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Quality Silver Systems

Conductive Microstructures and Connections for Microelectronics Made by Ink-Jet Technology

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Materials with nano size fillers create very new possibilities and new applications.

New possibilities needs special type of equipment.

Equipment -> Ink Jet Dispenser System.

Short reminder for Ink Jet 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:* *10^5g (during each shoot)*

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Ink Jet technology is well known for many applications especially when very uniform fluid is used.

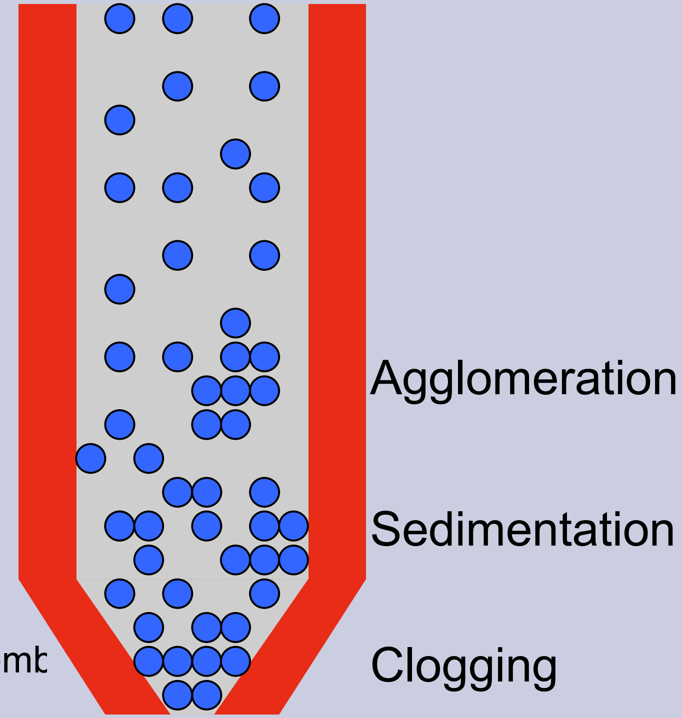
With formulations which is mixtuer of two different phases: fluid binder and solid filler – problem is much more complicated. Let's use some fluid classification:

- 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



Much better situation is when conductive filler has diameter less 10 nm.

Than formulation start to be very uniform and stable with properties similar to „true fluid”.

Is a number methods for obtaining nano size silver powder, for example:

- *Metal dissipation in plasma prosess,*
- *Chemical reaction process,*
- *Electrochemical process,*
- *Thermal decomposition process,*
- *Vapor condensation process, etc.*

For preparing silver with size of single 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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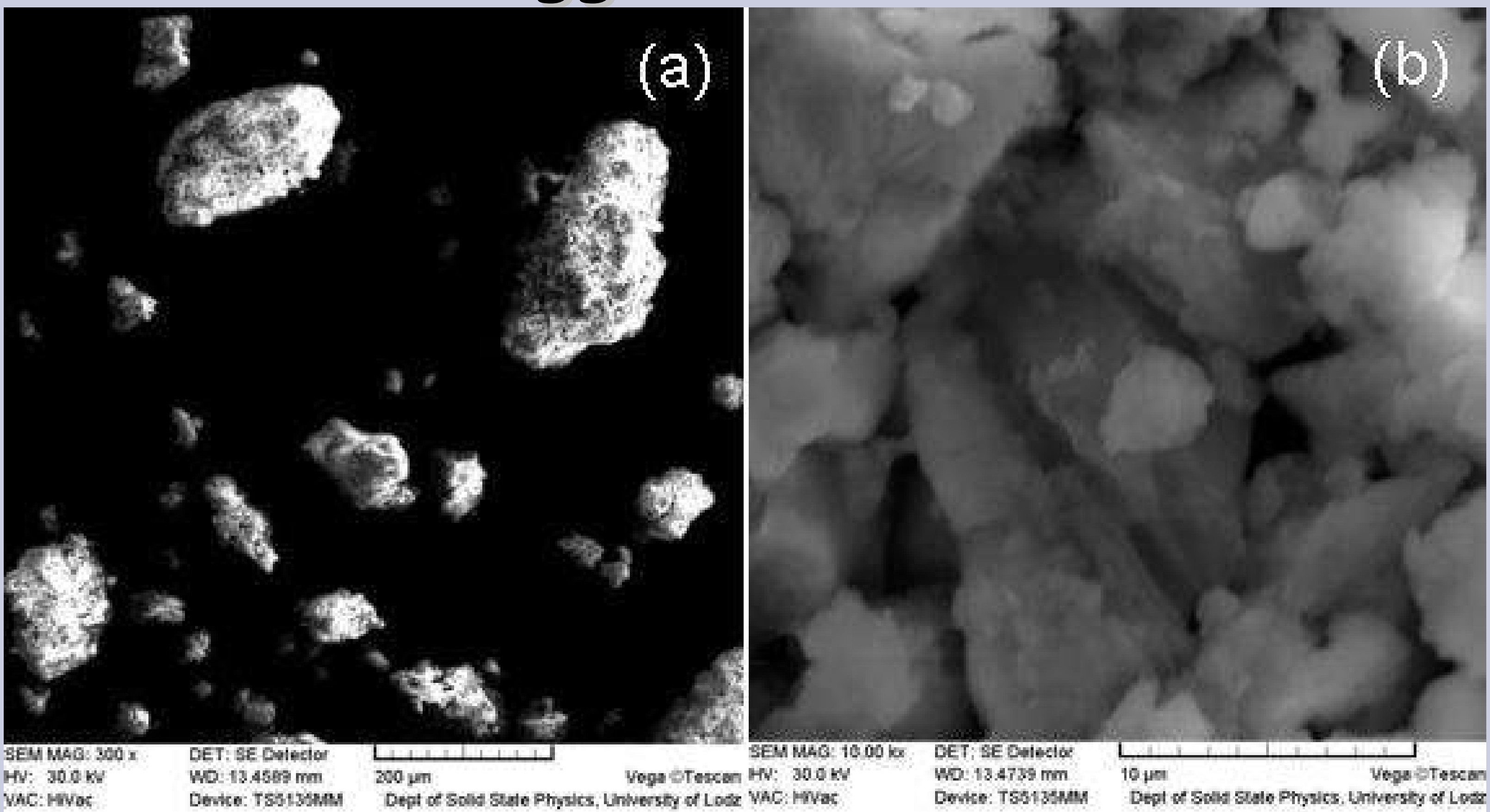
SEM Pictures ofNano Silver Agglomerates



Courtesy Solid State Physics University of Łódź.

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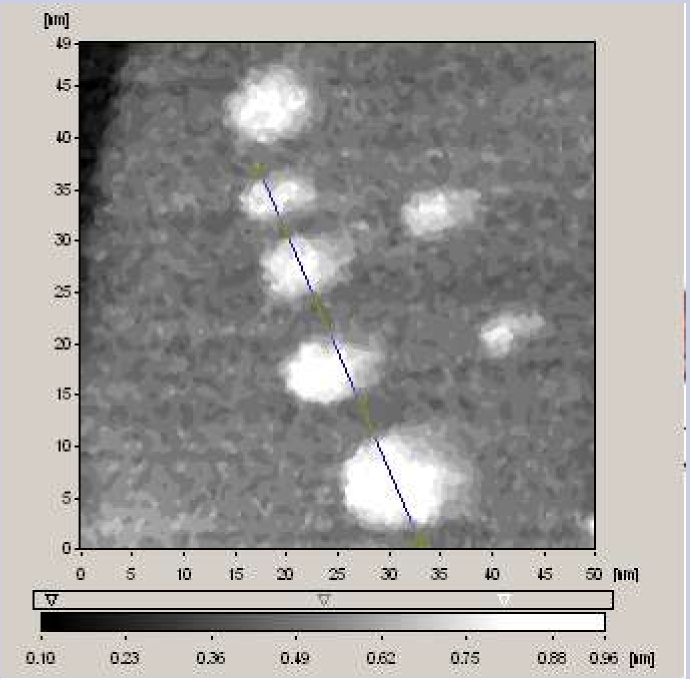
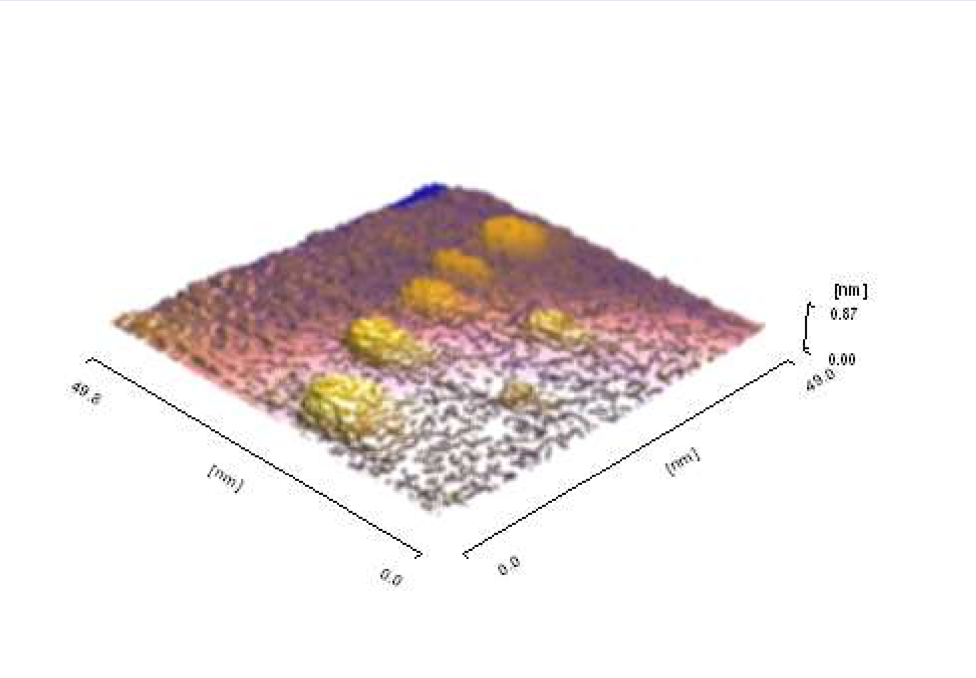
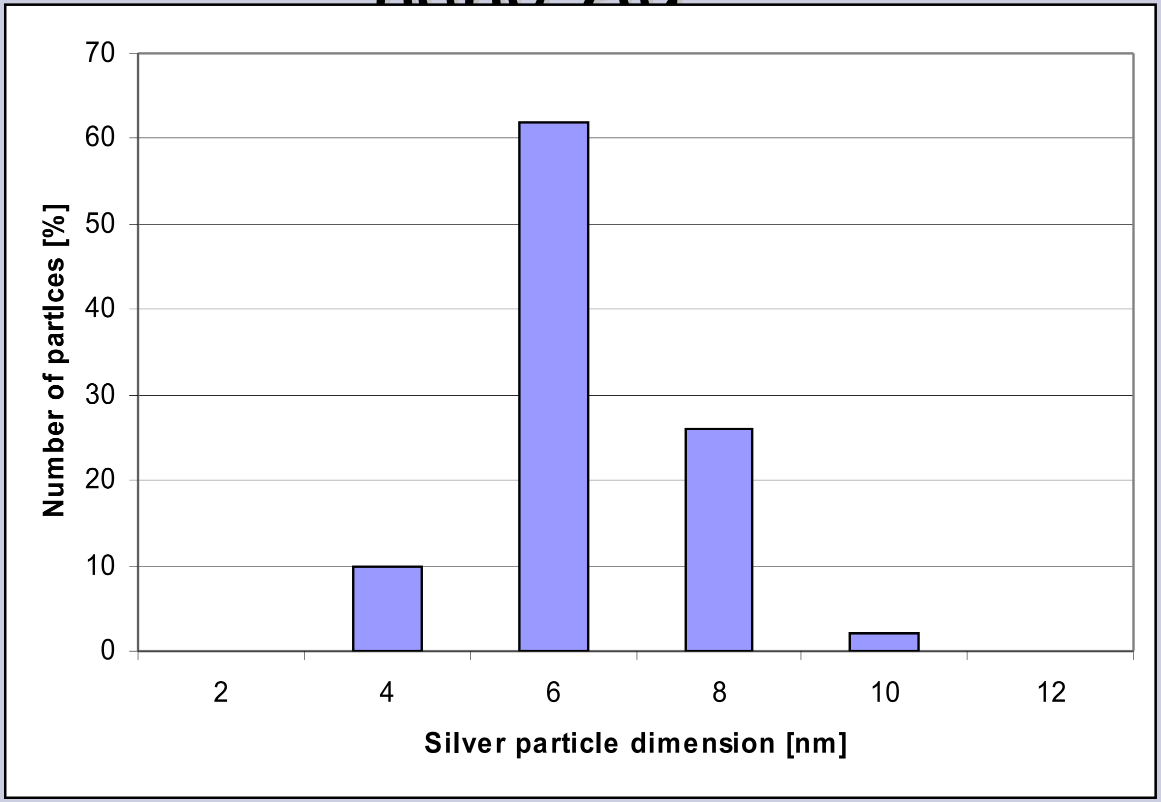
STM Pictures ofNano Silver





Courtesy Solid State Physics University of Łódź.

Histogram for particles size of Amepox nano Ag



SIlver Atom Diameter 2.88 Å (1 nm = 10 Å)

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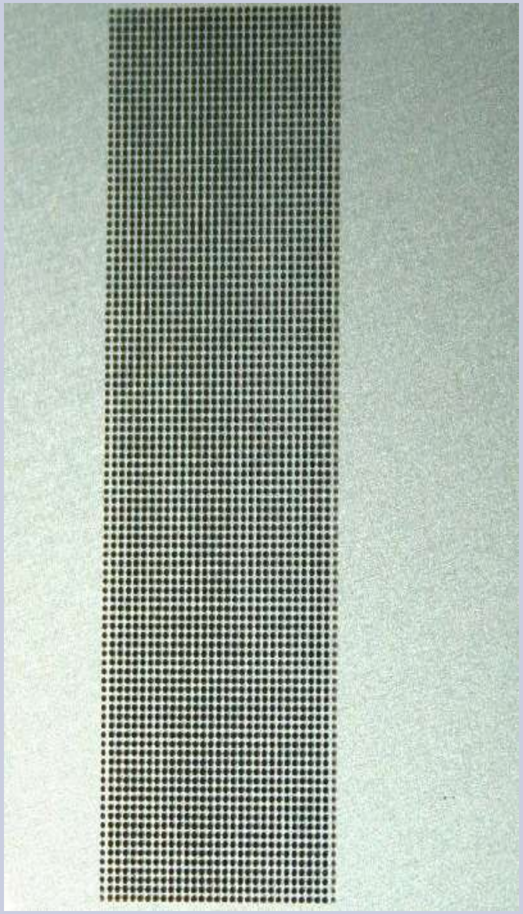
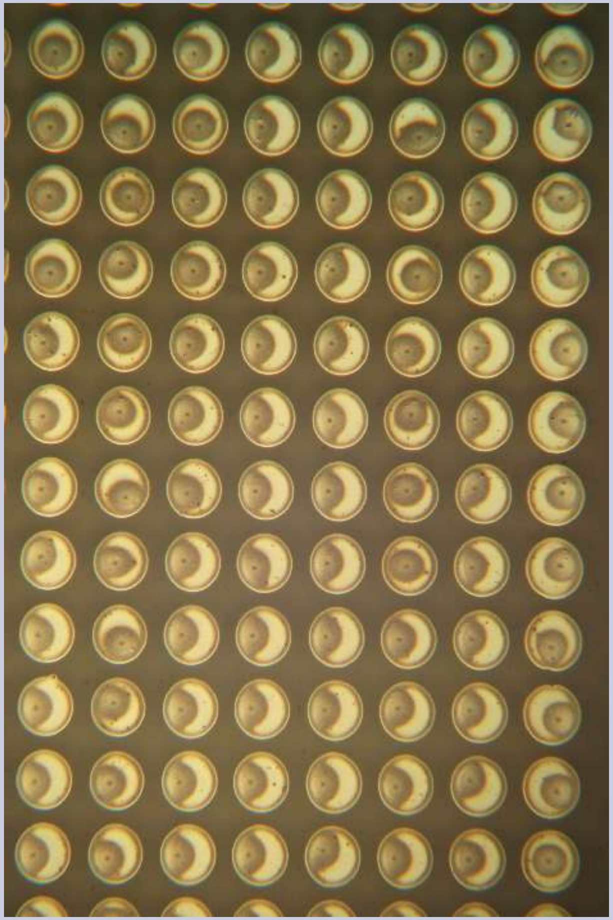
Electrically Conductive Ink with Nano Silver

Number of components	One
Consistency	Very low viscous ink
Color	Dark brown to black with metalic shade
Percentage of silver filler (inside ink)	40 – 60 % (*actual 45%*)
Specific gravity	1.3 – 1.6 g/cm^3
Viscosity	1.4 – 1.55 mPas
Thixotropy index	~ 1.0
Surface tension value	28.5 – 32.5 dynes/cm
Recommended sintering conditions	230 ˚C - 60 min
Percentage of silver after „curing”	95 – 97 %
Electrical resistivity	(1 – 3) 10^{-5} Ωcm
Storage	6 months in room temperature

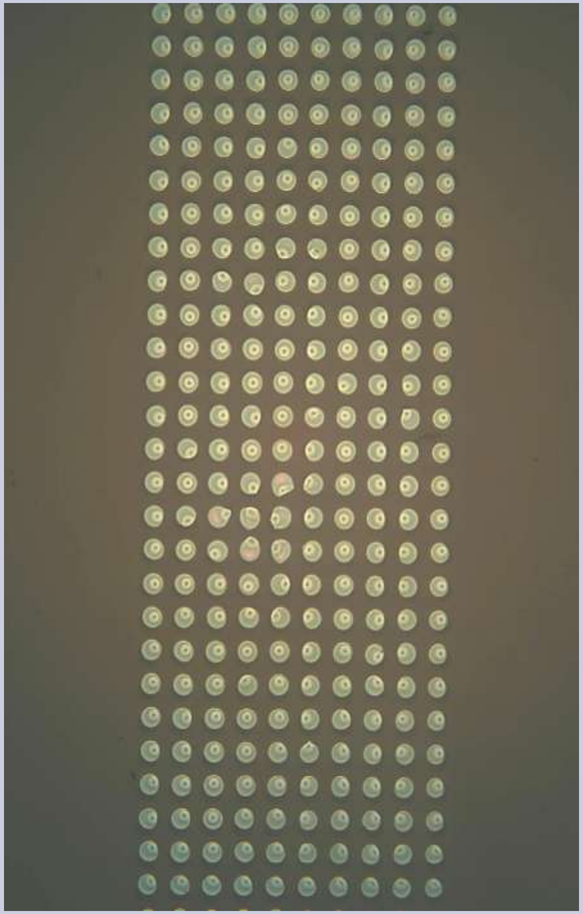
Results of Ink Jet tests



Dots: ***Macro Picture***



Nozzle 66 microns



Nozzle 34 microns

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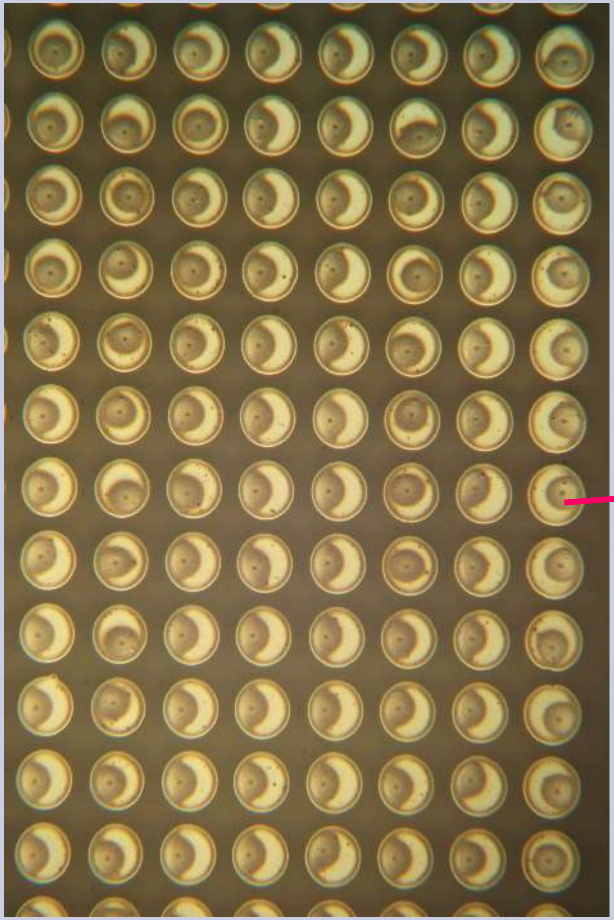
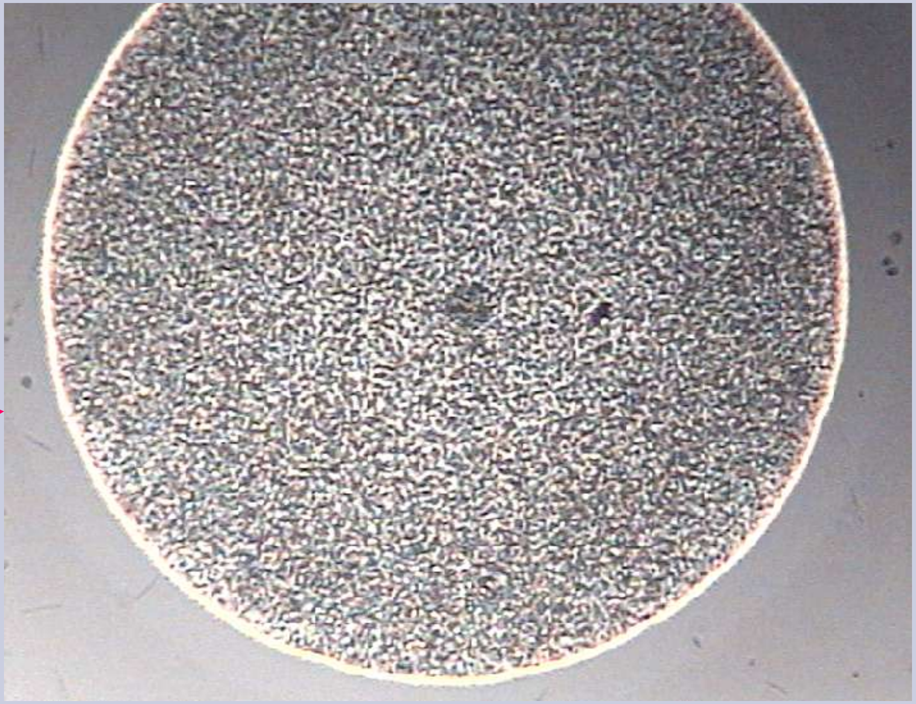
Results of Ink Jet tests

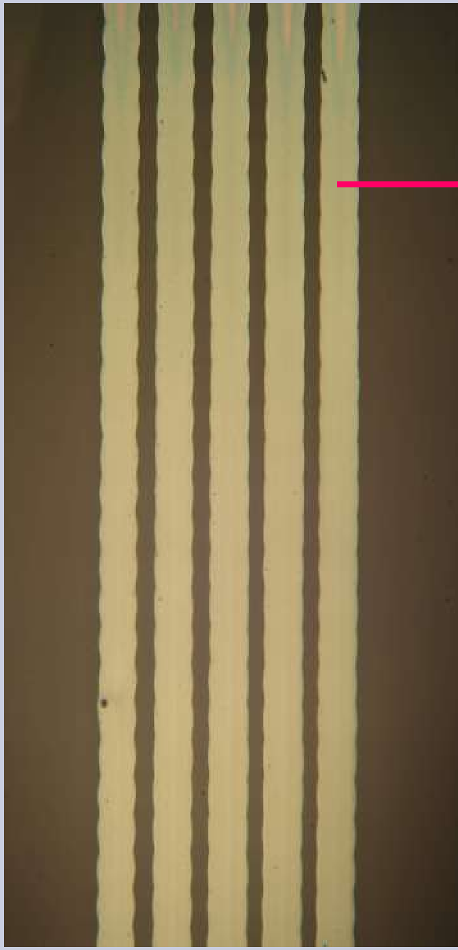


Nozzle 66 microns

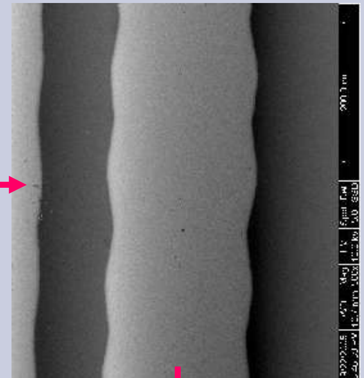


Mag. X 200

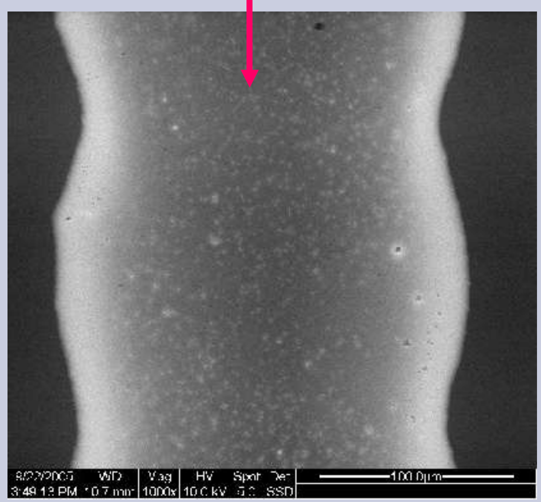
Results of Ink Jet tests



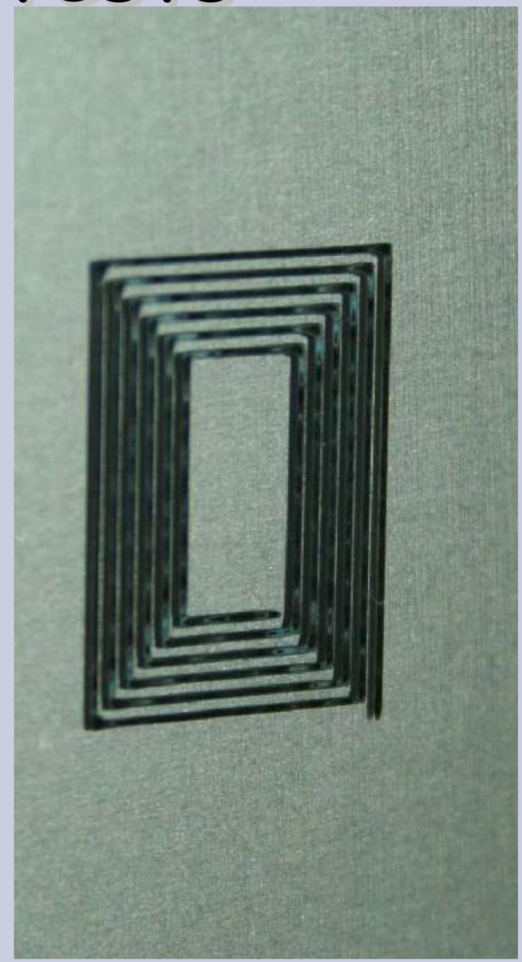
200 µm



100 µm



Courtesy of TNO Industrial-Eindhoven



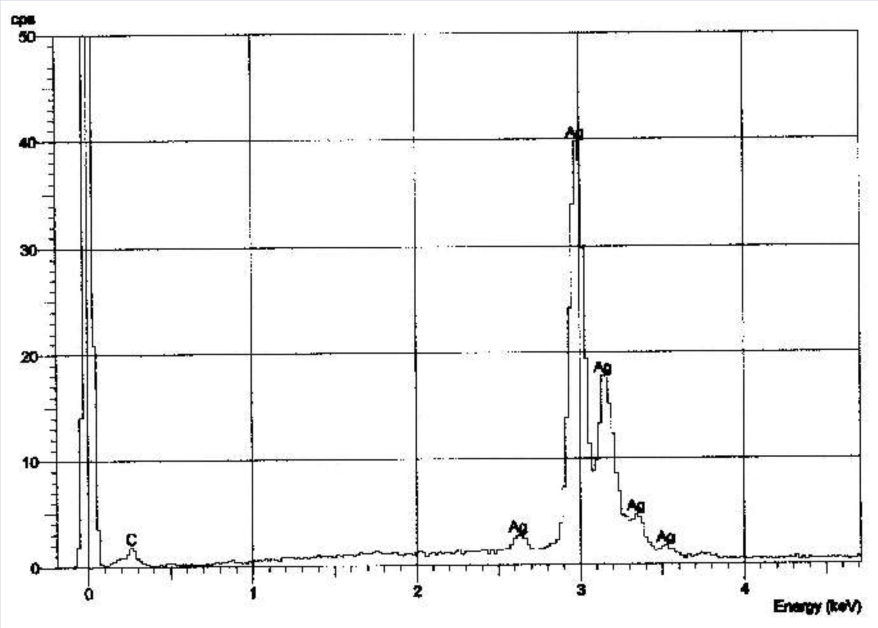
Lines: ***Nozzle 66 microns***

Single line SEM picture

Macro Picture

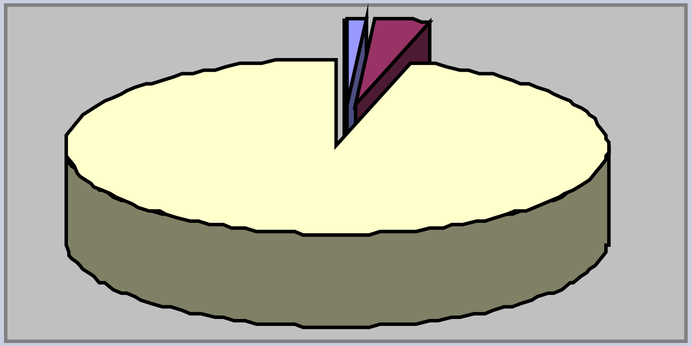
Obtaining electrical conductivity

Each nAg particle is protected by special chemical „schell".
This „schell" layer is built during nAg production process.



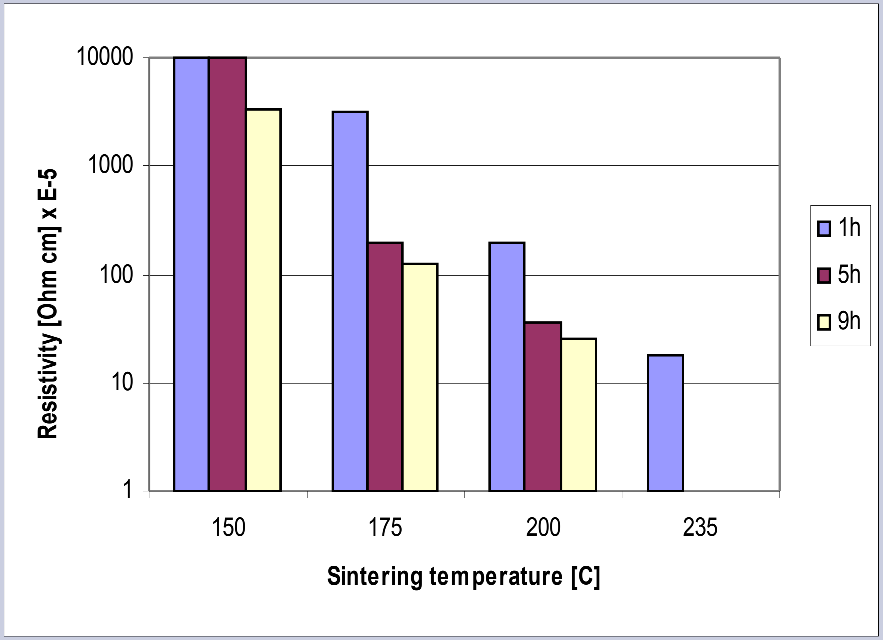
Ag 95.3 %

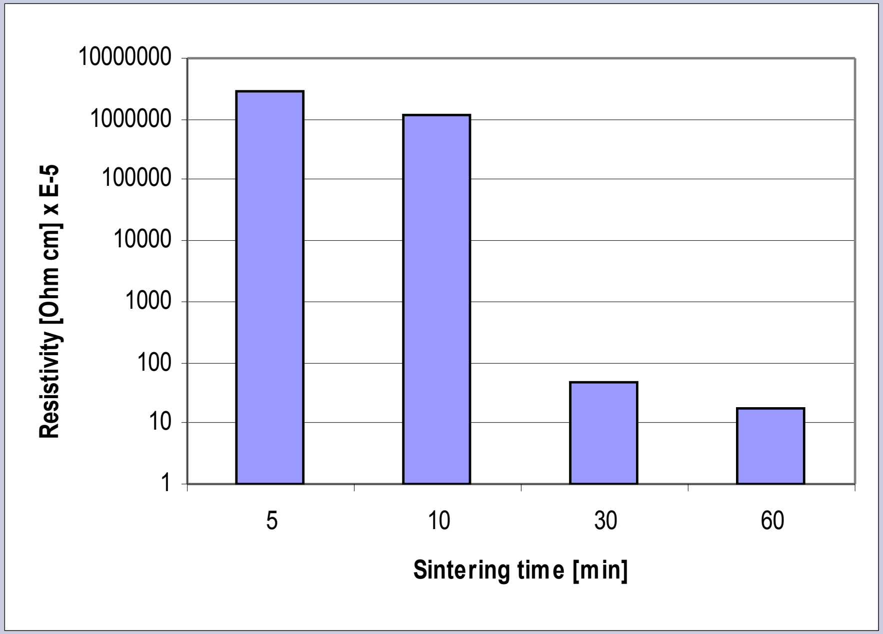
C 2.7±1.0 %



Tolerance ± 1 %

Obtaining electrical conductivity as a function of sintering time





SIntering temp. 235°C

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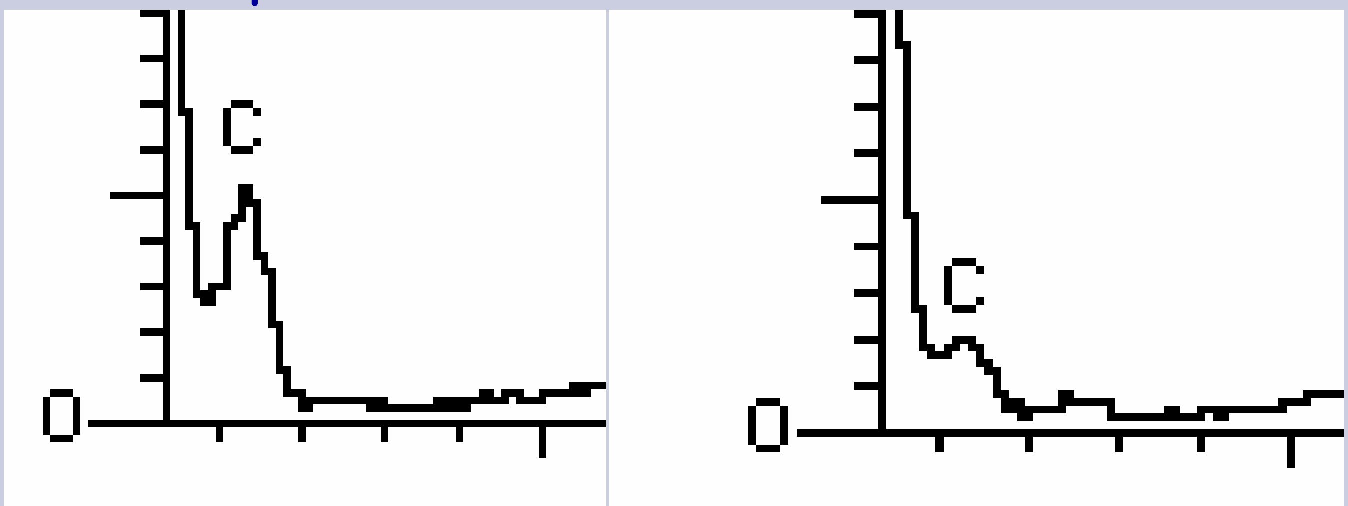
Obtaining electrical conductivity *-Phenomena-*

For electrical conductivity – is necessary to remove protection chemical „schell"



Purity test by EDX method :

LEFT – Just after drying **RIGHT** – after sintering 175°C/9 h

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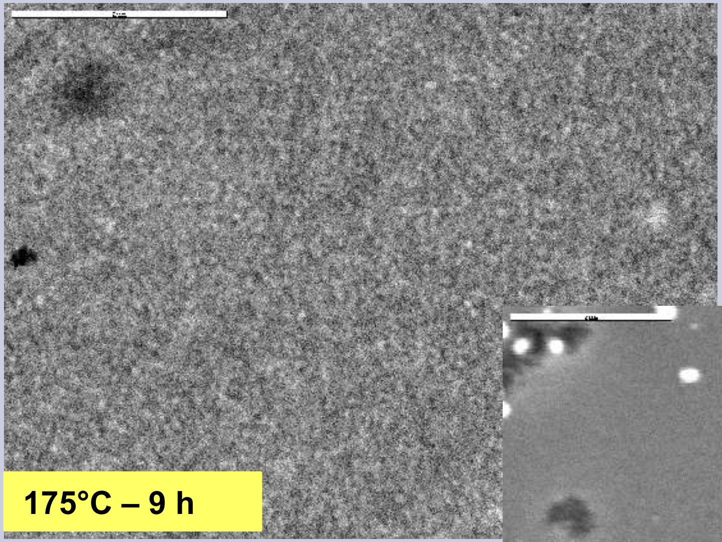
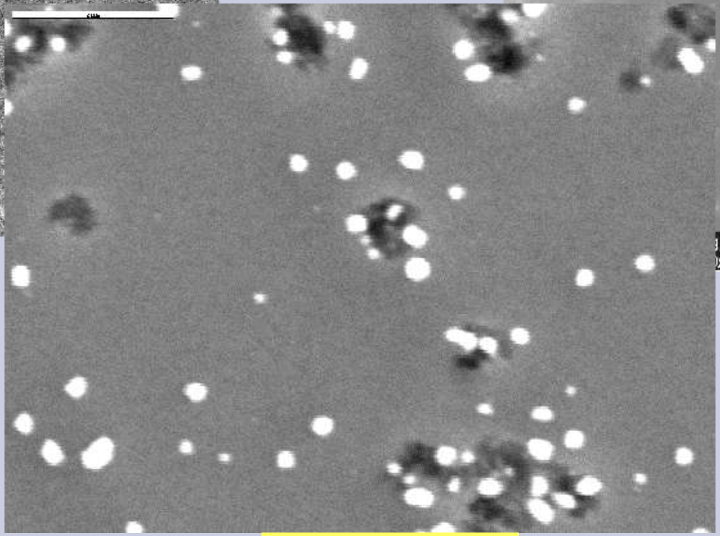
Obtaining electrical conductivity

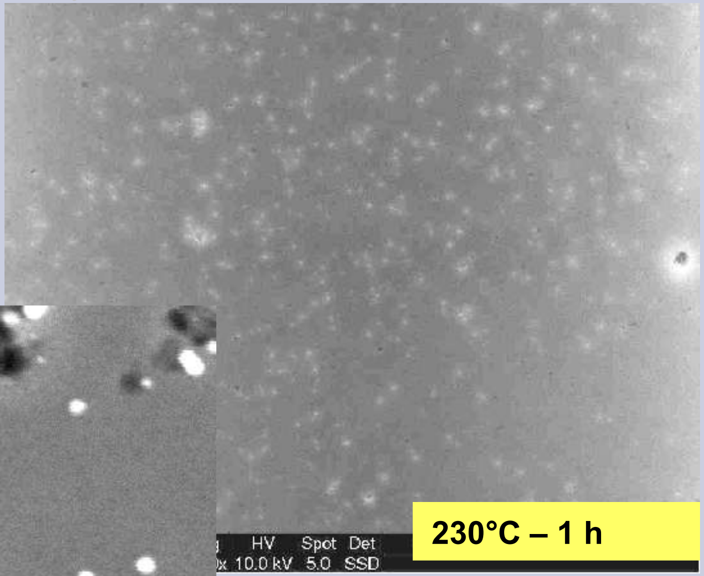
-Sintering Phenomena-



175°C – 9 h



200°C – 9 h



230°C – 1 h

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CONCLUSIONS:

1. Nature of nAg powder needs protective „schell" with chemical depended from technology.
2. Mechanism obtaining electrical conductivity is different like for standard (micron size Ag) Inks.
3. The major role in this mechanism plays kind of „schell" and it's removing from nAg surface and nAg sintering.

ADVANTAGES:

5. **Very high packaging possibility,**
6. **Nature of Nano Inks - formula is with the best homogeneous properties (uniform concentration),**
7. **The highest repeatability of dosing ink volumes,**
8. **Very high repeatability of printed shapes,**