Workshop

Future trends in PCB technologies for space applications
22nd-23rd October 2009
ESTEC, Noordwijk, The Netherlands
Status and trends in RF and microwave PCB technologies and manufacturing

General Overview
RF and microwave PCBs

- CIMULEC Group
- RF and microwave world
- Materials for RF and microwave boards
- Technologies and manufacturing process
- PCB finishes
- Next steps
CIMULEC Group

Two plants for a global offer on the European market

<table>
<thead>
<tr>
<th>Cimulec</th>
<th>Special technologies (SBU, HDI, Rigid-flex, metal core, RF, embedded, …)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metz, France</td>
<td></td>
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<tr>
<td><a href="http://www.cimulec.com">www.cimulec.com</a></td>
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<tr>
<td>CSI Sud-Ouest</td>
<td>Prototypes and short delivery times</td>
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<tr>
<td>Toulouse, France</td>
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<tr>
<td><a href="http://www.csi-pcb.com">www.csi-pcb.com</a></td>
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</tbody>
</table>

- CIMULEC Group is mainly dedicated to avionic, military and space markets
- Production of prototypes, small and medium series
- Employees: 120
- Global turnover: around 13 M€
RF & Microwave Printed world

- A complex world with many changes in the last decade
  - signal propagation is really different compared to analog or digital applications,
  - the amount and speed of the information processing is increasing as daily life becomes information dependent,
  - use of higher frequency bands

- RF and microwave: technology for the future?
  - higher frequencies request larger bandwidth,
  - mass savings,
  - advanced technologies,
  - flexibility, mixed digital and microwave boards
Materials for RF and microwave boards

Main suppliers providing RF materials

- Hitachi Chemical
- nelco
- isola
- ROGERS CORPORATION
- ARLON
- GORE
- TACONIC
- Panasonic

Two main properties give the right answer for a defined application:

- the dielectric constant \( [Dk] \) : determines the speed of the electronic signal in the PCB
- the dissipation factor \( [Df] \) : represents the dielectric loss of the signal in the circuit
- Both values affect the size of the PCB and the signal quality

Df and Dk may vary versus frequency, temperature and humidity
The different types of material available:

- modified epoxy
- thermoset
- thermoplastic: PTFE based materials

Each type can be reinforced by using glass fabric (X and Y axis) and/or organic fillers (Z axis)

The resin system is somewhat different from the well known and widely used epoxy or polyimide ones.
### Materials for RF and microwave boards

Some figures about key properties for RF and microwave materials

<table>
<thead>
<tr>
<th>Resin system type</th>
<th>Dk</th>
<th>Df</th>
<th>Tg (°C)</th>
<th>CTE (TMA) Z axis</th>
<th>Time to delamination (Copper removed)</th>
<th>Td (-5%) by TGA (10°C/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>DSC 50-260°C</td>
<td>T260</td>
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<tr>
<td>Modified epoxy</td>
<td>3.5 - 3.8</td>
<td>0.008 - 0.02</td>
<td>180 - 210</td>
<td>&lt;3.5%</td>
<td>&gt;60 min</td>
<td>&gt; 10</td>
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<tr>
<td>Thermoset</td>
<td>3.2 - 10</td>
<td>0.003 - 0.006</td>
<td>&gt; 260</td>
<td>&lt;3.5%</td>
<td>&gt;60 min</td>
<td>&gt; 20</td>
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<tr>
<td>Thermoplastic</td>
<td>2.2 - 10</td>
<td>0.0012 - 0.003</td>
<td>&gt; 280</td>
<td>&lt;3.5%</td>
<td>&gt;60 min</td>
<td>&gt; 15</td>
</tr>
</tbody>
</table>

### Summary

<table>
<thead>
<tr>
<th></th>
<th>Modified epoxy</th>
<th>Thermoset</th>
<th>Thermoplastic</th>
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</thead>
<tbody>
<tr>
<td>Low losses</td>
<td>-</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Homogenous prepreg</td>
<td>++</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Thermo-mechanical properties</td>
<td>+</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Processability</td>
<td>++</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Cost</td>
<td>++</td>
<td>+</td>
<td>-</td>
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</tbody>
</table>
RF and microwave PCB technologies

- All technologies available for epoxy and polyimide boards are achievable:
  - single side or double sides PCBs
  - standard multilayers boards
  - sequential build-up

For standard multilayers and SBU boards, there are some limitation based on the material choices

- Process has to be manage:
  - lamination cycle (temperature, pressure, …)
  - drilling parameters (RF materials are good candidate to smearing)
  - metallisation (desmear, electroless copper, …)
  - routing parameters
  - improved etching tolerances
RF and microwave PCB technologies

- **Standard multilayer**
  - 8 layers board full Rogers 4003
  - Prepreg Rogers 4350
  - Dk : 3.54
  - Df : 0.005

![Microsection picture]

- **Sequential build-up using polyimide prepreg (antenna application)**

![Diagram of sequential build-up]
RF and microwave PCB technologies

Useful tips for RF applications
(already in use in production on a daily basis, including for space application)

- Embedded resistors: more functionality such as signal division and/or distribution, reduce signal adaptation issues, reduce assembly time. Thin film NiP technology (Ohmega or Ticer)

- “RF openings”: avoid issues with signal adaptation and reduces signal losses

- Backdrills: improve buildup (less drilling sequences) and minimize antenna phenomenon
RF and microwave PCB technologies

Useful tips for RF applications (continue)
(already in use in production on a daily basis, including for space application)

• Mechanical blind holes with depth control drilling

• Mixed lay-up as for example PFTE based material and polyimide.
  Mixing materials has to be manage with care:
  - $\Delta$ CTEz can cause reliability failure
  - only one prepreg type in one lamination cycle

• External or internal heat sink for thermal management
RF and microwave PCB technologies

Space application: Beam Forming Network (STENTOR)

<table>
<thead>
<tr>
<th>Layer</th>
<th>Material 1</th>
<th>Material 2</th>
<th>Thickness [µm]</th>
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<tr>
<td>10</td>
<td>Copper</td>
<td>Core</td>
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<tr>
<td></td>
<td>RT 5002</td>
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<td>9</td>
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<td>Prepreg</td>
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<td>2644</td>
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</table>

Overall thickness: 2644 µm
RF and microwave PCB technologies

Mixed Multilayer RF/BF SBU with internal heat sink

Summary :
- 12 layers / 3 drilling seq.
- RO 4003 material
- Copper sink thickness : 0.8 mm
- Total thickness : 3.2 mm

Finishing :
- RF openings : pure gold (bonding)
- nickel on sink level
- Selective refused SnPb elsewhere
RF and microwave PCB technologies

**OhmegaPly® resistors:**
- 96 resistors implemented on 3 different layers in the BGA (pitch 0.8 mm) region.
- Resistor nominal value: 700 Ohms
- Resistor dimensions: 1960 x 280 µm
- Ohmegafoil characteristic: 100 Ω/□

**17 layers board with 3 drilling sequences**
- Dimension: 330x230 mm
- Thickness: 3 mm
- Aspect ratio: 10
- Mixed materials
- Impedance controlled
- 3 resistive layers
- Pad-on-hole technology
- Backdrilling with three different height
- Surface finish: ENIG and electrolytic AuCo
RF and microwave PCB finishes

- Tin-lead is the unique agency approved PCB finish at that time
- Tin-lead is not compliant with RF and microwave requirements

Need for a qualified alternative to SnPb

- Electroless Silver?
- NiPdAu?
- Galvanic Gold?
- ENIG?
RF and microwave PCB finishes

Some alternatives to SnPb are already used in RF space applications:

- ENIG: Globalstar 2, Meghatropics, Stentor and followings …
- Galvanic gold: used for gold wire bonding

NiPdAu looks promising on the paper for future needs:

- no black pads, no skip plating,
- compliant with Al and Au wire bonding,
- Pd allows SMT soldering,
- typical thicknesses are:
  - Ni = 3.5 to 5 µm
  - Pd = 0.2 to 0.4 µm
  - Au = 0.05 to 0.1 µm

To be tested in a near future
RF and microwave PCB in the future …

- The use of RF and microwave boards will increase in electronic devices including space applications
- PCBs will have a high level of integration (buried and blind vias, embedded components, heat sink, mixed materials, cavities, …)
- Material suppliers are still working on new development
  - novel modified polyimide low Dk / Df
  - novel flex low Dk / Df material
  - need for a low Dk / Df prepreg with standard flow properties
- PCB manufacturers will need to manage a wide range of specific and complex processes
- The keys for success are covered by:
  - Low losses material choices
  - design to cost, for manufacturability and reliability
  - end-users and PCB manufacturers have to work in a close relationship from the opening of a new project until the deliveries
- Need for a finish alternative to SnPb
- Need to anticipate new studies on disruptive process and technologies
Questions …

• Cimulec
  Ennery, France
  www.cimulec.com

• CSI Sud-Ouest
  Toulouse, France
  www.csi-pcb.com

Thank you for your attention