Development of Conductive Inks for Flexography.
Gwent Electronic Materials
Company History

- Formed in 1988
- Manufacture of passive electronic materials
- Contract Research
- Toll Manufacture
- Biosensor materials developed 1994
- AET acquired in 2001
- Development of handheld water quality testing system 2004
Products and Services

- Supply of custom inks for electronics
- Supply of custom inks for electroceramics
- Supply of custom inks for biosensors
- Supply of custom inks for sensors
- Contract research on ink formulations
- Supply electrochemical base electrodes
- Supply biosensors for environmental and agri-food market sectors
An Approach to Developing Conductive Inks

- Selection of Raw Material based on printing requirements.
- Manufacture of intermediates and final inks.
- Dispersion of Powders
- Rheological Measurement
- Electrical Conductivity Measurement
Selection of Raw Materials

- Solvents and the roles they play in the formulation.
- Polymer types and considerations.
- Functional Phases, Conductive powders.
Function of Solvents/Diluents

- Dissolve the selected resin system.
- Maintain printability.
- Control drying rate.
Formulation Considerations for Solvents.

- Resin must remain fully dissolved during printing and drying process.
- Generally several solvents are used with different boiling points and evaporation rates.
- Direct effect on the drying of the printed films.
Solvent Properties to Consider

- Solvents and diluent can be used.
- Solvents dissolve the resin, diluents do not.
- Solvents must remain in the ink formulation during drying process to maintain resin solubility.
- Combining solvents to give a blend gives the best drying properties to a printed ink.
- Drying is a “wicking” process that draws solvent from the printed ink film.
Function of the Resin

- Binder system to hold the particulates together.
- Gives the final dried film strength and adhesion to a given substrate.
- Transfer process from photopolymer to the substrate.
Formulation Considerations for Resins.

• Many types of resins can be used.
• Resin type depends on the substrate and adhesion required.
• Resin must prefer to adhere to the substrate rather than the photopolymer, otherwise no transfer will take place.
• Resin type used will also depend on the types of solvents that can be used to dissolve it.
• Dielectric effect of the resin used will affect the electrical conductivity of the dried film.
• Shrinkage of the resin on drying will have an effect on the electrical conductivity.
• Solvent release of the resin on drying.
Functional Components

- Silver Powders
- Silver Flakes
- Carbon Powders
- Graphite Powders
- Silver Complexes
- Silver Metallo-Organics
Function of Conductive Powders

• Give final dried print electrical conductivity.
• Particle size will also determine the rheology of the final ink.
Formulation Considerations for Conductive Powders

- Particle size.
- Particle size distribution.
- Tap density.
- Surface area.
Manufacturing of Silver Powders

- Chemical Precipitation.
- Coating of Powders.
- Processing of Powders.
- Manufacture of Flakes.
Effect of Silver Powder Coating

- Coatings are used to prevent agglomeration of the silver powder.
- Coating isolate each silver particle.
- Poor removal of the coating reduces conductivity.
- Solvents must be capable of removing the silver coating.
Selecting Silver Powder or Flake

- Powders
- Particle Size Distribution
Selecting Powder or Flake

• Typical Flake

• Particle Size Distribution
Selection of Silver Powder or Flake

- Powders are spherical.
- Have less particle to particle contact.
- Generally give low conductivity in polymer systems.
- Can be added to improve conductivity of flake formulations.

- Flakes are flat platelets.
- Have greater overlap of particles when printed.
- Generally give higher conductivity in polymer formulations.
- Wide range of flake sizes.
Manufacture of Inks

- Dissolve Resin to produce a carrier system.
- Add Powders to produce a pre-mix.
- Disperse powders.
- Adjust to Viscosity
Dispersion Techniques

• Triple Roll Milling
Dispersion Techniques

- Bead Milling
Dispersion Techniques

- Toursmill
- High Shear Mixer and Basket Mill
Typical Constituents of a Functional Product

<table>
<thead>
<tr>
<th>Material</th>
<th>Weight (%)</th>
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<tbody>
<tr>
<td>Functional Phase</td>
<td>27 - 70</td>
</tr>
<tr>
<td>Organic Binder</td>
<td>9 - 3</td>
</tr>
<tr>
<td>Organic Solvents</td>
<td>64 - 27</td>
</tr>
</tbody>
</table>

Shrinkage of film

- Wet Ink layer: 25 microns
- Dried Ink Layer: 12 microns
Rheological Measurement

- Cone and Plate
- Haake VT 550
- Ford Cup No 4
- Brookfield RVT
- With RVT Spindles
Rheology of Conductive Flexographic Inks.

**Silver Flexo Ink**
C2080815D1 #2090115.08

**Carbon Flexo Ink**
C2080529D7 #2080618.25


Why is the resistance of printed metal films higher than theoretical figures?
Resistivity

- Units: ohms meters
- Measure a cube of material
Volume Resistivity

- **Volume resistivity** is defined as the ratio of the dc voltage drop per unit thickness to the amount of current per unit area passing through the material.

- A basic material property, volume resistivity indicates how readily a material conducts electricity through the bulk of the material.

- Volume resistivity is expressed in ohm-centimeters (Ω-cm).
Measurement of Volume Resistivity

- 4 Point probes.
- Current applied, at a known voltage though two outer probes.
- Voltage drop is measured, by a second set of probes.
- Resistance is calculated.
- Volume resistance is calculated based on the sample test area and thickness.
Sheet Resistance

- Printed Circuits. With known dimensions so that number of squares can be calculated.
- Measure Resistance, and thickness.
- Calculate to give resistance per square
- Units ohms/square/thickness
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