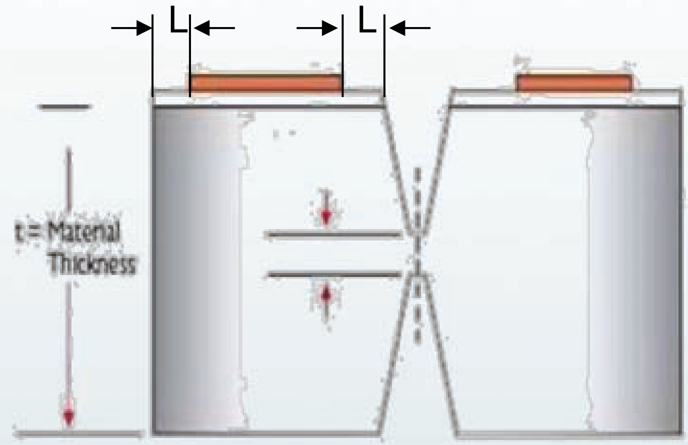



| | Base copper thickness | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|
| Outer layer | 12um/ $^{1}/_{3}$oz | / | / | / | / | / | / |
| | 18um / ½oz | 0.015mm | 0.10mm | 0.10mm | 0.15mm | 0.25mm | 0.25mm |
| | 35um / 1oz | 0.02mm | 0.10mm | 0.10mm | 0.15mm | 0.28mm | 0.25mm |
| | 70um / 2oz | 0.03mm | 0.15mm | 0.15mm | 0.20mm | 0.35mm | 0.28mm |
| | 105um / 3oz | 0.045mm | 0.20mm | 0.20mm | 0.25mm | 0.48mm | 0.30mm |
| | 140um / 4oz | 0.07mm | 0.25mm | 0.25mm | 0.35mm | 0.65mm | 0.35mm |

# Design consideration

## Safe distance of copper to board edge (L)

| Copper to edge distance for high pot test | | | |
|---|---|---|---|
| Distance | Highest testing votage (VDC) | | Thickness of Dielectric |
| | No SM cover | SM cover | |
| 0.35mm | DC600V\0.5 mA | DC1300V\0.5 mA | 100um+/-30% |
| 0.45mm | DC800V\0.5 mA | DC1700V\0.5 mA | 100um+/-30% |
| 0.55mm | DC1000V\0.5 mA | DC2100V\0.5 mA | 100um+/-30% |
| 0.65mm | DC1200V\0.5 mA | DC2200V\0.5 mA | 100um+/-30% |
| 0.75mm | DC1300V\0.5 mA | DC2200V\0.5 mA | 100um+/-30% |
| 0.85mm | DC1400V\0.5 mA | DC2400V\0.5 mA | 100um+/-30% |
| 0.95mm | DC1400V\0.5 mA | DC2600V\0.5 mA | 100um+/-30% |
| 1.05mm | DC1500V\0.5 mA | DC2800V\0.5 mA | 100um+/-30% |

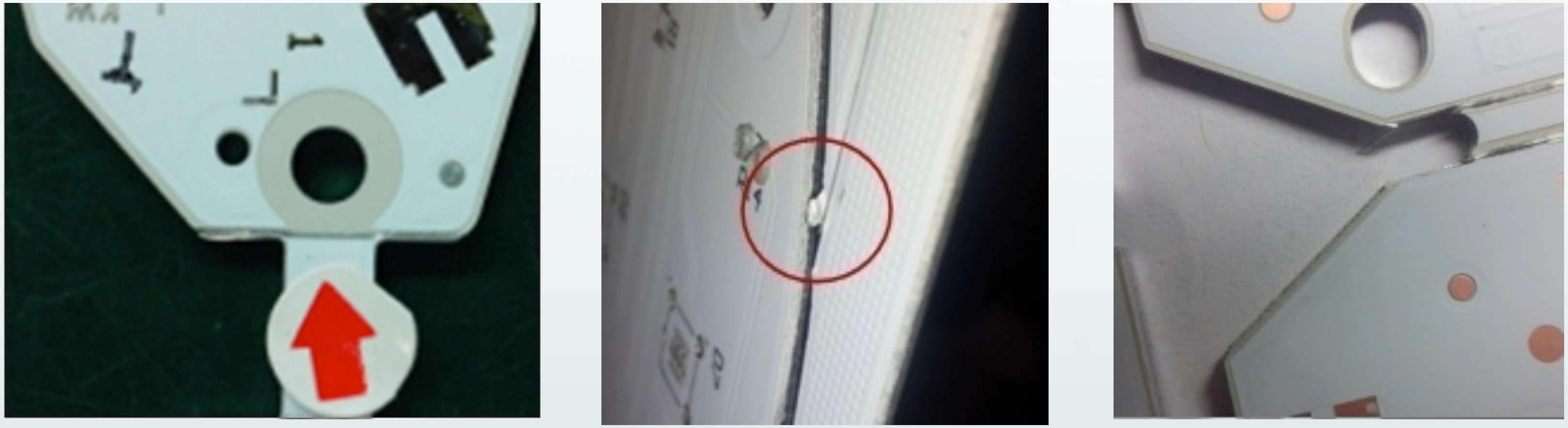



The high pot resistance conflicts with thermal conductivity - normally a lower dielectric thickness is better for thermal conductivity, but electric insulation strength will be weaker.

So keep the safe distance of copper to edge as well as considering thickness of dielectric at the design stage.

# Design consideration

Routing / punching and V-cut line cannot aim to be edge-to-edge otherwise there is a risk that  burrs will occur.



For  punching, hole to board edge ≥ board thickness, because of the risk of deformation / damage to holes.

# Design consideration

Minimum hole size ≥ ¾ of board thickness and ≥ 1.0mm, otherwise there is a risk of drill bit breakage (cause missing holes).

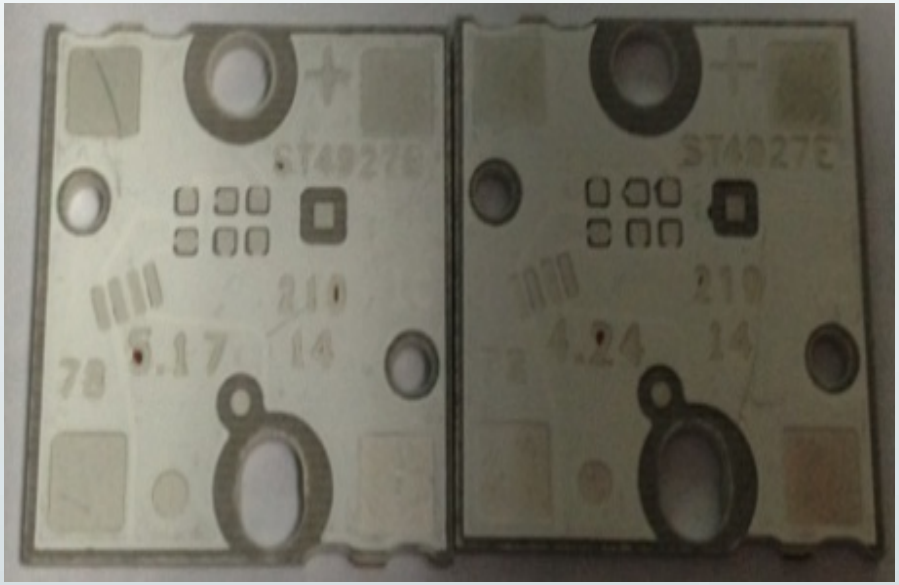
The minimum gap for routing shall be 1.80mm.

For high pot test, according to high pot requirement, the copper to board edge distance will be difference, it is direct ratio.

For example, DC600V, distance of copper to board edge>=0.35mm, plus punching tolerance +/-0.1mm (punching), safety distance should be 0.45mm.

# Design consideration

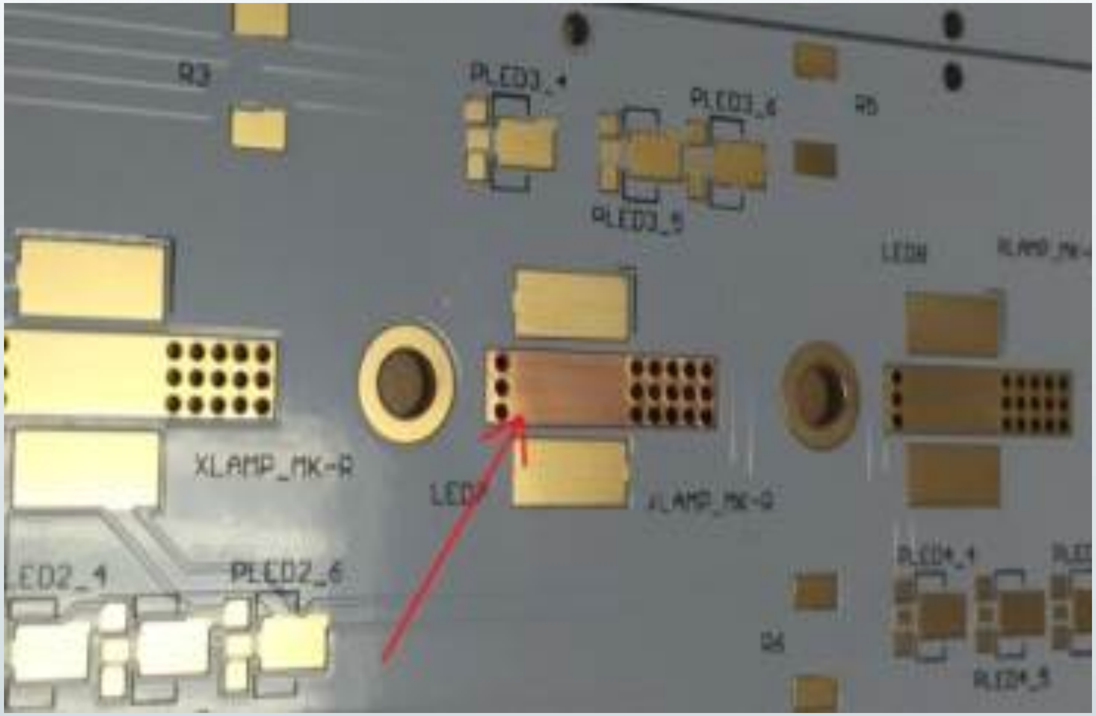
If the surface treatment is immersion tin, then there is a risk that words or markings applied in soldermask (such as in “8” “6” etc.) may be loose definition or peel off. Where possible should fully filled or change it to be etched or silkscreen.



## DESIGN FOR MANUFACTURE

# Design consideration

If the surface treatment is ENIG, and after ENIG second stage drilling is applied within the pads, then the pad may be discolored with copper as the drilling process may affect the nickel and gold.




Cost factors

# Cost factors

**The main factors that affect the cost of an IMS PCB:**

1. Different metal bases / cores – aluminium, copper, steel
2. Different thickness of material – copper weights, metal base, dielectric thickness
3. Dielectric thermal properties – 1W, 2W, 3W, 5W, 8W
4. Surface finish
5. Profile type – punch, routing, score
6. Material utilisation

## COST FACTORS

# Surface finishes

We know already that different finishes have positives and negatives:

**HASL – Tin/Lead hot air solder level**
Typical thickness 1 – 40um. Shelf life:12 months

**OSP (Organic Solderability Preservative)**
Typical thickness 0.20-0.65µm. Shelf life: 6 months

**LF HASL – Lead Free hot air solder level**
Typical thickness 1 – 40um. Shelf life: 12 months

**Immersion Ag – Immersion Silver**
Typical thickness 0.12 – 0.40um. Shelf life: 6 months

**ENIG – Immersion gold / Electroless Nickel Immersion Gold**
Typical thickness 3 – 6um Nickel / 0.05 – 0.125um Gold. Shelf life: 12 months

1. Immersion finish = excellent flatness
2. Good for fine pitch / BGA / smaller components
3. Tried and tested process
4. Wire bondable

1. Expensive finish
2. Black pad concerns on BGA
3. Can be aggressive to soldermask – larger soldermask dam preferred
4. Avoid soldermask defined BGA's
5. Should not plug holes on one side only

NCAB GROUP

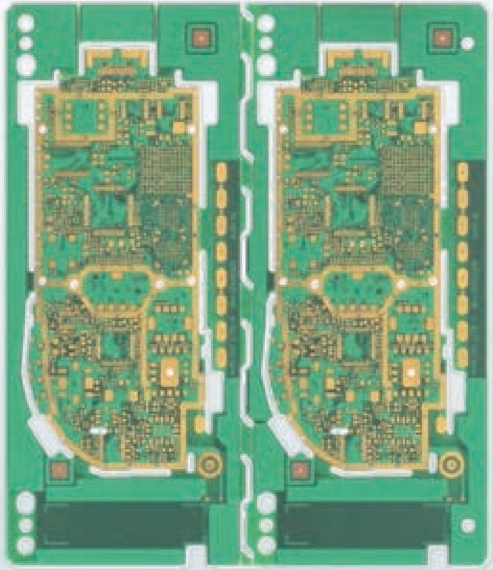
COST FACTORS

# Surface finishes

Example below is to show difference the finish makes to a raw PCB.

Prices may vary from factory to factory.

| Type | 2-Layer | 12-Layer |
|---|---|---|
| OSP | 0% | 0% |
| HASL | 0% | 0% |
| LF HASL | 3% | 0,8% |
| Imm Ag | 18% | 4.5% |
| Imm Sn | 18% | 4.5% |
| ENIG | 22% | 5.5% |
| ENEPIG | By quote | By quote |



COST FACTORS

# Profile type

## Three main methods:

**Punching**

1 High efficiency
2 Reproducability and repeatability
3 Good quality finish

**Routing**

1 Suitable for complex outline
2 Suitable for sample / low volume

**V-Score / Routing**

1 High material utilisation
2 Good for all volumes - large to small

1 Only for simple outlines (straight lines)
2 Hard to break out into single unit
3 Burrs and deformation can occur after separation

NCAB GROUP

COST FACTORS

# Profile type

Example below based upon real project using panel size of 500 x 600mm and a circuit size 460.00 x 6.00mm.

| | Material utilisation | Output / Efficiency |
|---|---|---|
| **Punching** | 72 ccts per panel<br>66.2% material utilisation | 1000 ccts / hour<br>(> 13 panels per hour) |
| **Routing** | 72 ccts per panel<br>66.2% material utilisation | 72 ccts / hour<br>(1 panel per hour) |
| **V-Score / Routing** | 96 ccts per panel<br>88.3% material utilisation | 261 ccts / hour<br>(>2.7 panels per hour) |

Summary – very much volume and design dependant.

NCAB GROUP

COST FACTORS

# Material utilisation

IMS material is available in limited panel sizes, the standard is:

**Polytronics**
500 x 600mm, 457 x 610mm, 500 x 1200mm
*480 x 574mm, 437 x 584mm, 480 x 1174mm*

**Bergquist**
457 x 610mm
*437 x 584mm*

**Laird**
457 x 610mm
*437 x 584mm*

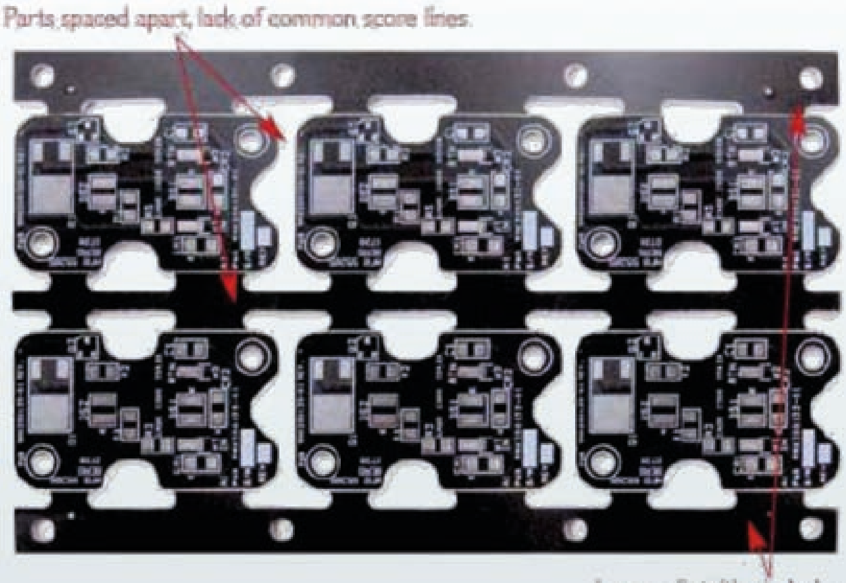
**Kinwong**
450 x 600mm, 390 x 600mm, 330 x 600mm
*430 x 574mm, 370 x 574mm, 310 x 574mm*

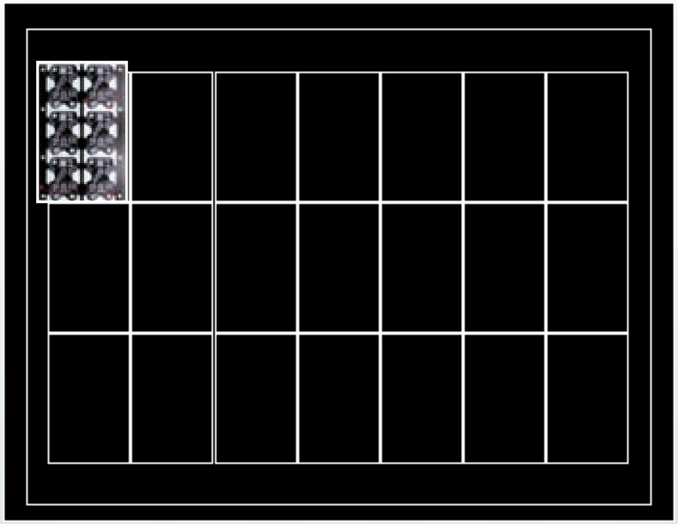
**NOTE**: We must remove 13mm on each edge in the X, and 10mm in the Y

COST FACTORS

# Material utilisation

## Example – original



**Circuit size** = 24 x 40mm, Panel size = 78 x 124mm

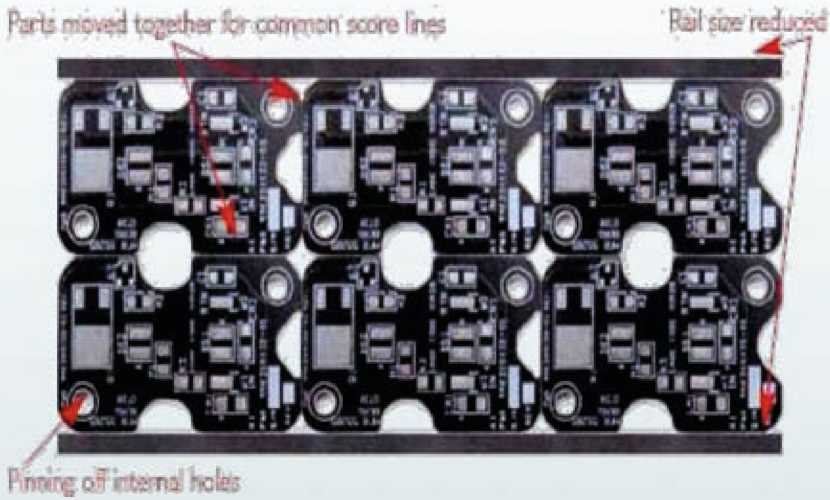
**Material** = Bergquist MP = 457 x 610mm (*437 x 584mm*)

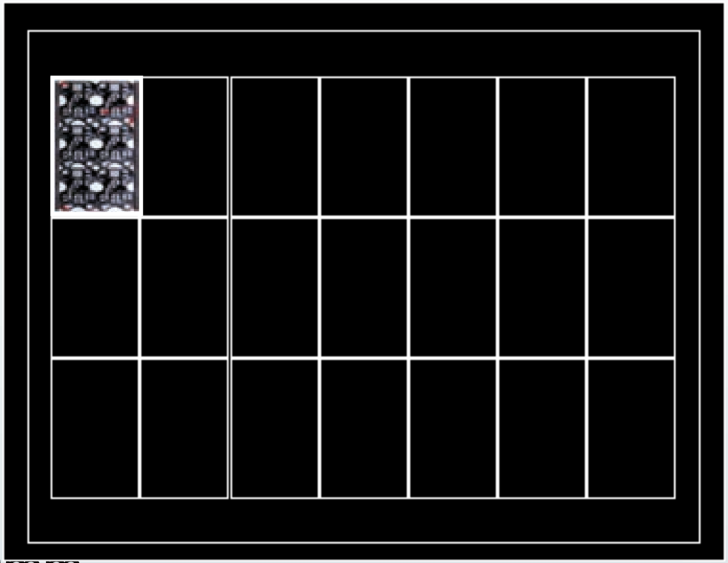
**Panelisation** = 126 circuits / 21 panels, with utilization of 43.4%

COST FACTORS

# Material utilisation

**Example – reduce spacing and carrier** (routing will cut into carrier)



**Circuit size** = 24 x 40mm, Panel size = 58 x 120mm

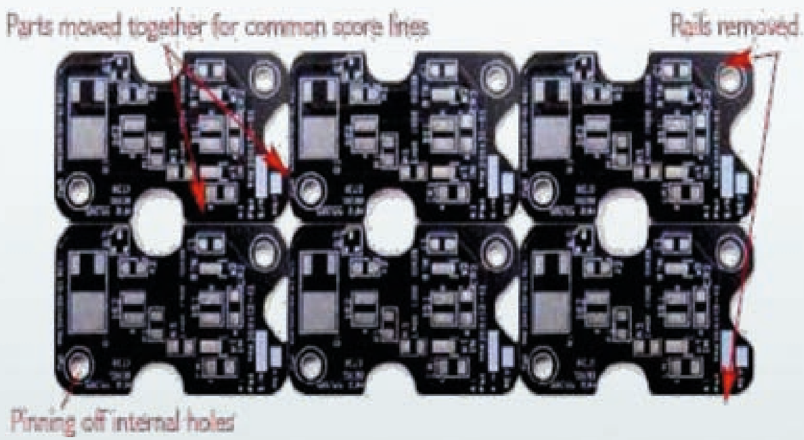
**Material** = Bergquist MP = 457 x 610mm (*437 x 584mm*)

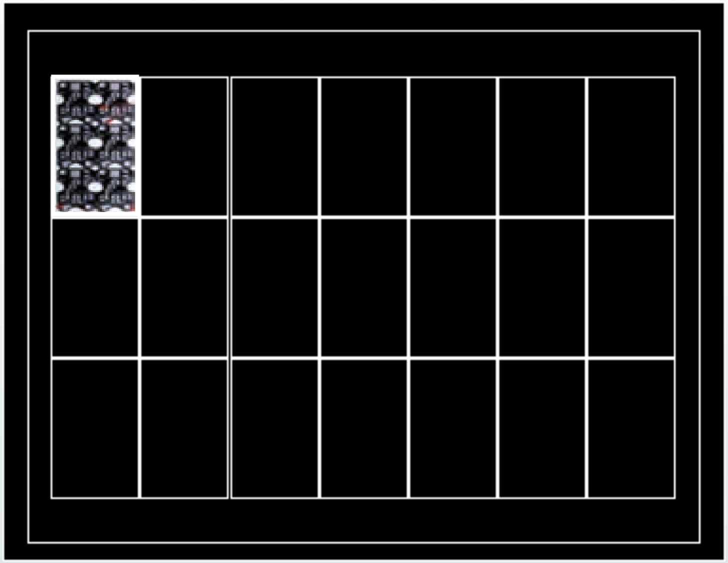
**Panelisation** = 186 circuits / 31 panels, with utilization of 64.1%

COST FACTORS

# Material utilisation

## Example – remove carrier completely



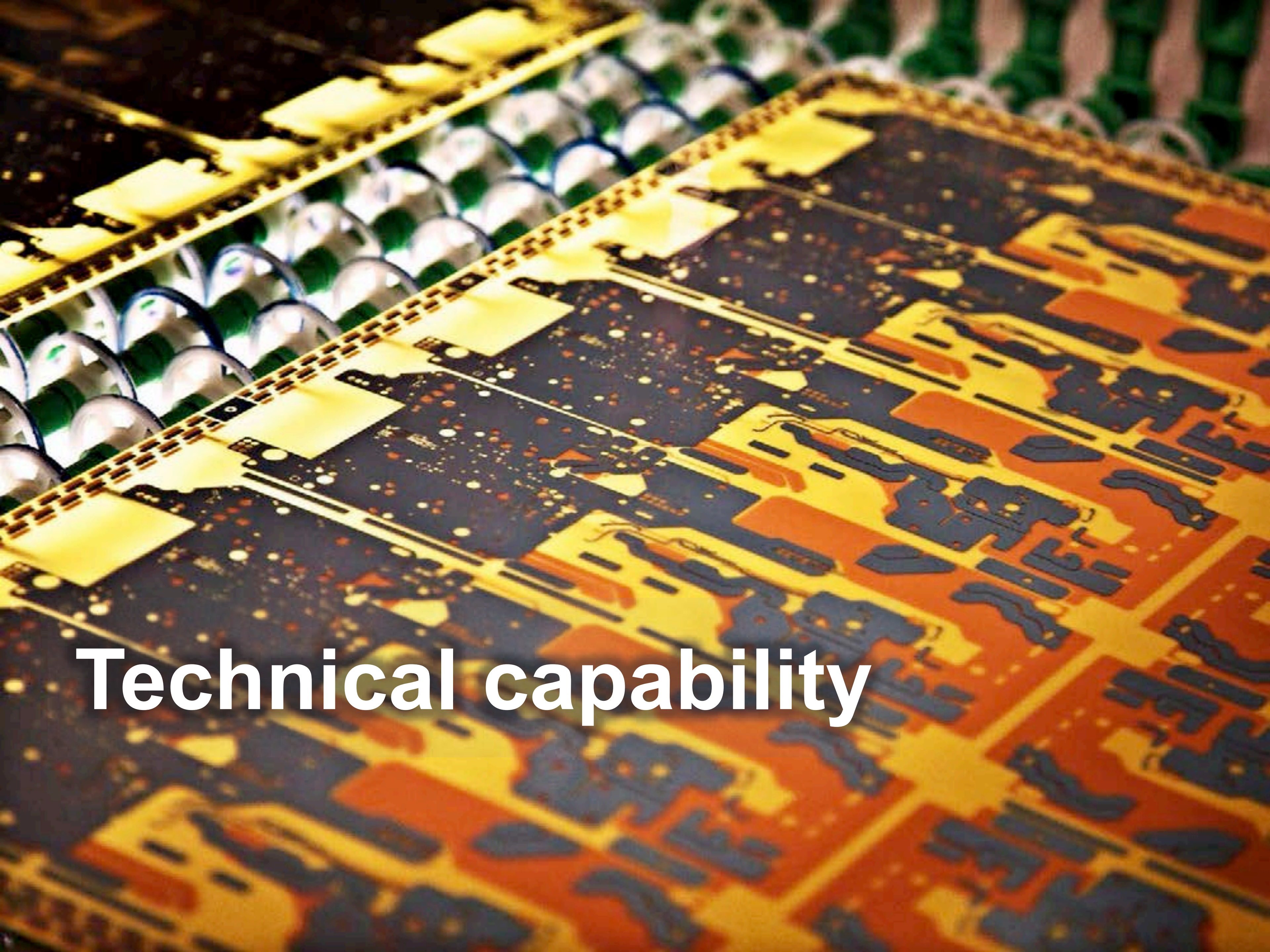



**Circuit size** = 24 x 40mm, Panel size = 48 x 120mm

**Material** = Bergquist MP = 457 x 610mm (*437 x 584mm*)

**Panelisation** = 222 circuits / 37 panels, with utilization of 76.5%

# Technical capability



# TECHNICAL CAPABILITY – PROCESS CAPABILITY

| Item | Feature | Processing capacity |
|---|---|---|
| Laminate | Brand of MCCL | Bergquist, Laird, PTTC, Kinwong, Arlon, Doushan, SYE, Chin-shi (Qingxi), Ventec, |
| | Laminate type | AL base , Copper base, Stainless steel base, |
| | Metal type | AL:1100H14, 5052H34, 6061T6 |
| | | Cu:C1100, C1220, Stainless steel：SUS430 |
| | Material size | Standard = 600 x 457mm Maximum = 1200 x 550mm |
| | Final board Thickness | 0.4 - 3.2mm |
| | Standard Metal Thickness | 0.3mm, 0.4mm, 0.5mm, 0.6mm,0.8mm, 1.0mm,1.2mm, 1.5mm, 2.0mm, 2.5mm, 3.0mm |
| | Tolerance of board thickness | ± 0.10mm |
| | Dielectric thickness | 0.05 - 0.2mm |
| | Thermal Conductivity | 1W/m.k - 8W/m.k |
| | Breakdown Voltage | >=500V/mil (per data sheet) |
| | Layer Count | 1 - 8L |
| Trace | Min trace width | 0.10mm |
| | Min trace space | 0.10mm |
| | Tolerance of trace width/space | ±15% |
| Copper thickness | Copper thickness | 1/3-4Oz with UL, 5-6OZ without UL |
| Hole size | Drilling Hole size | 0.50 - 6.00mm |
| | Finished Hole size (NPTH) | 0.50 - 6.00mm |
| | Hole size tolerance (Metal and FR4) | ±0.075mm |
| | Hole position tolerance | ±0.10mm |
| | Min Counter sink size | 1.0mm |
| | Countersink angle | 90 - 180 degree |
| | Min depth of Counter sink | 0.15mm |
| | Aspect ratio | 5:2 |

NCAB GROUP

# TECHNICAL CAPABILITY – PROCESS CAPABILITY

| Item | Feature | Processing capacity |
|---|---|---|
| V-Cut | V-Cut angle | 30°, 45°, 60° |
| | V-Cut angle tolerance | ± 5° |
| | V-Cut depth tolerance | ± 0.1mm |
| | Min.V-Cut web thickness | Punching after V-Cut: 0.2mm |
| | | Manual separate boards after V-Cut:0.2mm |
| | V-Cut board thickness | 0.5 - 3.2mm |
| | V-Cut outline dimensional / positional tolerance | 0.1mm |
| Solder mask | Approved solder mask types | Taiyo, Tamura, Greencure |
| | Min Solder Dam | 0.1mm |
| | Min Solder mask opening | 0.05mm |
| | Solder mask cover conductor | 0.05mm |
| Dimension | Punching tolerance of outline dimension | ±0.10mm |
| | Routing tolerance of outline dimension | ±0.10mm |
| Surface finish | HAL, LF HASL, OSP, ENIG, Immersion Silver, Immersion Tin, Silver plate, | |

NCAB GROUP


Questions?
RoHS

### NCAB GROUP SEMINARS

# Improve your knowledge about PCBs – participate in our seminars

- Technical trends in the global PCB industry
- How to produce a printed circuit boards
- New technologies
- Cost drivers in PCB production
- Surface finishes
- HDI - High Density Interconnect
- IMS - Insulated Metal Substrate
- Rigid-flex

- NCAB Group PCB Specification
- Impedance controlled boards
- DFM – Design For Manufacturing
- IPC vs. Perfag
- Reliability, IPC & NCAB
- Material for lead-free production
- Technical advice
- NCAB Group Laboratory