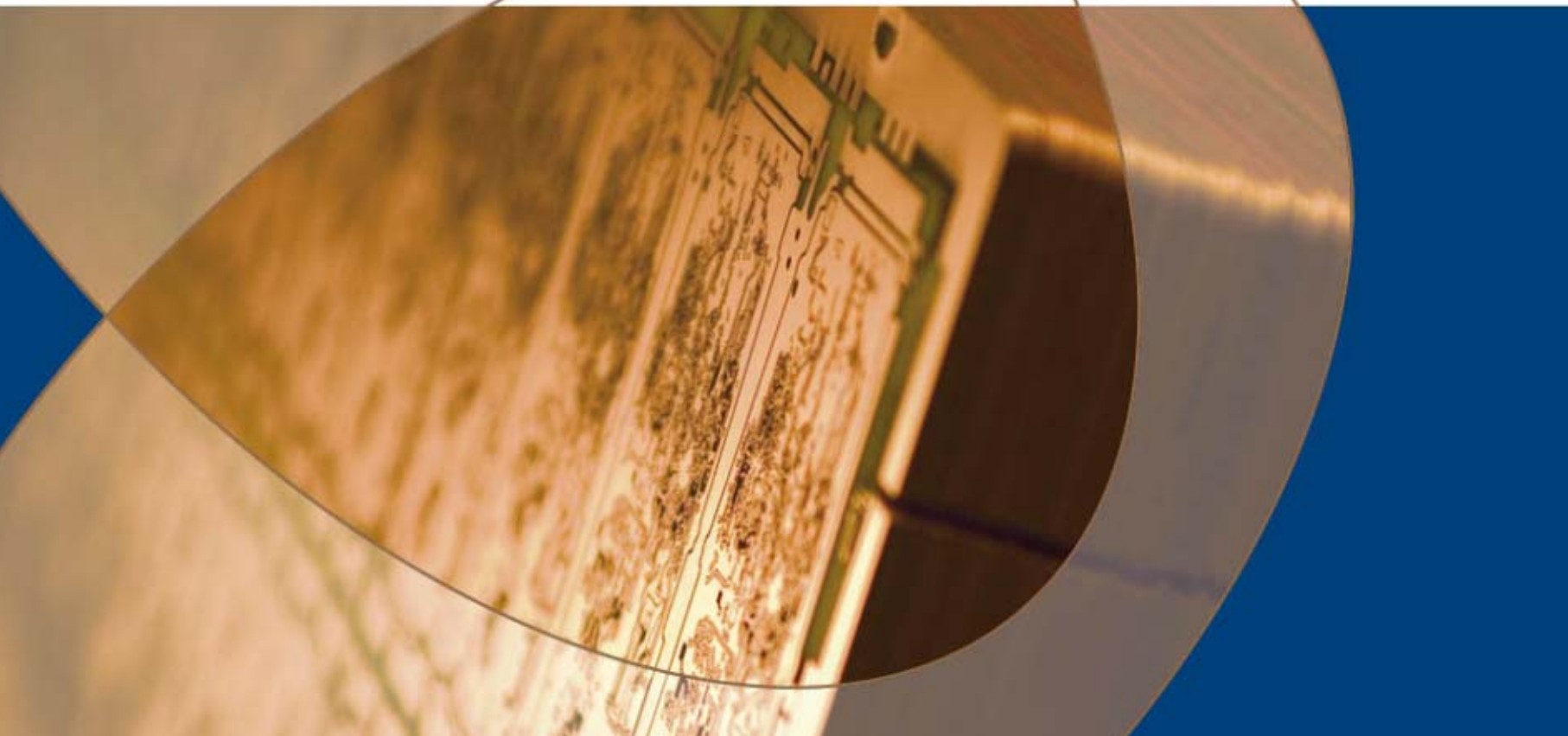
ASPOCOMP



Kimmo Perälä

BENEFITS OF EMBEDDED RESISTORS

Electronica 2004

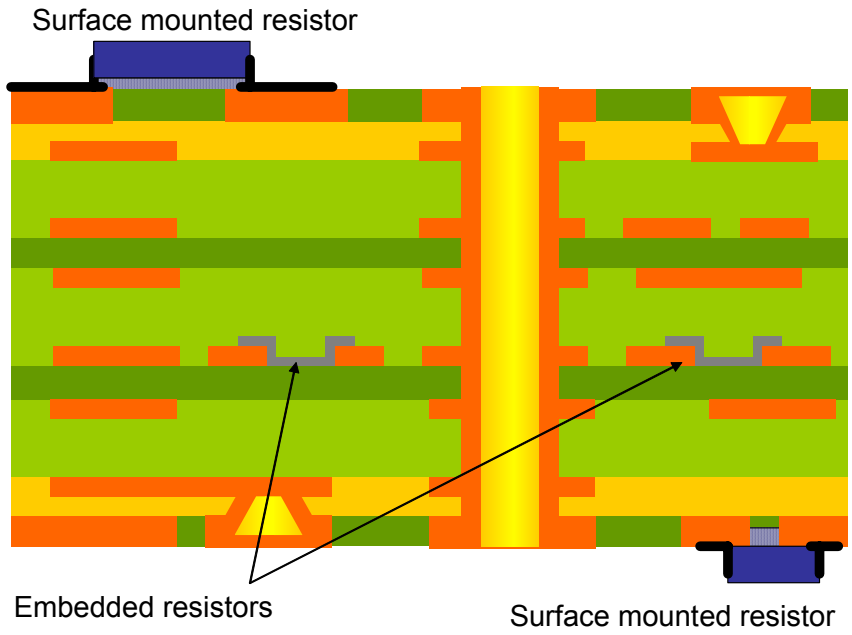
November 9-12, 2004 Munich, Germany

BENEFITS OF EMBEDDED RESISTORS - OUTLINE

- Drivers for the technology
- Introduction to different technologies
  - Thin film and PTF
- Space savings
- Improved high frequency performance
- Reduced cost

WHAT IS AN EMBEDDED RESISTOR ?

- Embedded resistor is a resistor that has been fabricated into the innerlayer of a printed wiring board

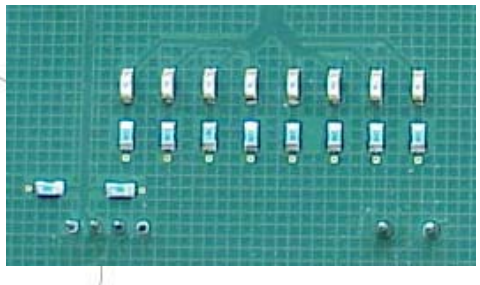


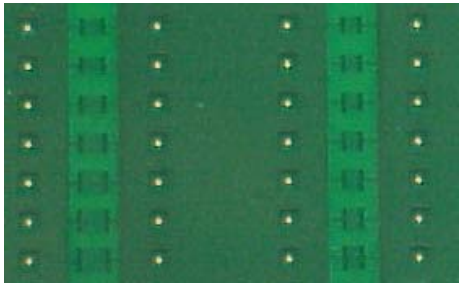
DRIVERS FOR EMBEDDED RESISTORS (1/2)

- Space limitation
  - Size of electronic equipment is getting smaller and functionality is increasing
    - By embedding the resistors we can increase functionality and/or decrease the size of the board
- Parasite elements
  - Operating frequencies and circuit densities are increasing
    - Using embedded resistors we can improve the circuit's performance

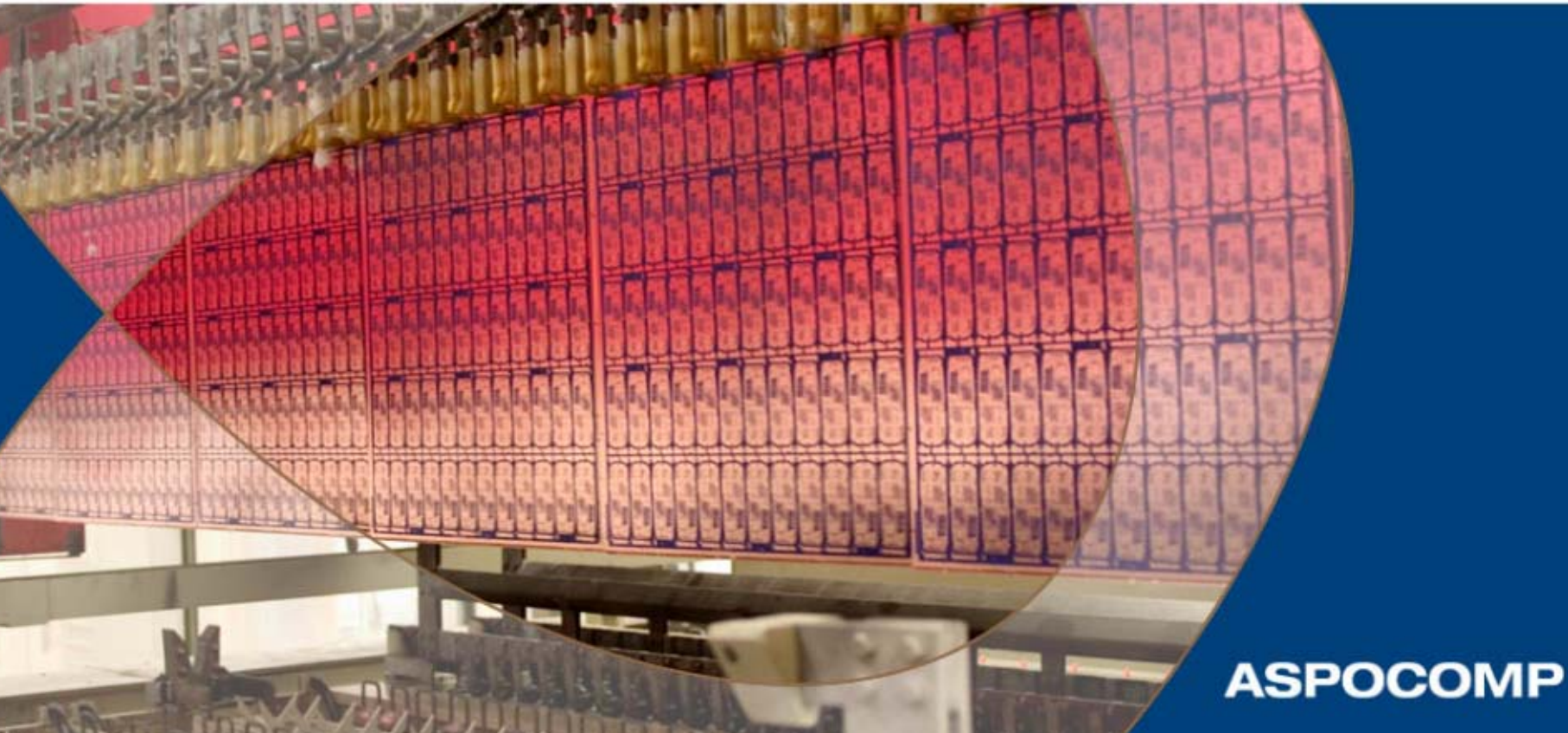
DRIVERS FOR EMBEDDED RESISTORS (2/2)

- Reliability
  - Using embedding technology we can get rid of the solder joints
- Cost
  - In right applications we can create cost saving to OEMs



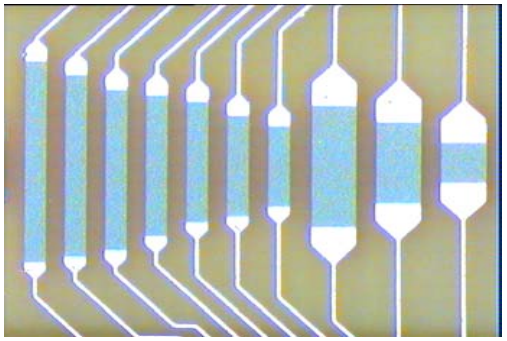


MATERIAL OPTIONS

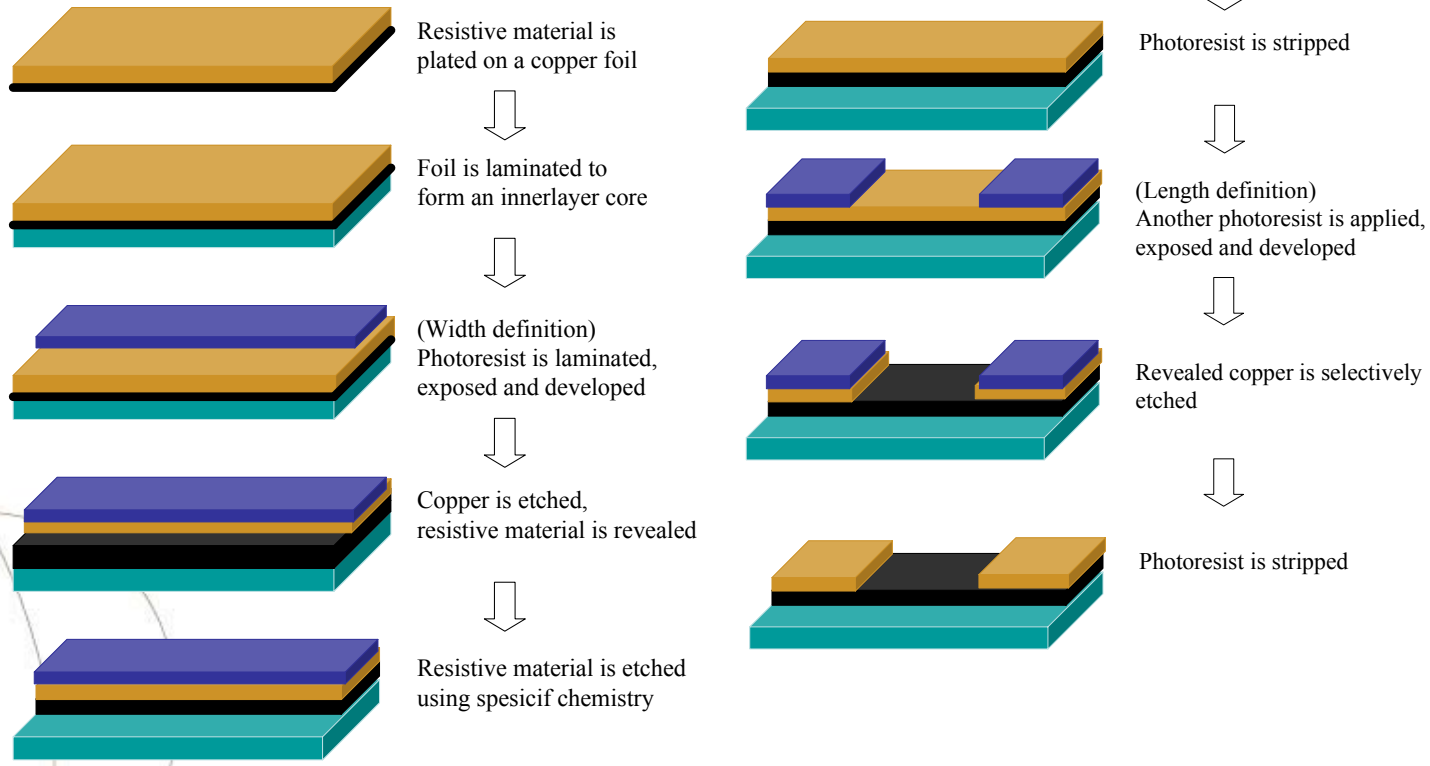


THIN FILM – MATERIAL CHARACTERISTICS

- Ultra thin
  - 0,04μm...0,4 μm
- Three major solutions
  - NiP resistive alloy is electrodeposited on a Cu foil; continuous “roll-to-sheet” electro-chemical plating
  - NiCr or NiCrAlSi alloy are sputtered on a copper foil
  - Pt + doping is coated using Combustion Chemical Vapor Deposition (CCVD) -method



THIN FILM - PROCESS



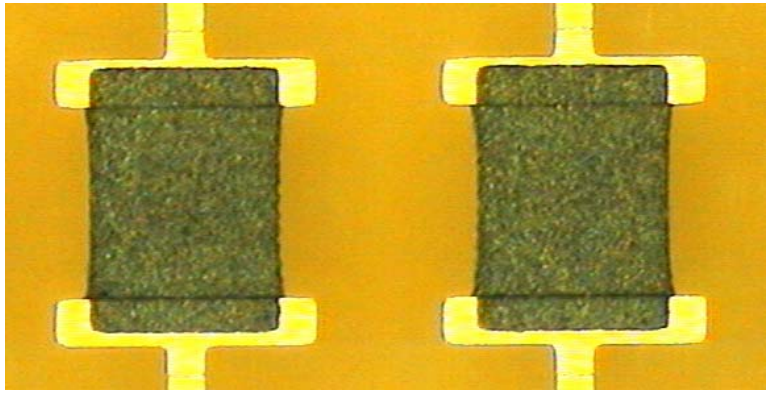
THIN FILM – SUMMARY

- Easy to fabricate
- Limited in resistance range
  - Very high values can not be embedded
- Good reliability properties
- Cost is high

⇨ **Best technology for high-end products with relatively low volumes**

PTF – MATERIAL CHARACTERISTICS

- Screen printable paste (PTF = Polymer Thick Film)
  - Printed thickness 10μm...20μm
- Carbon powders with polymer chains
  - Curing in convection owen or in infra-red owen



FABRICATION OF PTF EMBEDDED RESISTORS

- Standard innerlayer fabrication is performed to form the circuitry

- Termination pads are revealed via photoresist imaging

- Pads are plated, typically with silver, photoresist is stripped

- Paste is applied and cured

PTF – SUMMARY

- Easy to fabricate
- Very wide resistance range
  - All the values can be embedded
- Reliability is good, but worse than with thin films
- Cost is low

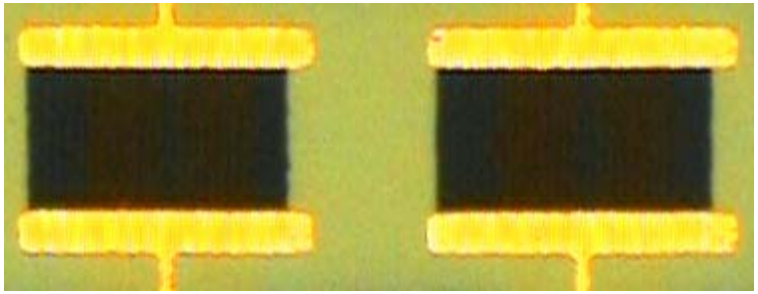
⇨ **Best technology for high volume products with tight cost frames**

⇨ **This is our recommended technology**

OTHER MATERIAL POSSIBILITIES

Ceramic thick film

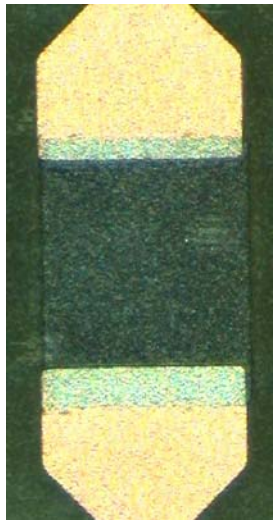
- Very stabile resistors
- Complicated process
- Not commercial today



⇨ **Best material for high-end products**

Plated thin film

- Easy process
- Limited sheet resistivity

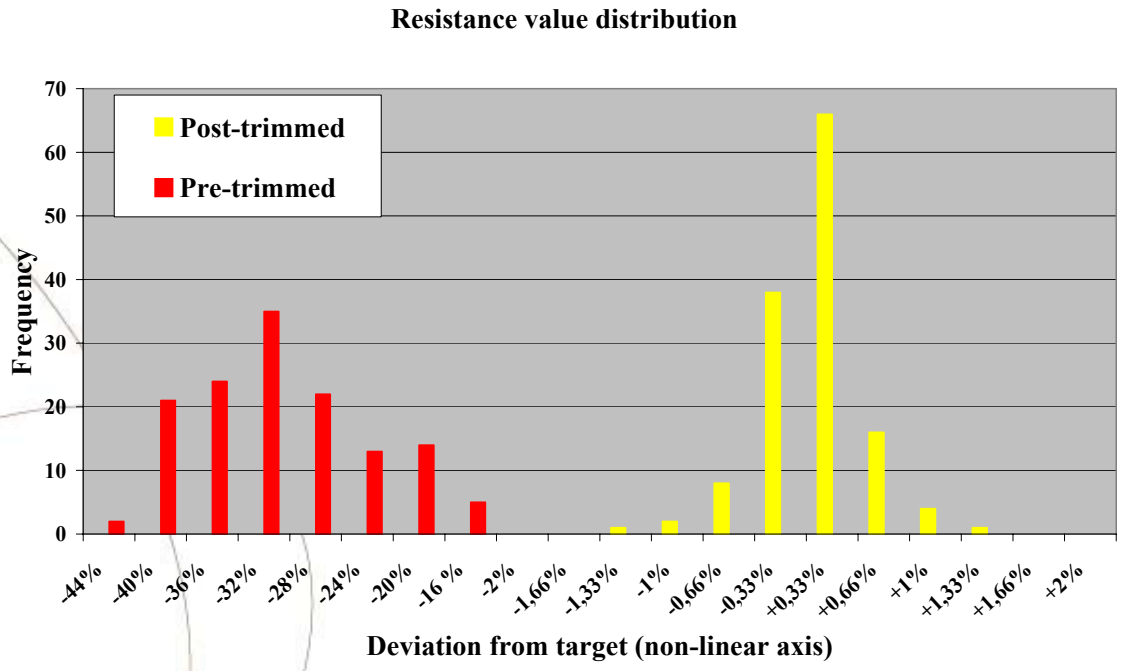


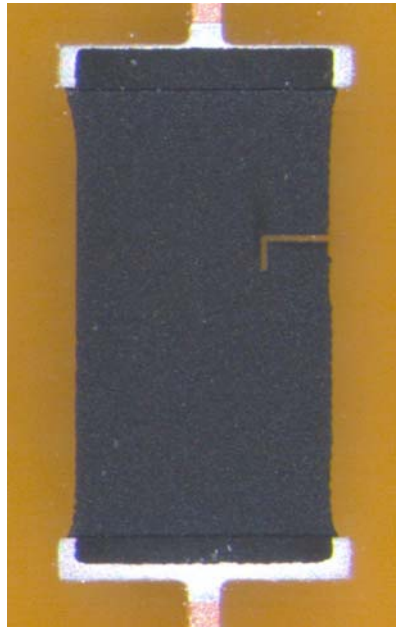
⇨ **Best material for special applications**

TRIMMING

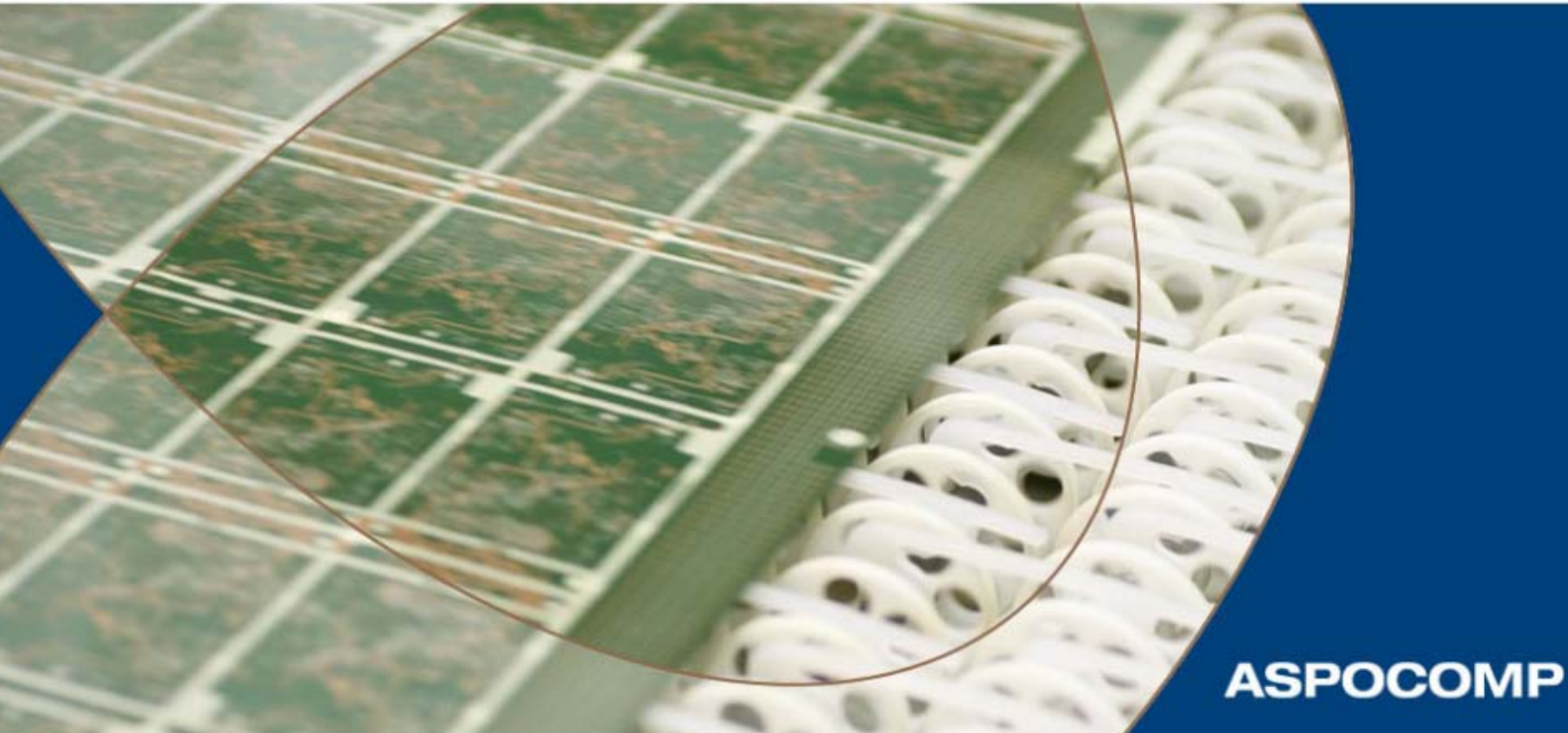
Using laser trimming we are able to achieve tight tolerances

- Laser ablates resistive material and simultaneously measures resistance
- ±1% or better right after trimming





SPACE SAVINGS



SPACE SAVINGS (1/2)

- Typical areas that surface mount resistors occupy from the PCB surface
  - 0805: 7,5 ... 9,5 mm^2 0603: 4,5 ... 6,0 mm^2
  - 0402: 2,0 ... 3,5 mm^2 0201: 0,7 ... 2,0 mm^2

Test Case

- One specific design contained 500 surface mount resistors that were able to be embedded, half were 0805 and half 0603.
  - We were able to release 3600 mm^2 from the PWB surface
    - 13% of the board area
      - ⇨ Board size was decreased
        - ⇨We were able to have more boards up per panel
      - ⇨Routing density decreased

SPACE SAVINGS (2/2)

- Releasing PCB surface area has many benefits
  - We can make smaller boards
  - We can have more boards up per panel
    - Cost savings
  - We can add more components (add functionality) into the same size of board
  - We can decrease the routing density
    - Improve manufacturing yields
- The possible benefits of the space savings are always application dependent

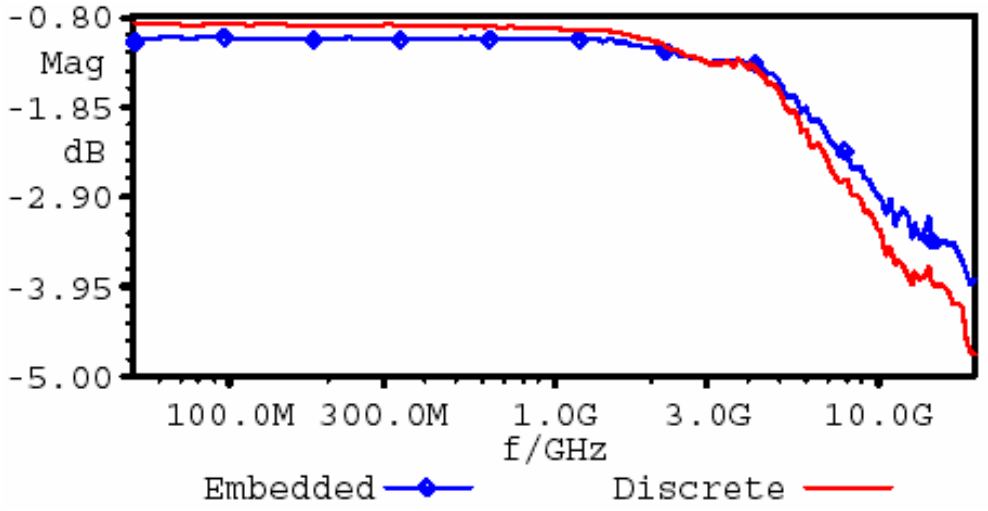
HIGH FREQUENCY PERFORMANCE

IMPROVED HIGH FREQUENCY PERFORMANCE (1/2)

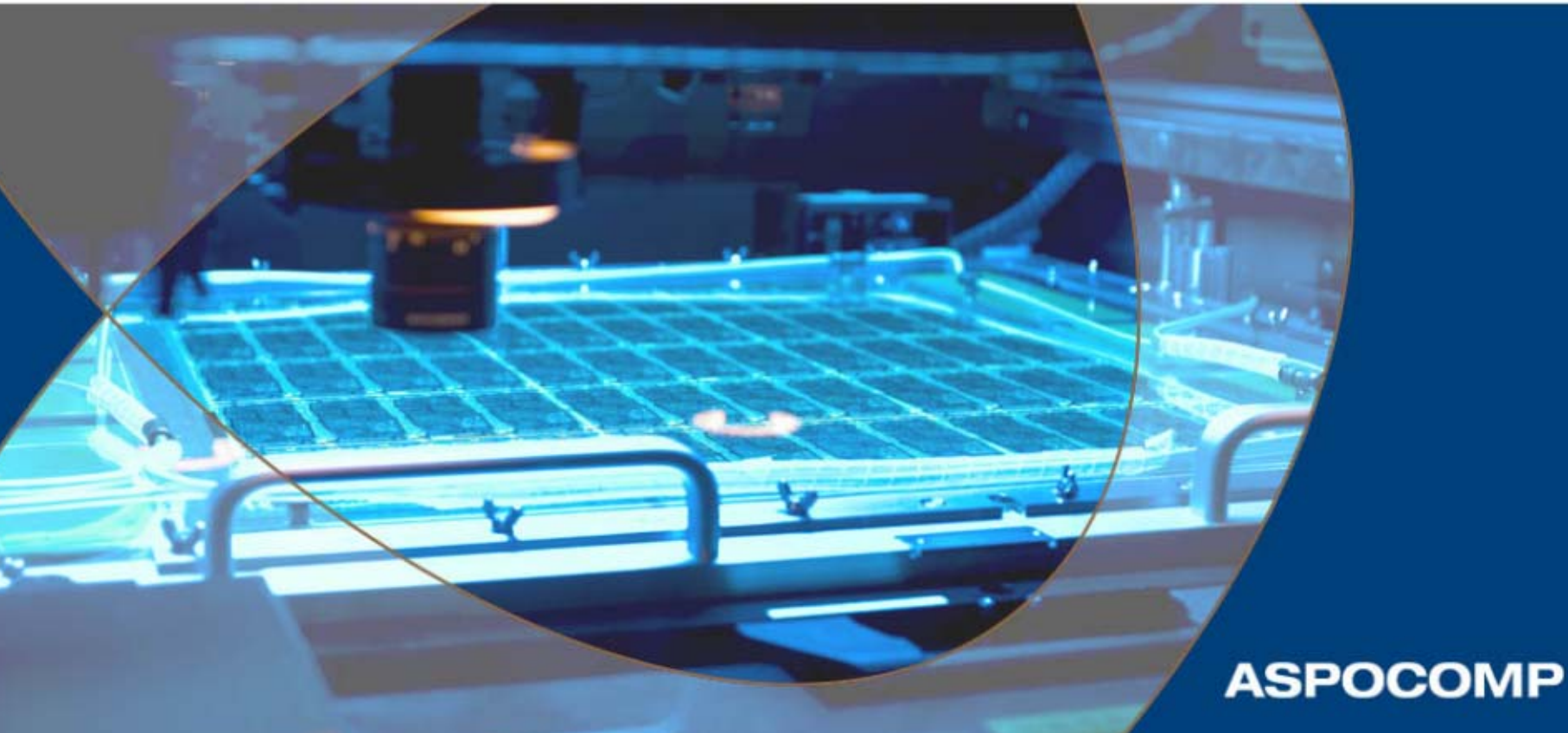
- As we are able to re-locate the resistors into the innerlayers of a board we have the freedom to place them directly where they are needed.
  - We are able to decrease the length of the signal traces
    - Inductance is decreased
- The routing density in the innerlayers is usually much lower than in the surface layers
  - We are able to use wider signal traces
    - Inductance is again decreased
  - In some cases we are able to get rid of closely located parallel-oriented lines
    - Capacitive and inductive decoupling are decreased
    - Cross-talk is minimized

IMPROVED HIGH FREQUENCY PERFORMANCE (2/2)

- In addition to what the theory predicts, real life measurements demonstrates the improved properties in the S21-parameters
  - These tests do not include any decreased signal traces etc. Only the effect of resistor type is measured.



COST SAVINGS



COST SAVINGS (1/3)

Almost always the PCB cost will be higher when embedded, but in right appliactions the total system cost can be reduced

- The issues that are reducing the total cost are
  - Decreased discrete expenses
    - Actual component prices
    - Transportation, storage, handling, soldering, assembly, test and rework –expenses
  - Better production panel area utilization
    - More boards up per panel will distribute the total panel price per larger number of boards

COST SAVINGS (2/3)

Test case

- We converted conventional six-layer board to an embedded resistor PCB using PTF technology
  - No extra layers
  - Additional cost was introduced through investment depreciation, additional material and process cost, labour cost and decreased yield
  - We were able to decrease the size of the board so much that it was possible to have 12 boards up per panel instead of 10 up
  - Total cost was decreased through decreased assembly cost

COST SAVINGS (3/3)

Test case

	Price per panel (€)	Price per board (€)
Original price, 10 boards up per panel	**400**	**40**
Investment cost	13	
Increased labour expenses	17	
Increased process and material (inc. resistors) expenses	15	
Increased cost because of decreased yield	9	
Subtotal, Embedded price, 12 boards up per panel	**454**	**37,83**
Decreased chip cost (0,1c*500)		-0,5
Decreased chip assembly+other cost (1,5c*500)		-7,5
Total embedded price		**29,83**

RELIABILITY

RELIABILITY (1/2)

Ohmega-Ply® has been used for high-end products for years

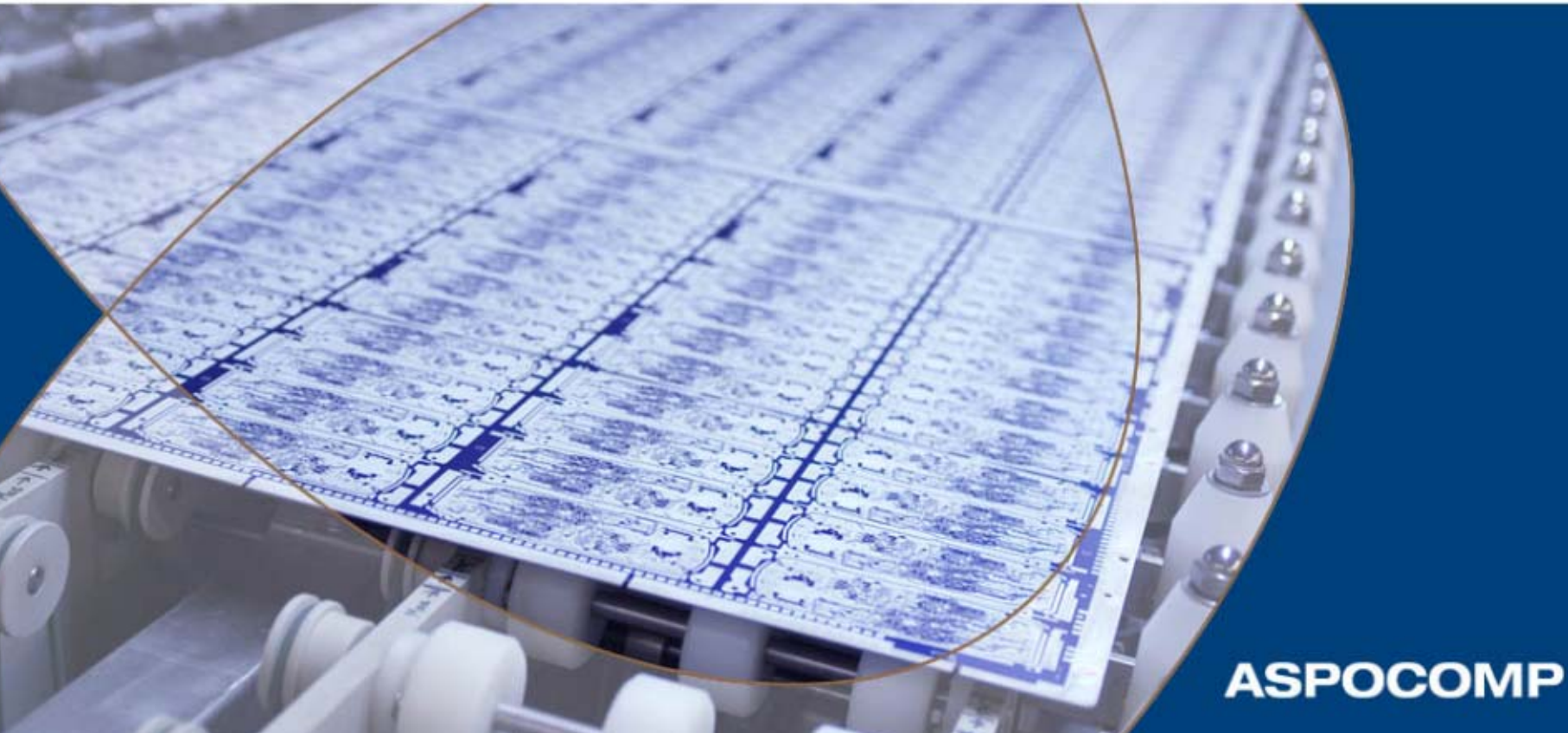
- E.g. aerospace solutions
- *Motorola* has used PTF resistors in their products for some years
- More and more applications entering the markets all the time

RELIABILITY (2/2)

Some examples:

- Best thin films
  - TCR: 80 ppm/°C
  - Thermal cycling (-40°C...+125°C 1005hrs): < 0,5% change
  - Thermal shock (-55°C...+125°C): <2% change
  - 85RH/85 °C: 1% change
- PTF
  - TCR: 400 ppm/°C
  - Reflow test (peak temperature +250°C): 3,5% change
  - Solder dip test (260 °C for 5 seconds): <1% change

SUMMARY



SUMMARY

To meet the challenges of miniturization, new emerging technologies has to be adopted

Embedded resistors can offer:

- Size reduction
- Increased functionality
- Improved high frequency performance
- Improved reliability
- Cost reduction

SUMMARY

If you are interested, contact us. We have the capability of

- Evaluating the lay-outs
  - We can make the decisions which ones to embed and how
- Carrying out the whole design process
- Making complete cost analysis
  - PCB cost and the overall system cost
- Fabricating the boards

We also have embedded capacitor capability

THANK YOU FOR YOUR ATTENTION !

For more information, please

- Visit us in B1.475

Or

- Send me email to kimmo.perala@aspocomp.com