Choices of Materials for Metallisation

L. D. Embury

29 April 2020
Metallisation Processes

- Thin Film.
- Thick Film.
- Metallo –Organic.
- Electro –Plated.
- Polymer
Thin Film

- **Advantages:**
  - Wide variety of metals can be applied by same technique in same equipment.
  - Can obtain dense complete films.

- **Disadvantages:**
  - High cost of initial equipment.
  - High cost of masks for each job size.
  - Slow deposition rate.
  - Adhesion tends to be low.
Thick Film

**Advantages:-**
- Deposition by a range of techniques.
- Low cost methods of application.
- Low cost of masking techniques.
- Deposition of metal in one rapid operation.
- Excellent adhesion.

**Disadvantages:-**
- Further processes i.e. firing cycle required to obtain metallic film.
- Higher definition requires disproportional increase in costs.
Metallo - Organic

**Advantages:**
- Deposition as thick film.
- Ability to deposit metal in range between that of thin and thick film.
- Films can be laid that are 100% dense as thin film.
- Mixed metal films are true alloys.
- Very high definition possible.

**Disadvantages:**
- Higher cost on a weight basis than thick film.
- Gets more difficult to lay non-stressed film as film thickness increases.
Electro –Plating
Electroless / Electrolytic

• Advantages:-
  • Relatively simple technique.
  • Low raw material costs.
  • Can be easily applied to base metals.

• Disadvantages:-
  • Multi –stage process printing
    and etching of masks
    sometimes required.
  • Serious environmental
    problems associated with
    disposal of waste.
Mutallisation Objective

• Mechanical Connection.
• Electrical Connection.
Mechanical Connection

• To join ceramic to metal.
• To provide conductive pathway on inert substrate.
• To provide magnetic or electrical shielding.
# Mechanical Connection Properties of Metals

<table>
<thead>
<tr>
<th>Metal Melting Point</th>
<th>Electrical Resistivity (10^-6 Ω-m)</th>
<th>Thermal Expansion (10^-6 °C⁻¹)</th>
<th>Thermal Conductivity (W/m°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al. 660</td>
<td>2.42</td>
<td>23.1</td>
<td>237</td>
</tr>
<tr>
<td>Ag 960</td>
<td>1.6</td>
<td>19.7</td>
<td>418</td>
</tr>
<tr>
<td>Au. 1063</td>
<td>2.2</td>
<td>14.2</td>
<td>297</td>
</tr>
<tr>
<td>Cu. 1083</td>
<td>1.7</td>
<td>17.0</td>
<td>393</td>
</tr>
<tr>
<td>Ni 1445</td>
<td>6.16</td>
<td>13.4</td>
<td>91</td>
</tr>
<tr>
<td>Pd. 1552</td>
<td>10.8</td>
<td>11.0</td>
<td>71</td>
</tr>
<tr>
<td>Pt. 1774</td>
<td>10.6</td>
<td>9.0</td>
<td>71</td>
</tr>
<tr>
<td>Mo. 2625</td>
<td>5.2</td>
<td>5.0</td>
<td>146</td>
</tr>
<tr>
<td>W. 3415</td>
<td>5.5</td>
<td>4.5</td>
<td>201</td>
</tr>
</tbody>
</table>
Electrical Connection

• To provide the connection from the circuit to the electro ceramic or sensor device.
• May be internal or external to the component under consideration.
Component Varieties

- Capacitors.
- PZT Devices.
- Varistors.
- Tantalum Capacitors.
- Sensors.
- Microwave Components.
- Multilayered Devices.
- NTC Devices
- PTC Devices
Capacitors

• Electrodes are required to give:- Good mechanical adhesion.
• Surfaces that are capable of being soldered.
• Conductivity of metal film without ion migration into the ceramic body.
P.Z.T. Devices

• Electrodes are required to give:
  Resistance to mechanical stress.

• Resistance to ion migration under high electrical stress.
  – Resistance to poling bath chemicals.
  – Surfaces that are capable of being soldered.
Varistors

- Electrodes are required to give:
  - Good mechanical adhesion.
- Capability of carrying high current.
- Surfaces that are capable of being soldered
Tantalum Capacitors

- Electrode in two or three parts:
- Barrier layer paste, usually carbon, generally applied by dipping.
- High conductivity paste, usually silver polymer combination; if encapsulated, solderable.
- If S.M.D
- compatible with conductive adhesive.
- Conductive adhesive for lead frame.
Sensors

- Sensors are of two basic types and the electrodes are required to have:
- For active substrate i.e. oxygen sensor, good and stable electrical contact.
- For passive substrate, non-reactivity to applied sensor material
Microwave Components

- Electrodes are required to give:
  - Good adhesion.
  - High Definition.
  - High Conductivity.
  - High Density.
  - Good Solderability.
Multilayered Devices

- Require:-
- Internal Electrode.
- External Electrode.
**Internal Electrode**

- Required to give electrical connection onto the electroceramic.
- To withstand the high firing conditions of the electroceramic.
- To match the thermal expansion characteristics of the electroceramic.
- Not to migrate into the ceramic material during firing.
- To form “chemical key” if possible with the electroceramic.
External Electrode

• Required to carry signal only, and form an adhesive key to the component.
• Secondly, be capable of connection to leads or the circuit directly (S.M.D.).
N.T.C. Devices

- Electrode requirements:
- Good adhesion.
- Low electrode deterioration with time.
- Low ion migration.
- Metal type dependent upon the transition metal oxide that the N.T.C. component is made from.
# N.T.C. Electrodes

<table>
<thead>
<tr>
<th>Type of NTC</th>
<th>Application</th>
<th>Operating range</th>
<th>Metal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zero power thermal sensing</td>
<td>temperature measurement</td>
<td>0 to 250°C</td>
<td>Ag</td>
</tr>
<tr>
<td>Zero power thermal sensing</td>
<td>temperature measurement</td>
<td>0 to 350°C</td>
<td>Al</td>
</tr>
<tr>
<td>Zero power thermal sensing</td>
<td>temperature measurement</td>
<td>350°C plus</td>
<td>Ni / Pt / Pd etc.</td>
</tr>
<tr>
<td>Self heating sensing</td>
<td>Voltage regulation</td>
<td></td>
<td>Ag.</td>
</tr>
<tr>
<td>Indirectly heated sensing</td>
<td>Phase shifting</td>
<td>0 to 150°C</td>
<td>Ag.</td>
</tr>
</tbody>
</table>
P.T.C. Devices

• Requirements:-

• Good adhesion.

• Low ohmic contact onto the electroceramic.

• Capable of surviving high electrical and thermal stress.

• Capable either of compliance for clamp bonding or be solderable.
P.T.C. Devices

• Low Power :
  • Sensors
  • Static heaters.
  • Constant temp. heaters.
  • Current control.
  • Voltage control.
  • Heat dissipation control.

• High Power :
  • Dynamic Circuit timers.
  • Current timers.
  • Motor starting.
  • Choke timers.
  • Fuel evaporation.
  • Air heaters.
P.T.C. Devices

- Elements which can “poison” P.T.C. devices:
  - Alkali metal ions.
  - Transition metals.
  - Acceptor dopants.
  - Anions.
# P.T.C. Devices Typical Electrode Systems

<table>
<thead>
<tr>
<th>Electrode system</th>
<th>Method of application</th>
<th>Typical usage</th>
<th>Typical Usage Ohmic Connection</th>
<th>Conductive pathway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ni / P :Ag</td>
<td>Electro-less Ni &amp; Electrolytic Ag</td>
<td>Degausser / Motor Start</td>
<td>Ni : P</td>
<td>Ag</td>
</tr>
<tr>
<td>Al /Cu</td>
<td>Thin Film</td>
<td>Choke Heater / Degausser</td>
<td>Al</td>
<td>Cu</td>
</tr>
<tr>
<td>Ga / In</td>
<td>Ultrasonic Solder</td>
<td>R &amp; D</td>
<td>Ga</td>
<td>In</td>
</tr>
<tr>
<td>Ag / Zn :Ag</td>
<td>Thick Film</td>
<td>Current Control</td>
<td>Zn : Ag</td>
<td>Ag</td>
</tr>
<tr>
<td></td>
<td>Thin Film / Thick Film</td>
<td>Degausser / Heaters</td>
<td>Al</td>
<td>Al</td>
</tr>
</tbody>
</table>
Base Metal Electrode Systems

- Air Fireable Base Metal Electrodes:
  - Aluminium
  - Nickel
  - Fugitive (Metal Injection) processes.
New Electrode Systems

- Current Techniques to Lay Base Metals:
  - Thin Film.
  - Electroplating.
- New Electrodes by Air Fireable Base Metal Thick Film Inks:
  - Aluminium.
  - Nickel.
Air Fireable Base Metal Electrodes

- Properties:
  - Resistance to ion migration.
  - Conductivities in the same range as precious metal films.
  - Shrinkage matchable to electroceramics.
  - Major cost savings.
  - Fireable in existing equipment.
  - Possibility of solder contact.
New Termination Inks General

• **Polymer**
  • No high firing temperature.
  • Can be soldered.
  • Can be plated.
  • Reduced number of processing steps.
  • Reduced cost.
Summary

• **Trends:-**
  
  • Away from thin film.
  • Away from high cost precious metals.
  • Increased usage of organo –metallic films.
  • Increased usage of base metals as electrodes.
  • Potential of polymer terminations.
Les. Embury
Managing Director
The Gwent Group,
Sun Chemical.

Leslie.Embury@sunchemical.com
http://www.gwent.org
Tel: +44 (0)7785 931320
Fax: +44 (0) 1495 752121