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Quality Silver Systems

Conductivity Improvement of Microstructures Made by Nano-Size-Silver Filled Formulations

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Ink-Jet Printing Technology

1. The Ink-Jet printing is used year by year wider in microelectronic technologies.
2. I-J technology allowed to producing EC structures in the range of several micrometers size.
3. I-J needs inks with special properties as:
   - fully homogeneous ink structure and
   - very low viscosity value.

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Inks for I-P Technology

EC formulations mostly consist fluid binder and solid fillers. For this type formulations which are mixture of such a two different phases let us use classification as below:

Formulation:

- Mechanical type – classical, when filler size is over 0.5μm.
- Colloidal type – when filler is in range 0.5μm ~ 50 nm.
- True fluid type (similar „molecular" type) – when filler is less 20 nm.

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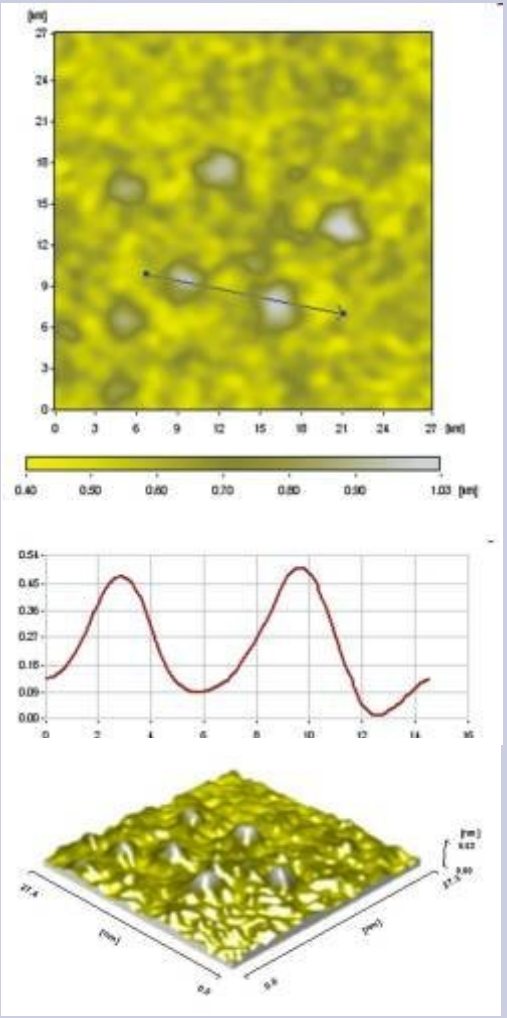
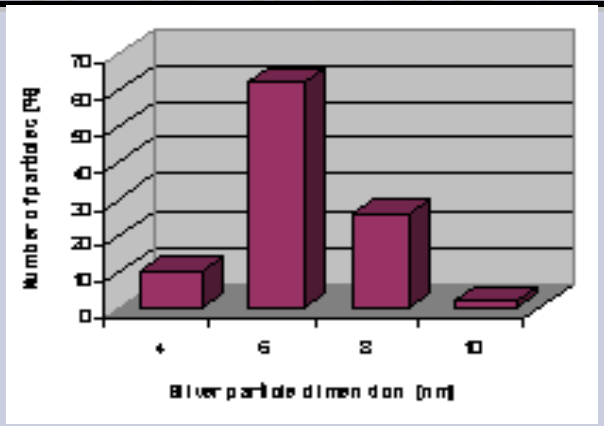
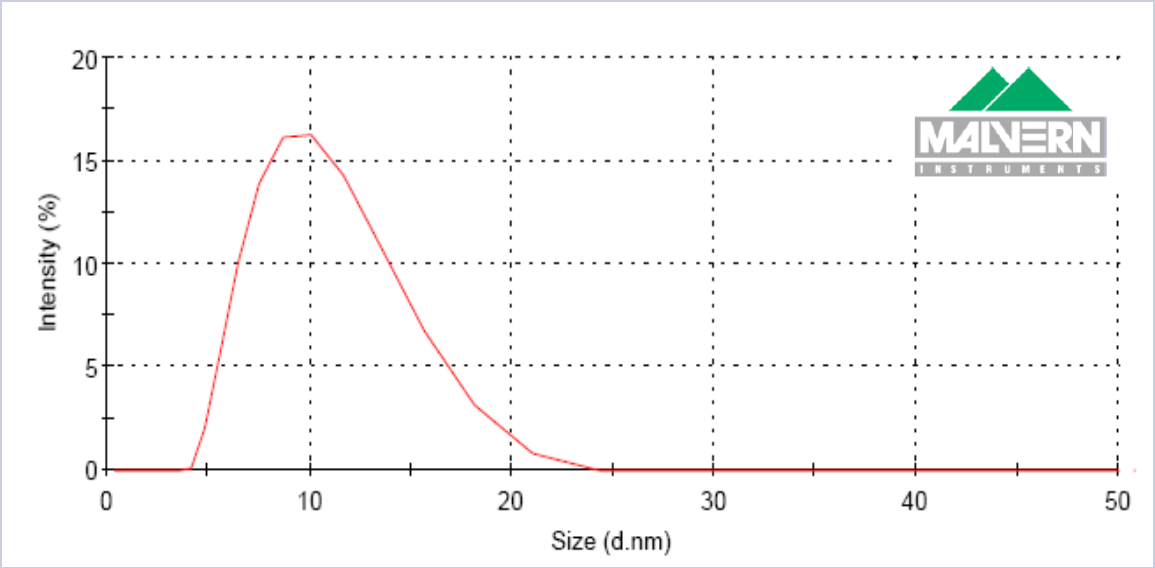
Nano Silver as a Nano Ink Filler





Nano Silver Histogram – on the left



3-8 nAg STM picture – separate grains

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Nano Ink Base Properties

Number of components	One
Consistency	Very low viscous ink
Color	Dark brown to black
Percentage of silver filler	45 ÷ 65 % (*actual tests 45%*)
Viscosity	4.5 ÷ 15 mPas
Thixotrophy index	~ 1.0
Surface tension value	28.5 ÷ 32.5 dynes/cm
Sintering conditions	Max. 250 °C – 60 min
Specific gravity	1.3 ÷ 1.6 g/cm³
Electrical resistivity	(1 ÷ 3) 10^{-5} Ωcm

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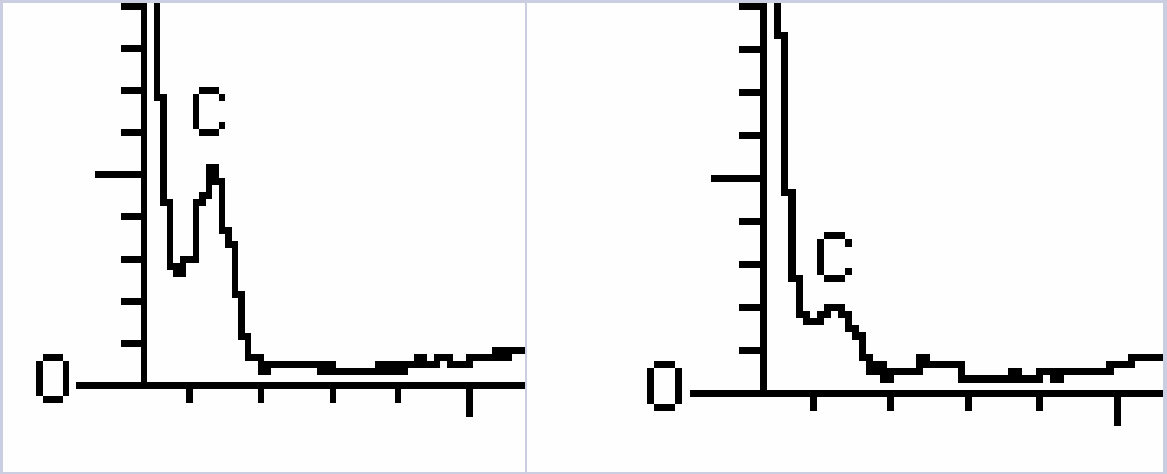
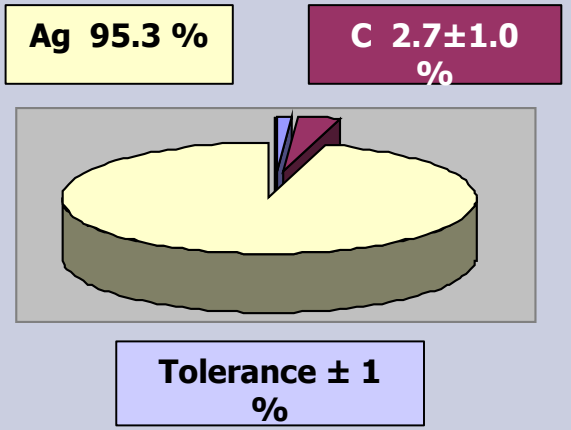
The Role of Protective Layer

1. After printing – nonconductive
2. After drying (110C-3 min) – nonconductive.
3. After sintering process - conductive



EDX Analysis



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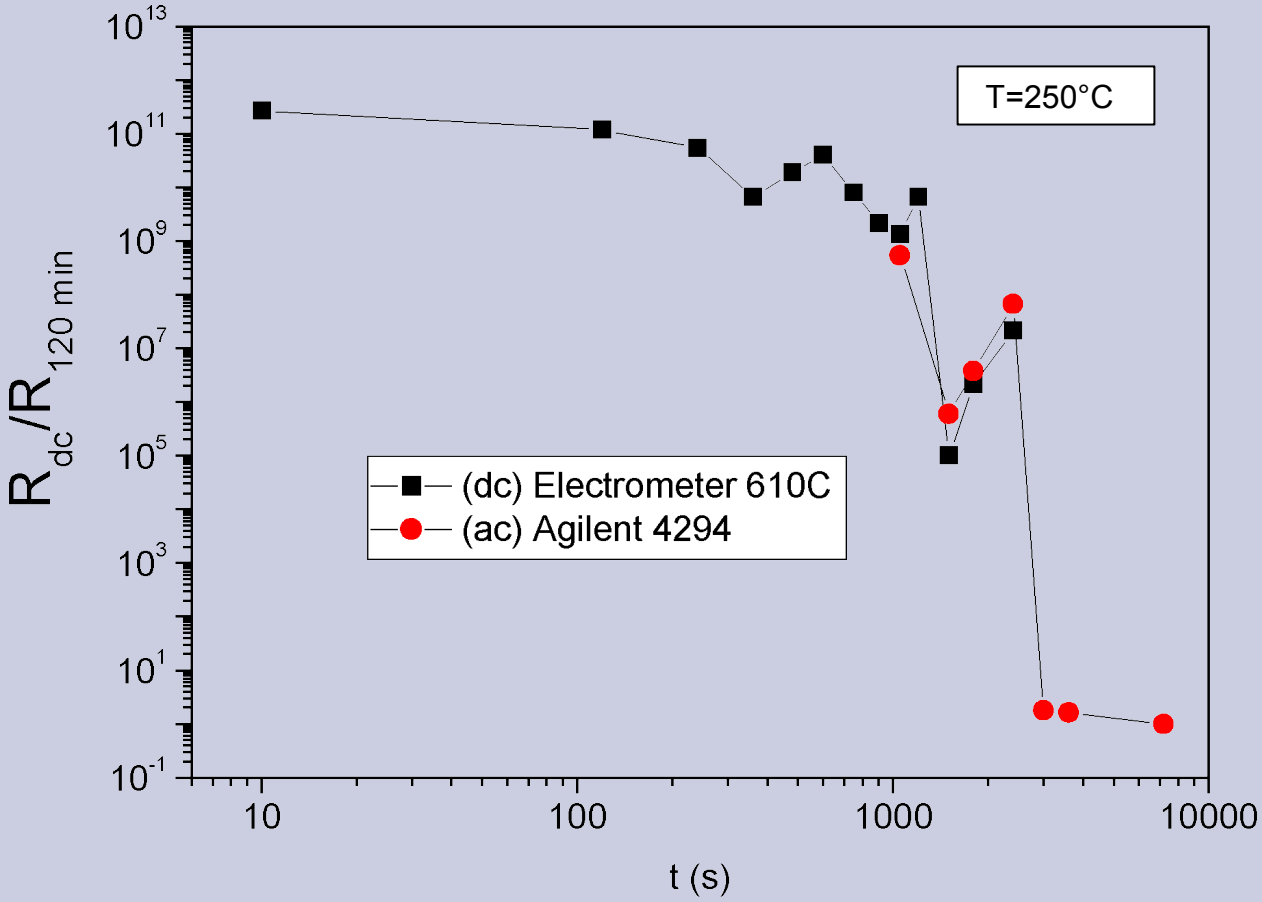
Sintering Process



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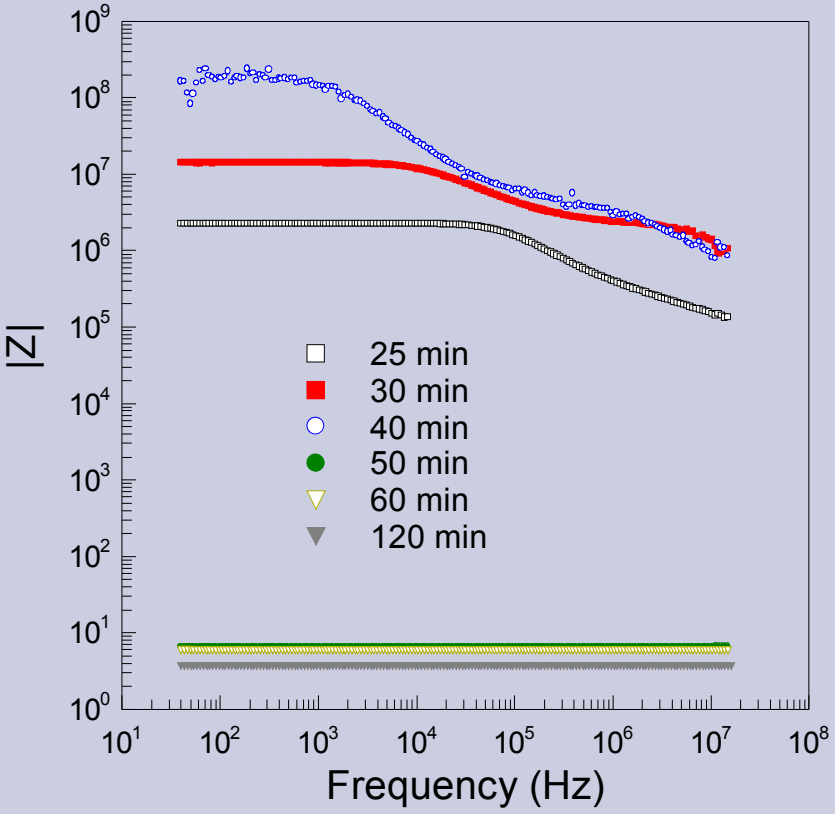
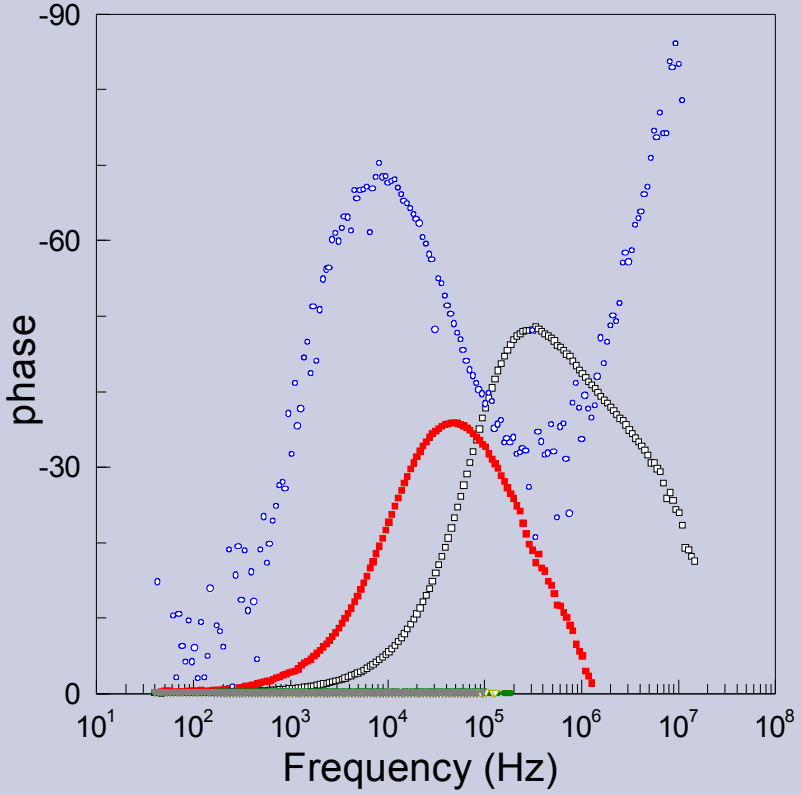
Sintering Process





Impedance absolute value and phase of printed layer in different time of heating process at 250ºC in the air atmosphere

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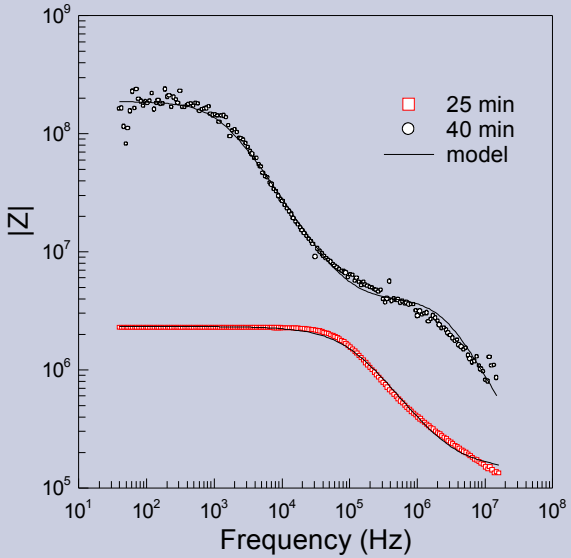
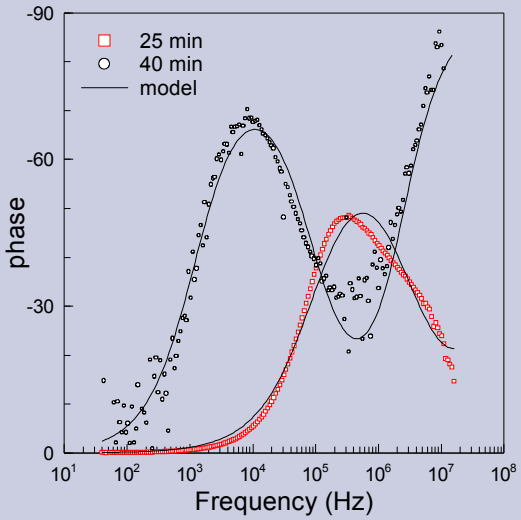
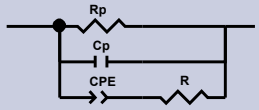
Sintering Process







Impedance absolute value and phase of printed layer for 25 and 40 minutes of heating at 250ºC in the air atmosphere; Continuous lines on graphs present the impedance behavior in the case of proposed electrical chart.

Element	Freedom	Value	Error	Error %
Rp	Free(+)	1,8786E8	4,6751E6	2,4886
Cp	Free(+)	1,7464E-14	5,0955E-16	2,9177
CPE-T	Free(+)	1,5055E-12	1,8987E-13	12,612
CPE-P	Free(+)	0,90594	0,011232	1,2398
R	Free(+)	4,1138E6	1,1529E5	2,8025

Chi-Squared: 0,070926
Weighted Sum of Squares: 24,328
Run Fitting / All Data Points (1 - 174)

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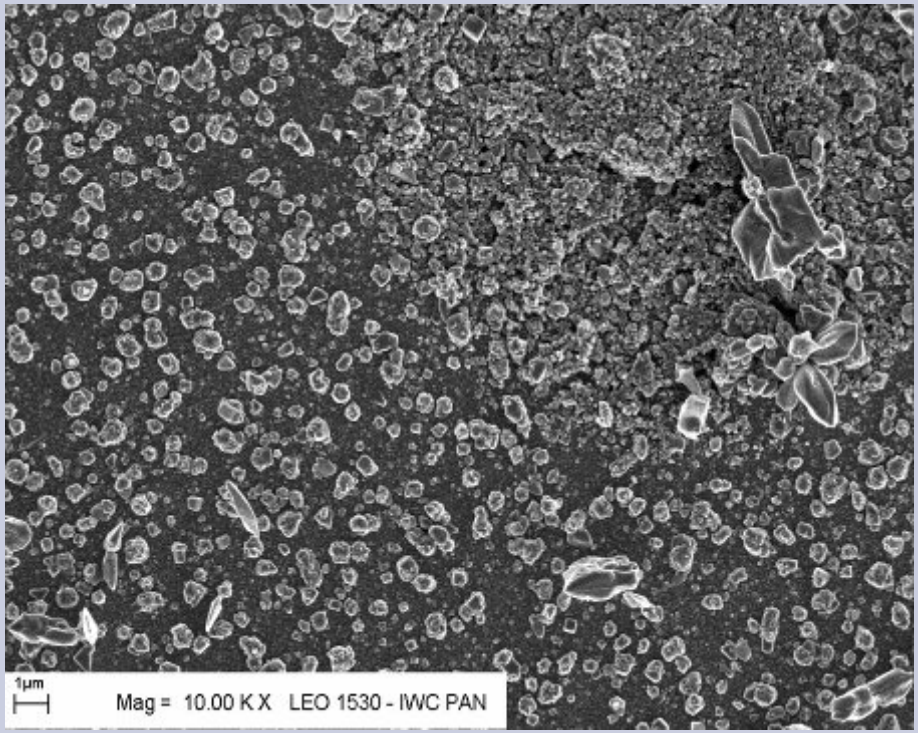
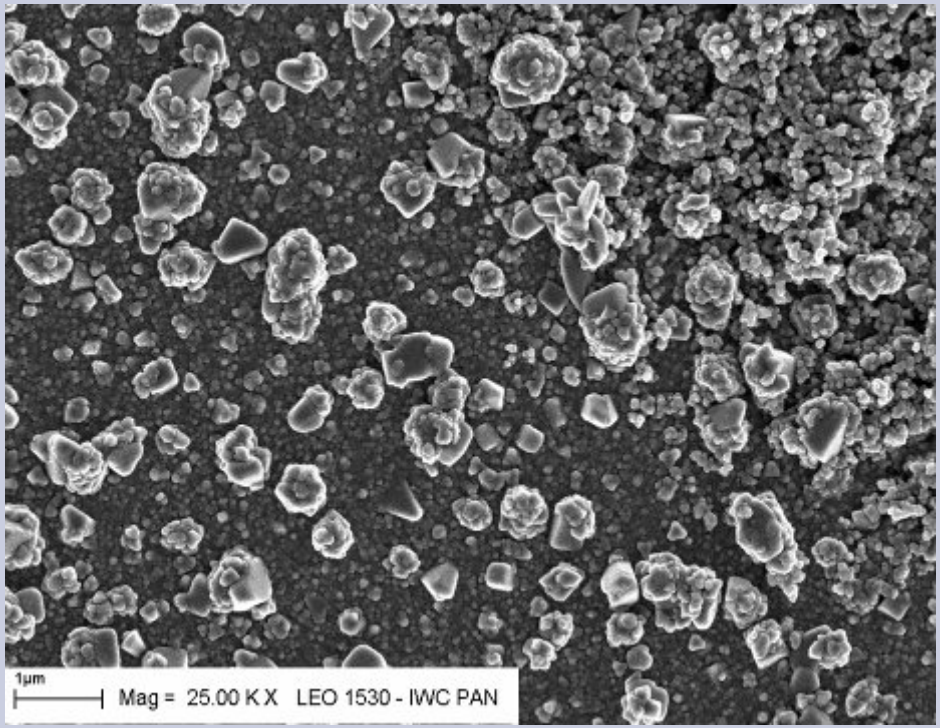
After sintering





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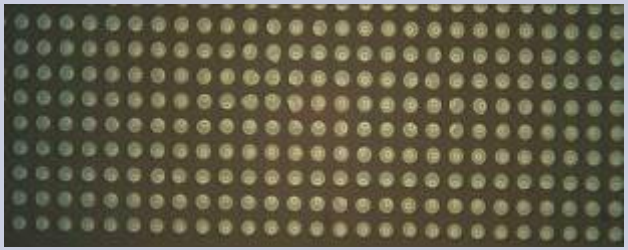
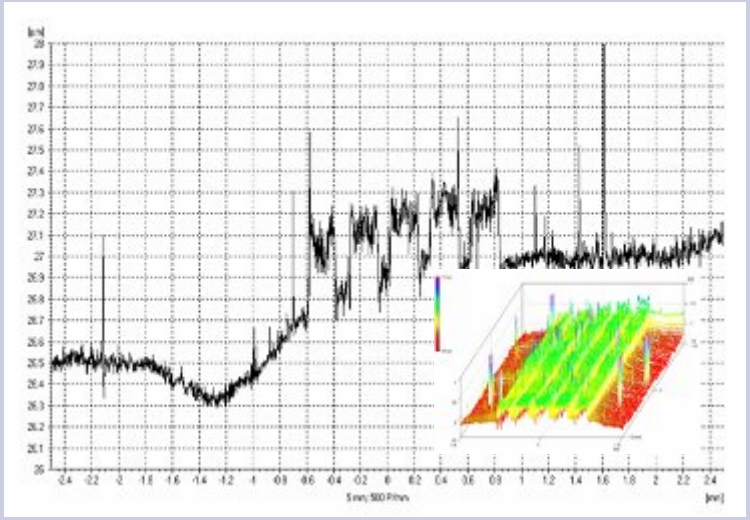
Electrically Conductive Structures





Measured resistivity - no higher like 3 10(-5) Ωcm (with measured thickness value ab. 0.25 microns)

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CONCLUSIONS:

1. *Nature of nAg powder needs protective layer with special kind of chemicals.*
2. *Mechanism obtaining electrical conductivity is different like for standard (micron size Ag) inks.*
3. *The major role in conductive mechanism plays kind of protective layer and it's removing from nAg surface during thermal process.*
4. *Work with new types of protective layers (low temperature and shorter sintering time) is during actual R&D process.*
5. *It is possible to use laser beam for removing protective layer.*