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

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

New equipment - Ink Jet Dispenser Systems.

Possibilities and requirements:

- *Single drop volume: 30 - 500 picoliters with variation approx. 1%*
- *Droplet diameter: 30 - 100 μm*
- *Drop rate: 0 - 2000/sec.*
- *Fluid viscosity range: 0.5 ~ 30 mPas. (unheated)*
- *Drop acceleration: $10^5 g$ (during each shoot)*

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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 $0.5\mu\text{m}$ is used.
- Colloidal type - when filler is in range $0.5\mu\text{m} \sim 50 \text{ nm}$.
- True fluid type (similar „molecular“ type) - when filler is less 20 nm .



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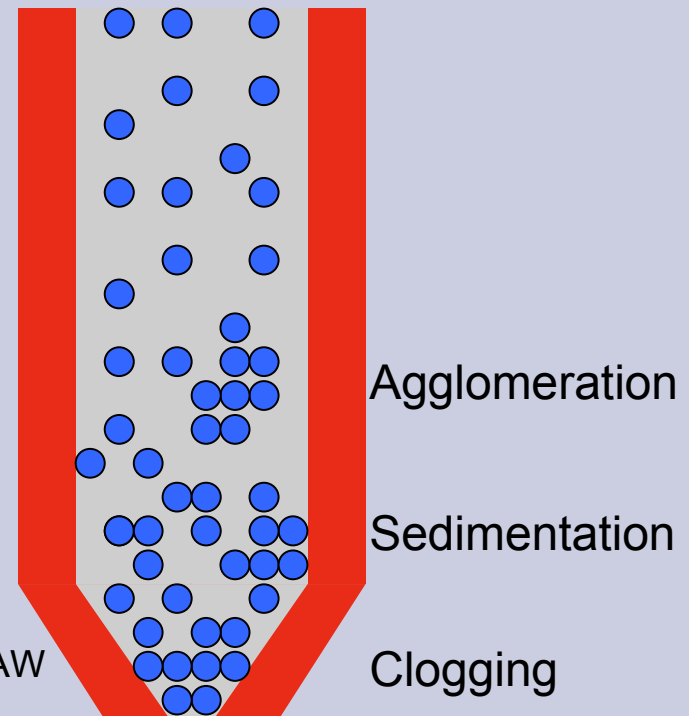
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Both: mechanical and colloidal types need very special ingredients and technology, but always the major problem will be exist - sedimentation.

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



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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.



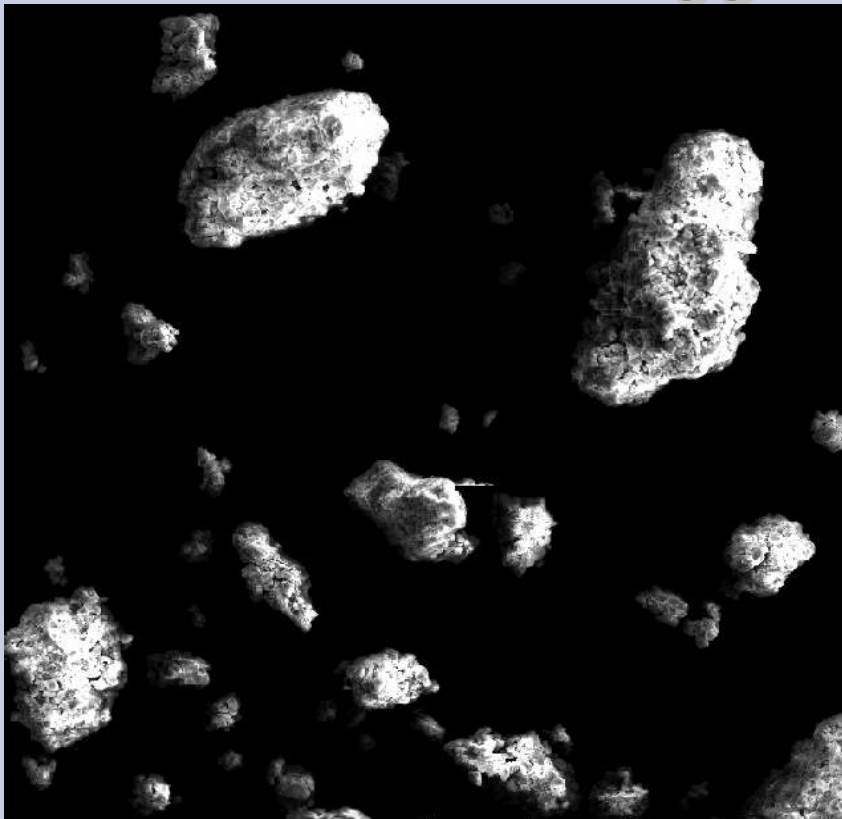
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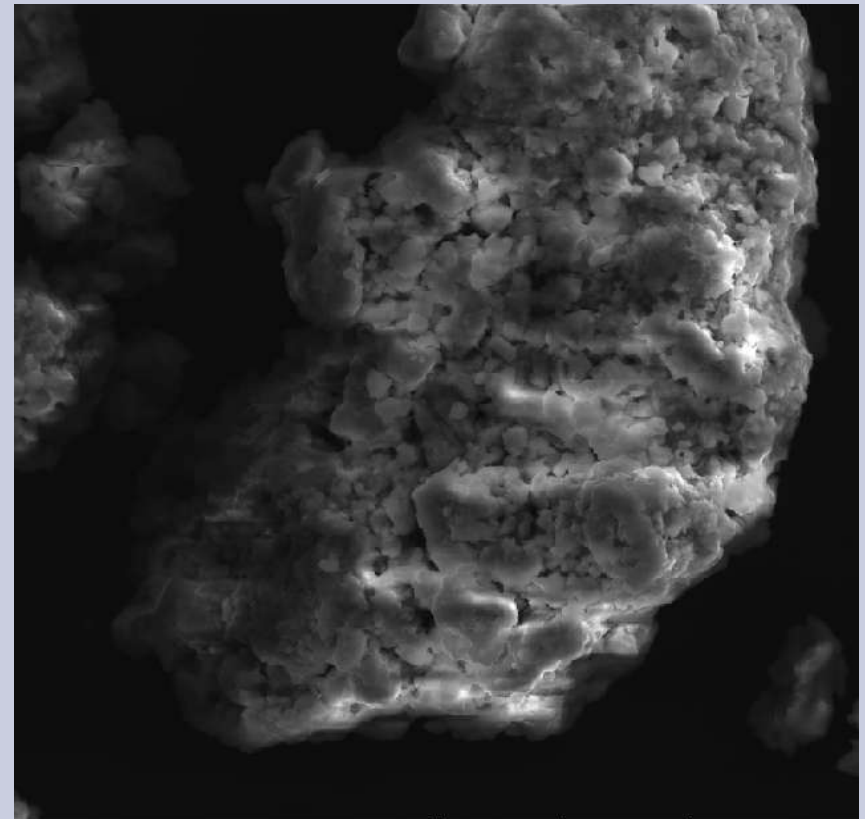


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SEM Pictures of Nano Silver Agglomerates



SEM MAG: 300 x DET: SE Detector 200 μ m Vega ©Tescan
HV: 30.0 kV WD: 13.4589 mm Dept of Solid State Physics, University of Lodz
VAC: HiVac Device: TS5135MM



SEM MAG: 1.50 kx DET: SE Detector 50 μ m Vega ©Tescan
HV: 30.0 kV WD: 13.4186 mm Dept of Solid State Physics, University of Lodz
VAC: HiVac Device: TS5135MM

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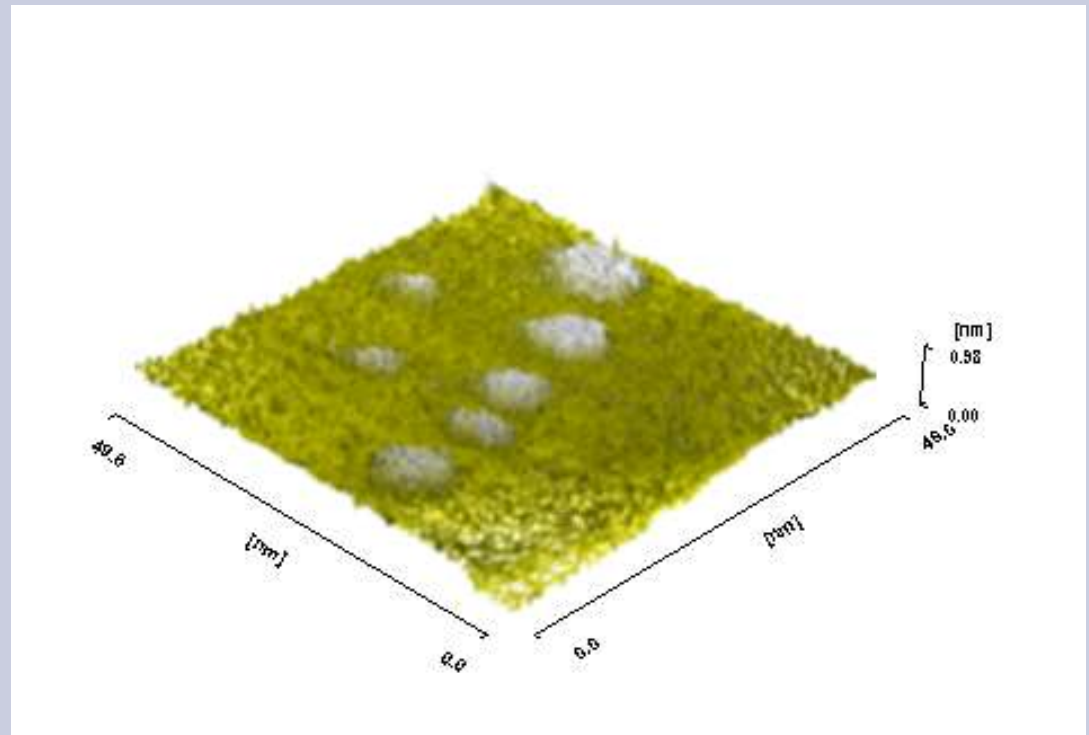
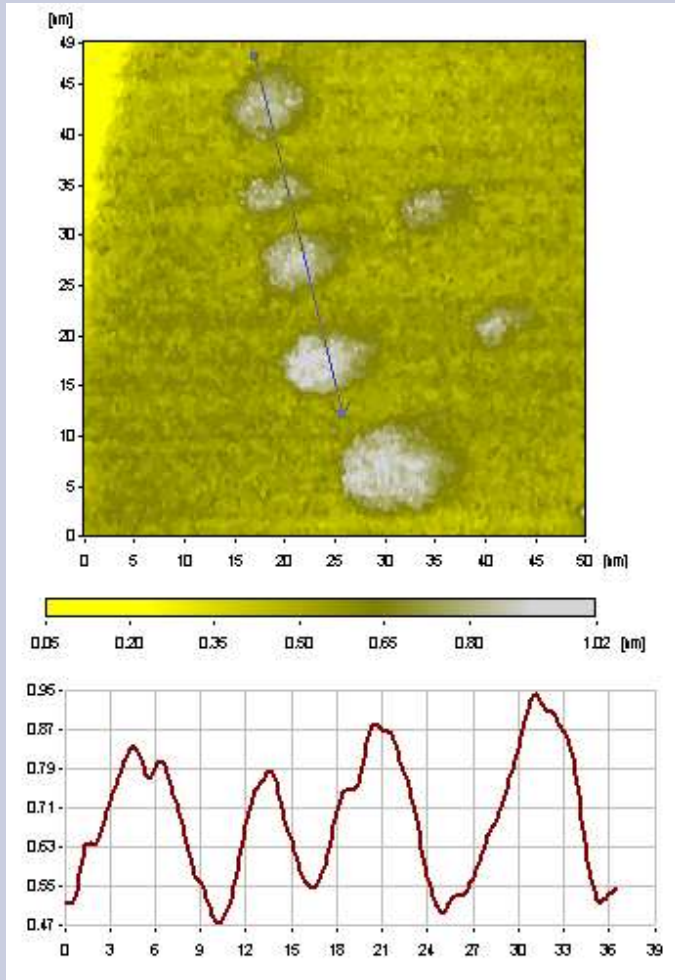
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STM Pictures of Nano Silver





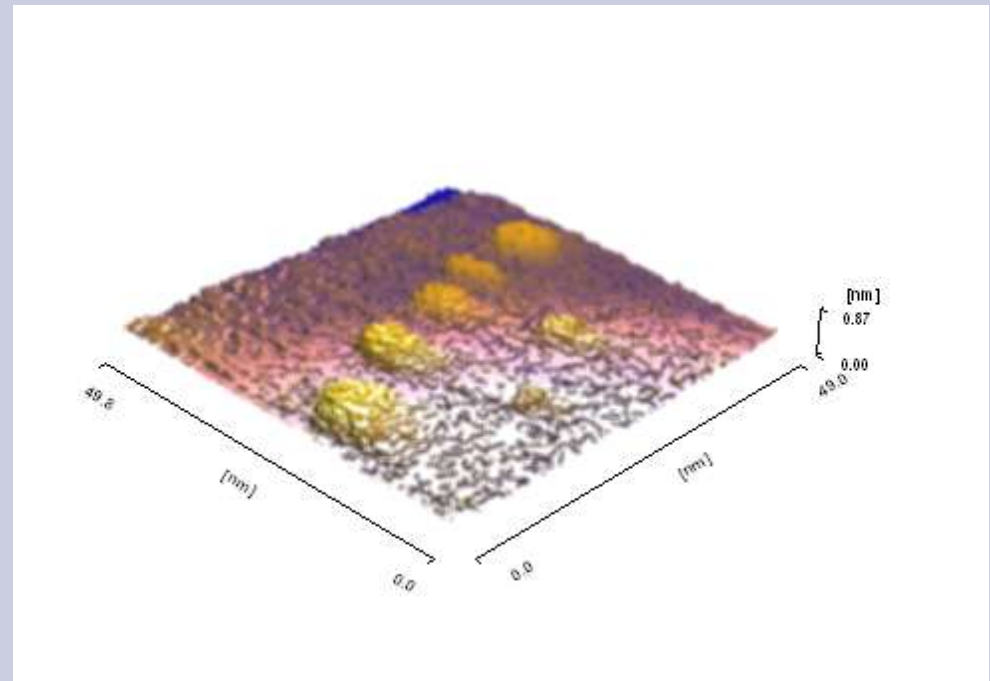
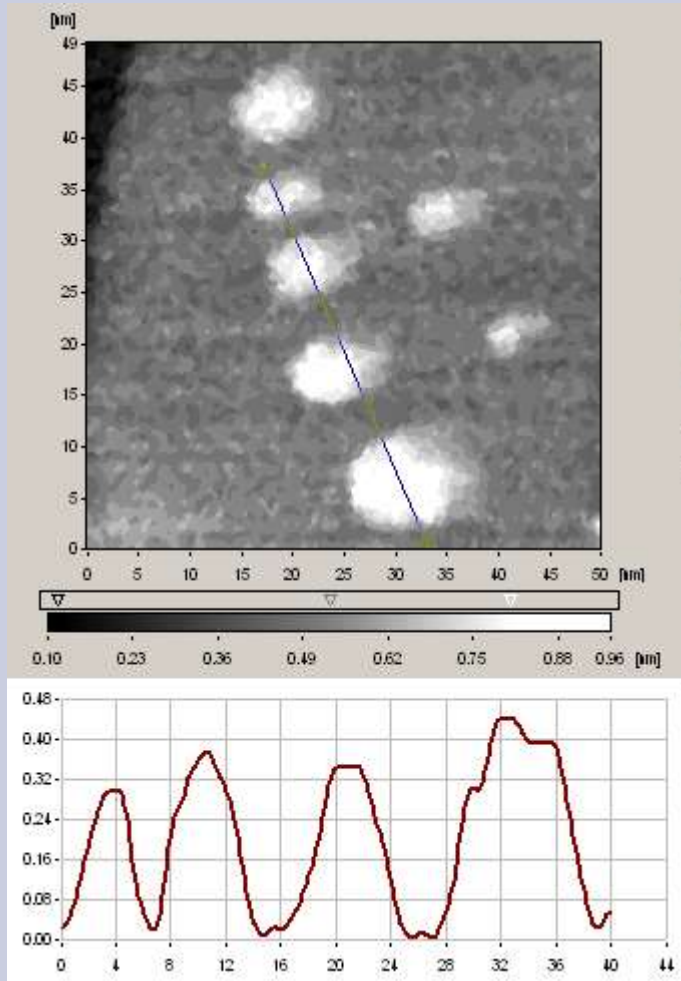
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STM Pictures of Nano Silver





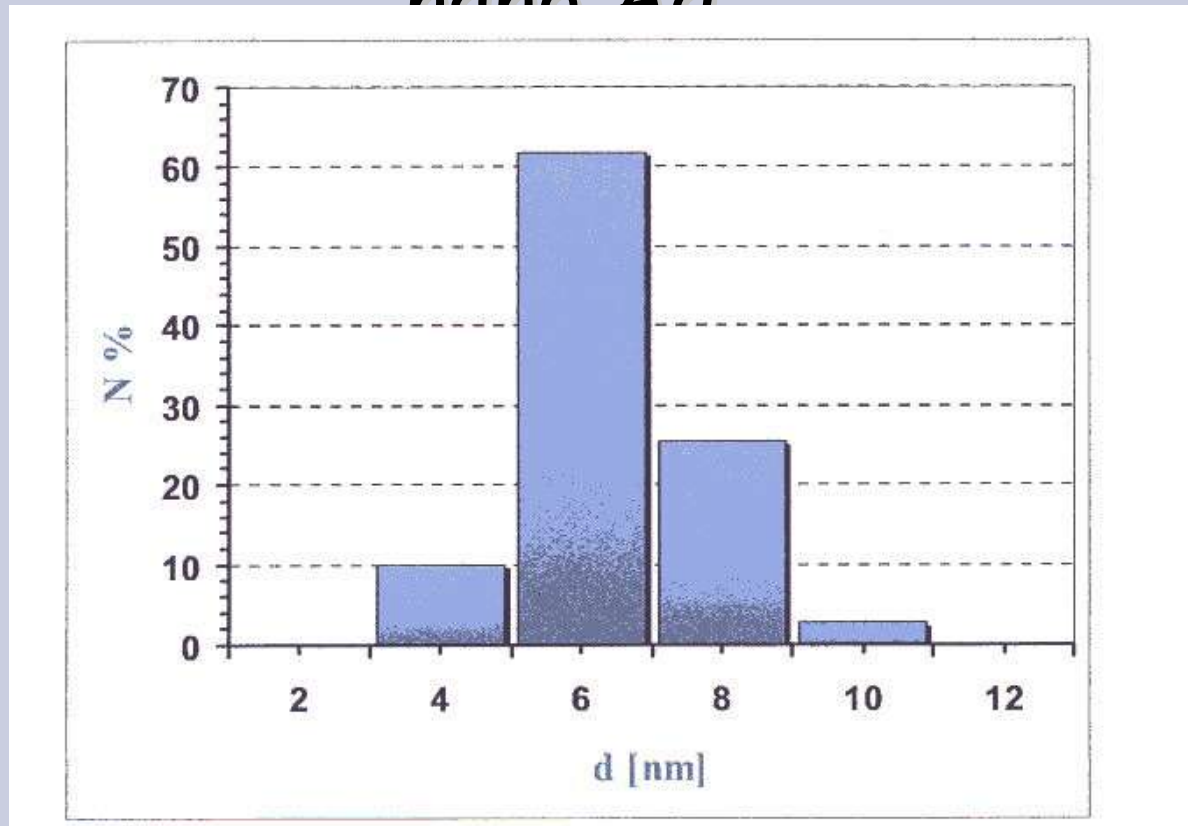
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Histogram for particles size of Amepox

nano Ag



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

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Electrically Conductive Ink with Nano Silver

Number of components	One
Consistency	Very low viscous liquid
Color	Dark brown to black with metallic shade
Percentage of silver filler (inside ink)	40 – 60 % (<i>actual 45%</i>)
Specific gravity	1.3 – 1.6 g/cm ³
Viscosity	1.4 – 1.55 mPas
Thixotropy index	~ 1.0
Surface tension value	28.5 – 34 dynes/cm
Recommended sintering conditions	230 – 240 °C - 120 min
Percentage of silver after „curing”	95 – 97 %
Electrical resistivity	(4 – 6) 10 ⁻⁶ Ωcm
Storage	6 months in room temperature



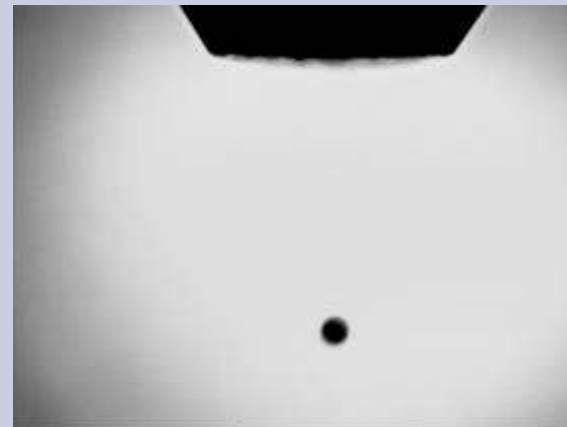
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Ink-Jet Dispenser Shoot and droplet forming



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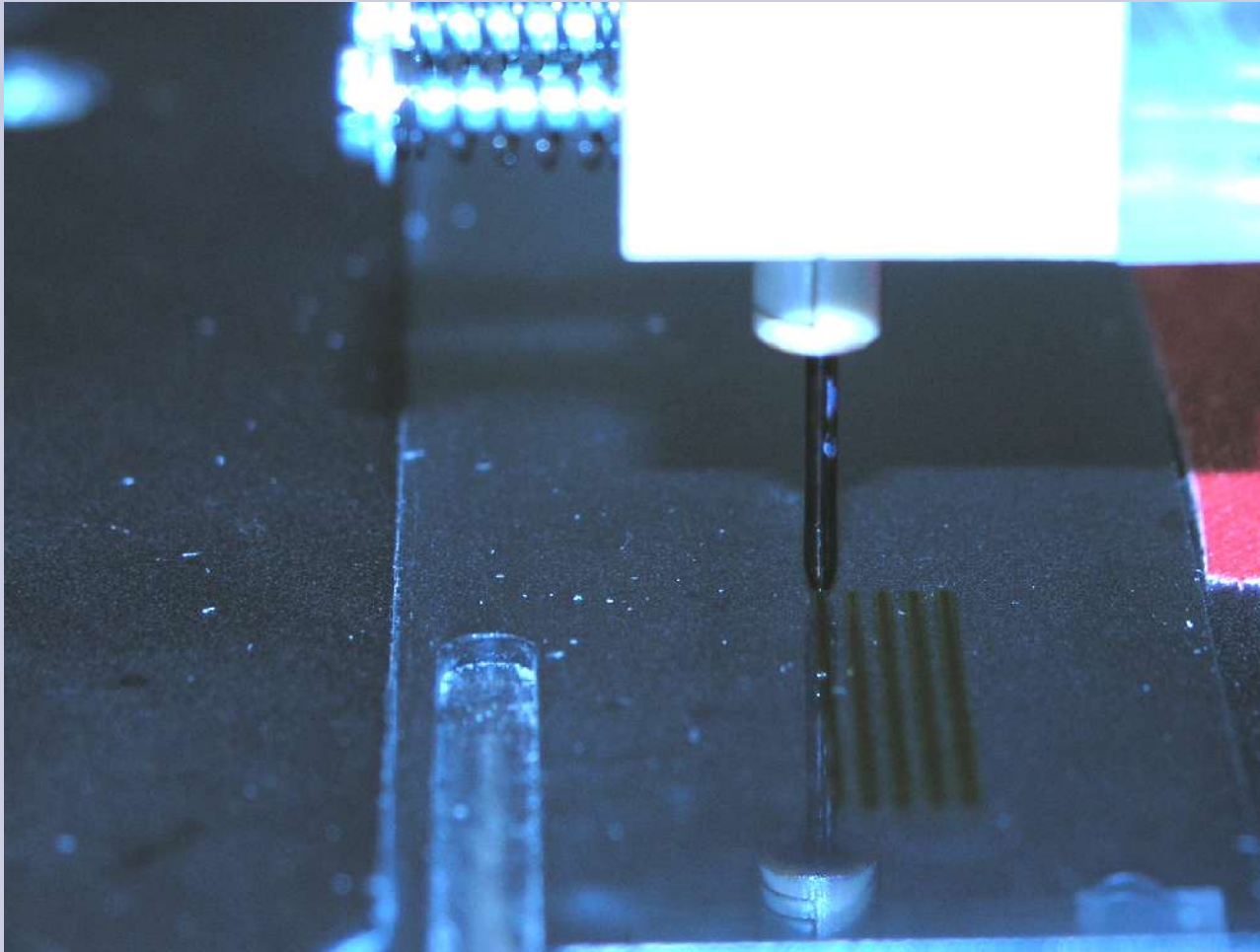
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Tests by Ink Jet Dispenser



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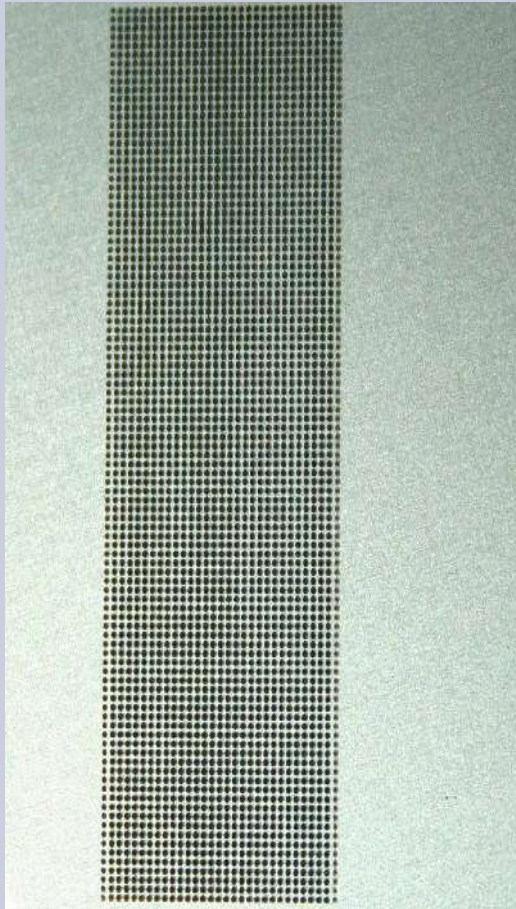
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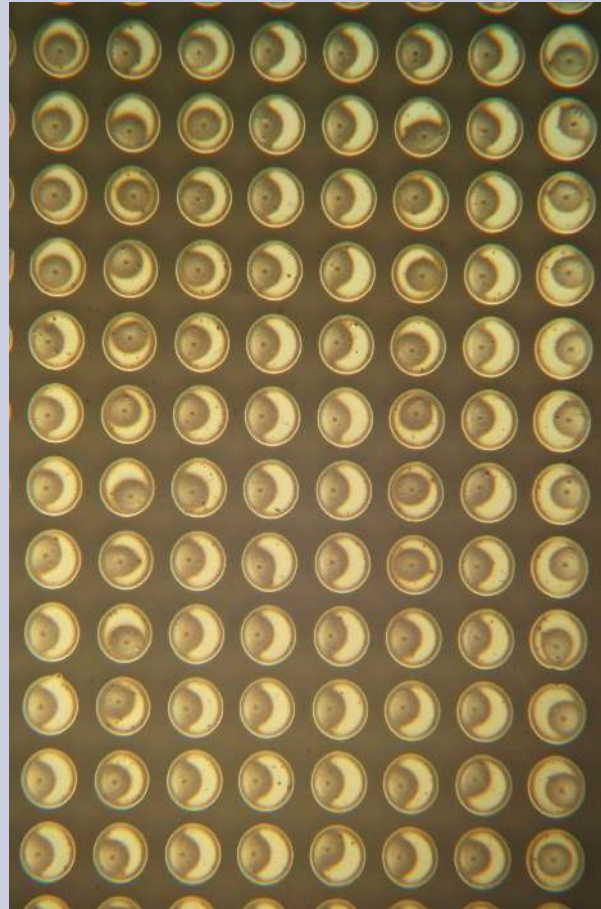


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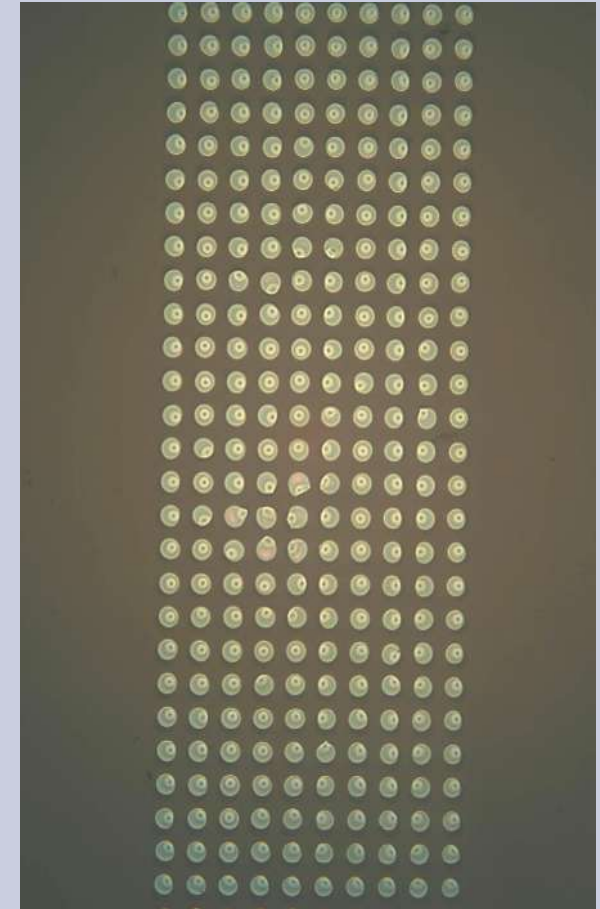
Results of Ink Jet tests



Dots: Macro Picture



Nozzle 66 microns



Nozzle 34 microns

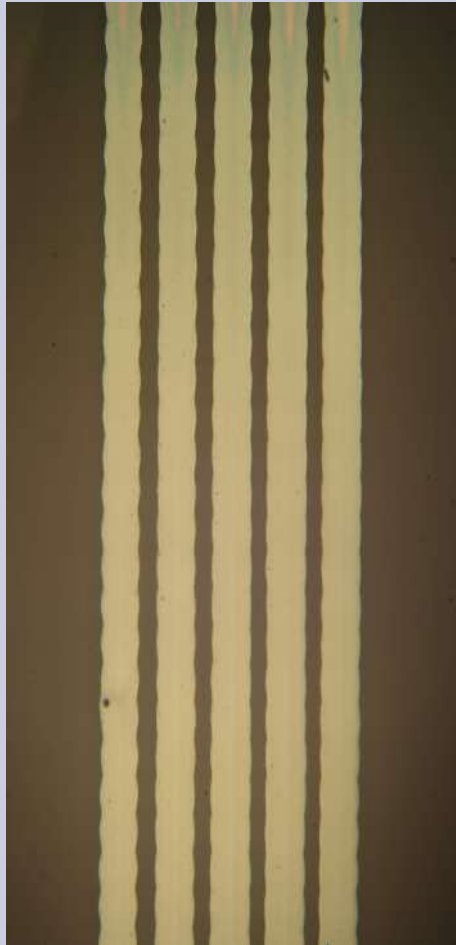
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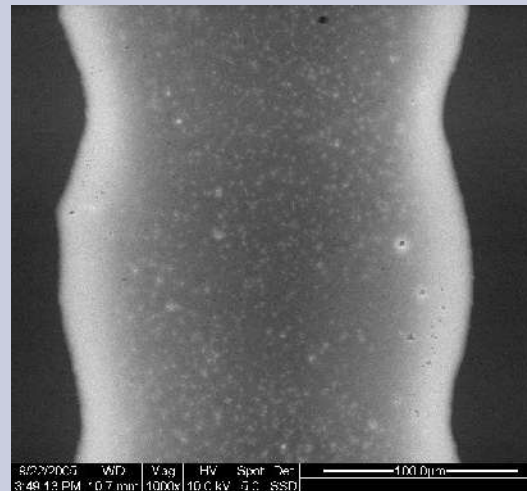
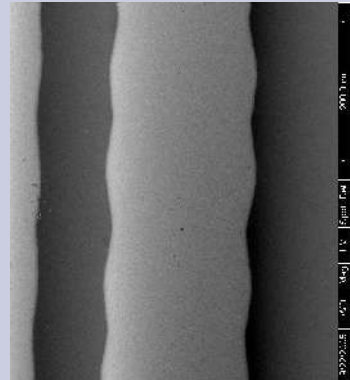
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Results of Ink Jet tests

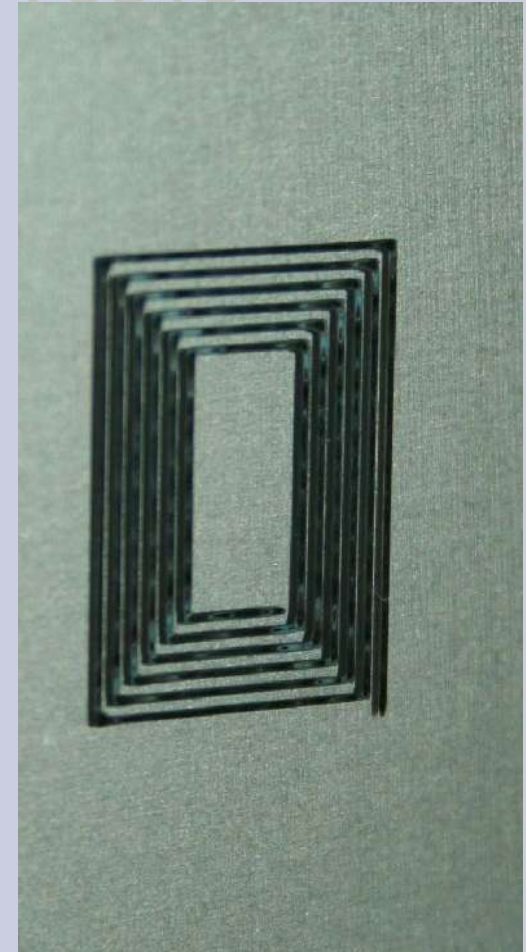


Lines: Nozzle 66 microns



Courtesy of TNO Industrial-Eindhoven

Single line SEM picture



Macro Picture



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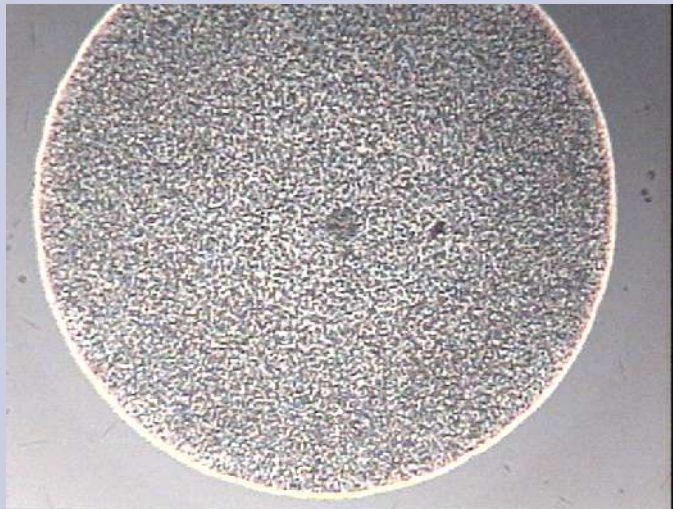
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Advantages of Jet Printing Techniques

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,



X 200



x 50

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Line resistance measurement results

Line number	Electrode distance	Resistance value [Ω]	Electrode distance	Resistance value [Ω]
1.	5 mm	5.2	25 mm	25.6
2.	5 mm	5.1	25 mm	25.6
3.	5 mm	5.2	25 mm	26.4
4.	5 mm	5.3	25 mm	26.2
5.	5 mm	5.3	25 mm	26.8
6.	5 mm	5.1	25 mm	25.8
7.	5 mm	5.2	25 mm	25.6
8.	5 mm	5.3	25 mm	26.2

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



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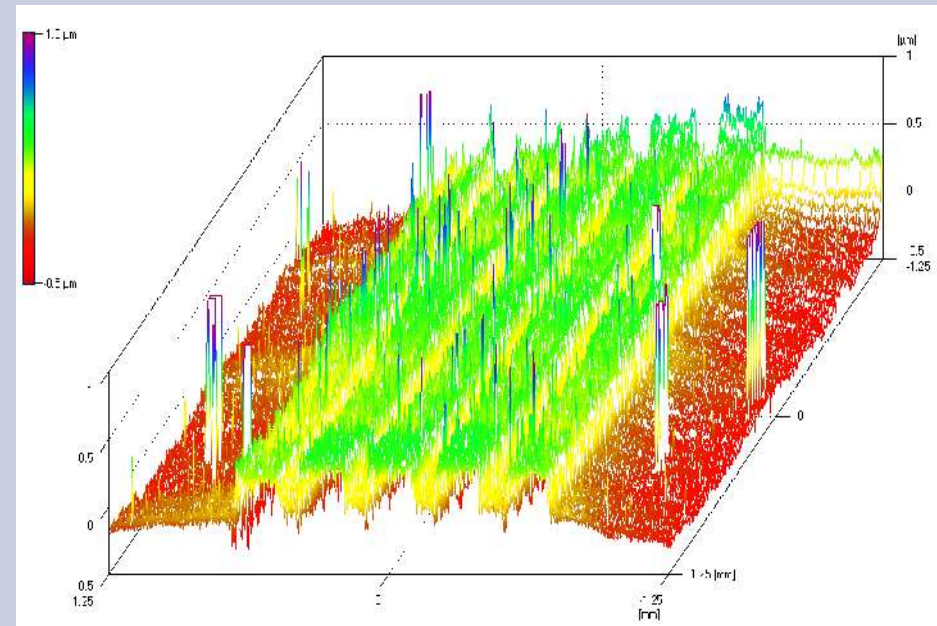
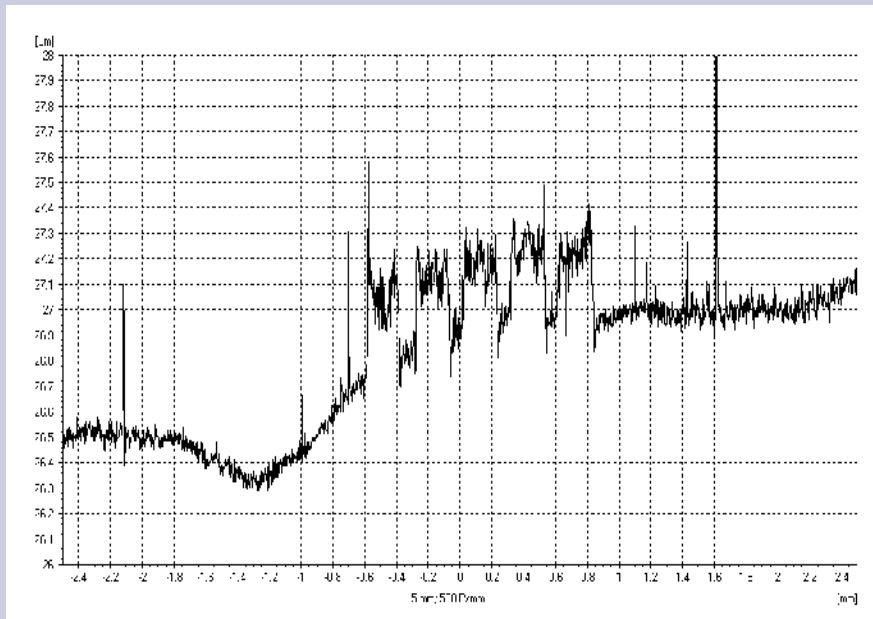
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Results of line thickness measurement

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



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

