Electrically Conductive Formulations
Filled Nano Size Silver Filler for
Ink-Jet Technology

Andrzej Mościcki*, Tadeusz Sobierajski*,
Jan Felba**, Józef Kudzia**,
Andreas Arp***, Wilhelm Meyer***

* Amepox Microelectronics, Ltd.
** Wrocław Technical University
*** Microdrop Technologies GmbH

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New materials with nano size conductive fillers - new possibilities for applications. New possibilities needs new type of equipment.


Possibilities and requirements:

- Single drop volume: $30 - 500$ picoliters with variation approx. $1\%$
- Droplet diameter: $30 - 100 \mu m$
- Drop rate: $0 - 2000$/sec.
- Fluid viscosity range: $0.5 - 30$ mPas. (unheated)
- Drop acceleration: $10^5 g$ (during each shoot)
Ink Jet technology is well known for many applications especially when very uniform fluid is used.

With formulations which are mixtures of two different phases: fluid binder and solid filler - problem is much more complicated. Let's use some classifications:

- Mechanical type - classical, when filler over 0.5µm is used.
- Colloidal type - when filler is in range 0.5µm ~ 50 nm.
- True fluid type (similar „molecular” type) - when filler is less 20 nm.
Both: mechanical and colloidal types need very special ingredients and technology, but always the major problem will be exist - sedimentation.

Very low binder viscosity plus:

- filler has much higher specific gravity,
- filler has much bigger particle size than binder molecule size,
- high % of filler inside formula
Different situation is when conductive filler has diameter less 10 nm. Than formulation is very uniform and stable as a "true fluid".

Such a situation needs silver with particles size in range of several atoms. For preparing silver with size of nano range, thermal decomposition of silver salts were used.

During very accurate studies this technology phenomena, Amepox established own process conditions and we are working with.
SEM Pictures of Nano Silver Agglomerates
STM Pictures of Nano Silver
STM Pictures of Nano Silver
Histogram for particles size of Ameperox nano Ag

Diameter of silver atom is 2.88 Å (1 nm = 10 Å)

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### Electrically Conductive Ink with Nano Silver

<table>
<thead>
<tr>
<th>Property</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of components</td>
<td>One</td>
</tr>
<tr>
<td>Consistency</td>
<td>Very low viscous liquid</td>
</tr>
<tr>
<td>Color</td>
<td>Dark brown to black with metallic shade</td>
</tr>
<tr>
<td>Percentage of silver filler (inside ink)</td>
<td>40 – 60 % <em>(actual 45%)</em></td>
</tr>
<tr>
<td>Specific gravity</td>
<td>1.3 – 1.6 g/cm³</td>
</tr>
<tr>
<td>Viscosity</td>
<td>1.4 – 1.55 mPas</td>
</tr>
<tr>
<td>Thixotropy index</td>
<td>~ 1.0</td>
</tr>
<tr>
<td>Surface tension value</td>
<td>28.5 – 34 dynes/cm</td>
</tr>
<tr>
<td>Recommended sintering conditions</td>
<td>230 – 240 °C - 120 min</td>
</tr>
<tr>
<td>Percentage of silver after „curing“</td>
<td>95 – 97 %</td>
</tr>
<tr>
<td>Electrical resistivity</td>
<td><em>(4 – 6)</em> 10⁻⁶ Ωcm</td>
</tr>
<tr>
<td>Storage</td>
<td>6 months in room temperature</td>
</tr>
</tbody>
</table>

*Note: The electrical resistivity is given for the 'curing' stage.*
Ink-Jet Dispenser Shoot and droplet forming
Tests by Ink Jet Dispenser
Results of Ink Jet tests

Dots:  Macro Picture
Nozzle 66 microns
Nozzle 34 microns

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Results of Ink Jet tests

Lines: Nozzle 66 microns

Single line SEM picture

Macro Picture

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Courtesy of TNO Industrial-Eindhoven
Advantages of Jet Printing Techniques

1. Very high packaging possibility,
2. Nature of Nano Inks - formula is with the best homogeneous properties (uniform concentration),
3. The highest repeatability of dosing ink volumes,
4. Very high repeatability of printed shapes,
# Line resistance measurement results

<table>
<thead>
<tr>
<th>Line number</th>
<th>Electrode distance</th>
<th>Resistance value [Ω]</th>
<th>Electrode distance</th>
<th>Resistance value [Ω]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>5 mm</td>
<td>5.2</td>
<td>25 mm</td>
<td>25.6</td>
</tr>
<tr>
<td>2.</td>
<td>5 mm</td>
<td>5.1</td>
<td>25 mm</td>
<td>25.6</td>
</tr>
<tr>
<td>3.</td>
<td>5 mm</td>
<td>5.2</td>
<td>25 mm</td>
<td>26.4</td>
</tr>
<tr>
<td>4.</td>
<td>5 mm</td>
<td>5.3</td>
<td>25 mm</td>
<td>26.2</td>
</tr>
<tr>
<td>5.</td>
<td>5 mm</td>
<td>5.3</td>
<td>25 mm</td>
<td>26.8</td>
</tr>
<tr>
<td>6.</td>
<td>5 mm</td>
<td>5.1</td>
<td>25 mm</td>
<td>25.8</td>
</tr>
<tr>
<td>7.</td>
<td>5 mm</td>
<td>5.2</td>
<td>25 mm</td>
<td>25.6</td>
</tr>
<tr>
<td>8.</td>
<td>5 mm</td>
<td>5.3</td>
<td>25 mm</td>
<td>26.2</td>
</tr>
</tbody>
</table>

Very high repeatability of resistance value show highly uniform formulation properties connected with perfect distribution of nano silver in unit volume.
Results of line thickness measurement

Single layer of Nano-Ink formulation is extremely thin after curing process.

Sample of thickness measurement result is showed on pictures:

UBM Measurement Ag lines

Courtesy of TNO Industrial-Eindhoven
Presented results are a part of EC founded project: G1RD-CT-2002-00656 „NANOJOINING”