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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:

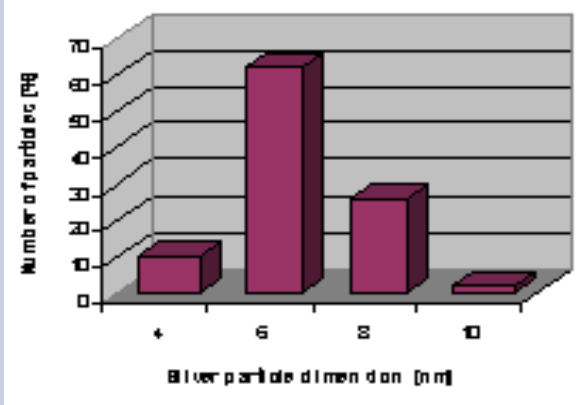
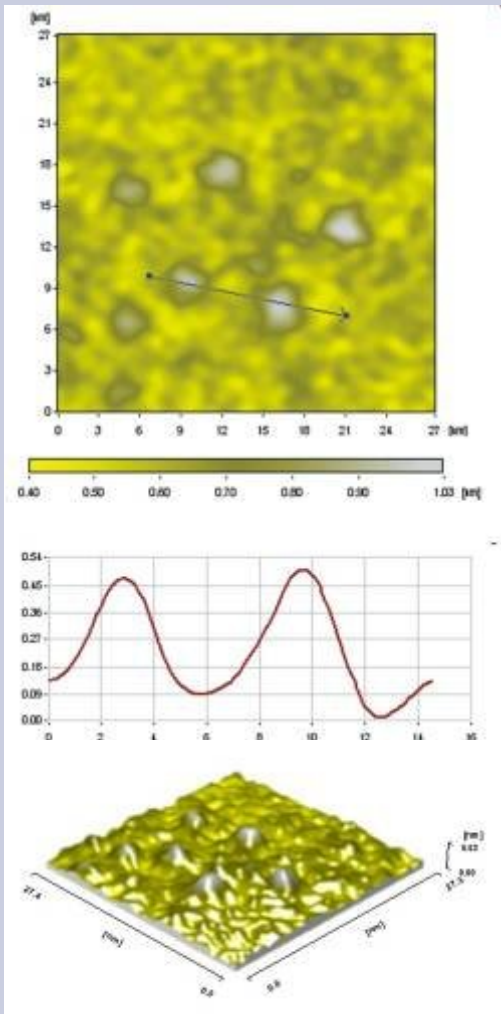
- Mechanical type - classical, when filler size is over $0.5\mu\text{m}$.
- Colloidal type - when filler is in range $0.5\mu\text{m} \sim 50 \text{ nm}$.
- True fluid type (similar „molecular“ type) - when filler is less 20 nm .



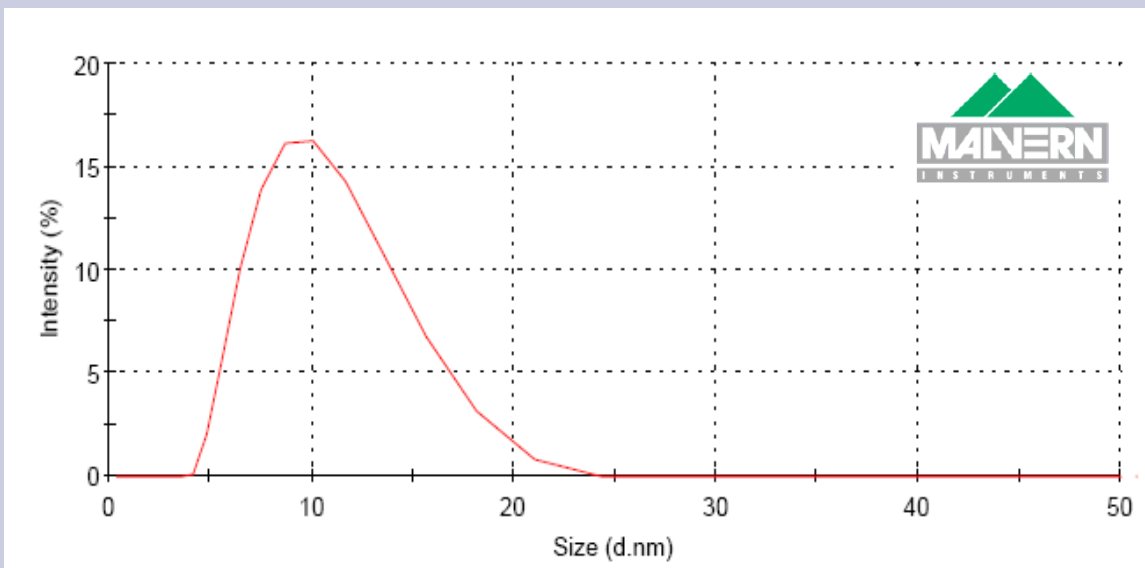
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Nano Silver as a Nano Ink Filler



Nano Silver Histogram – on the left



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3-8 nAg STM picture – separate grains



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Quality Silver Systems

Nano Ink Base Properties

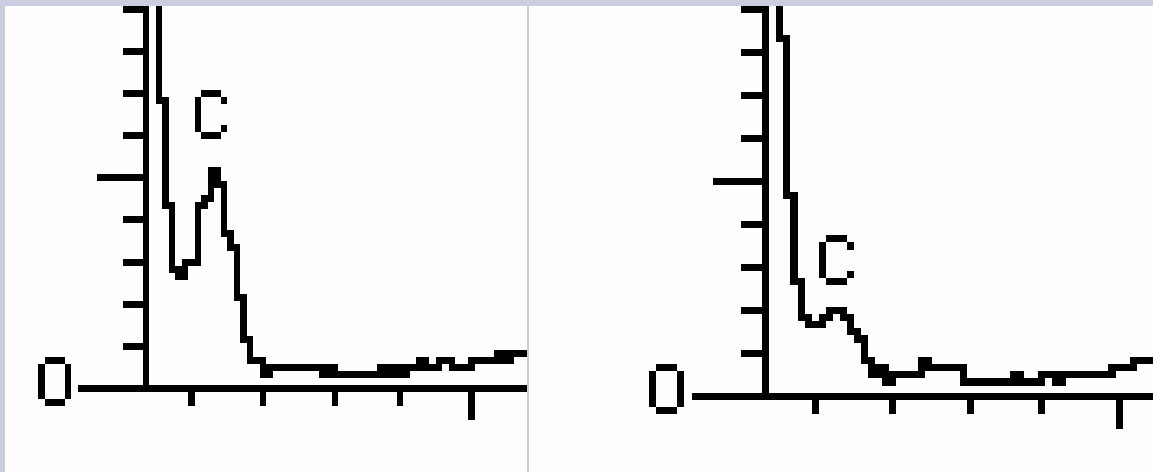
Number of components	One
Consistency	Very low viscous ink
Color	Dark brown to black
Percentage of silver filler	45 ÷ 65 % (<i>actual tests 45%</i>)
Viscosity	4.5 ÷ 15 mPas
Thixotropy index	~ 1.0
Surface tension value	28.5 ÷ 32.5 dynes/cm
Sintering conditions	Max. 250 °C – 60 min
Specific gravity	1.3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



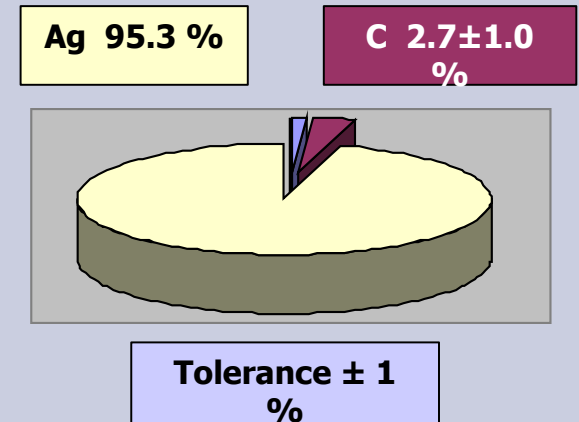


The Role of Protective Layer

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



EDX Analysis

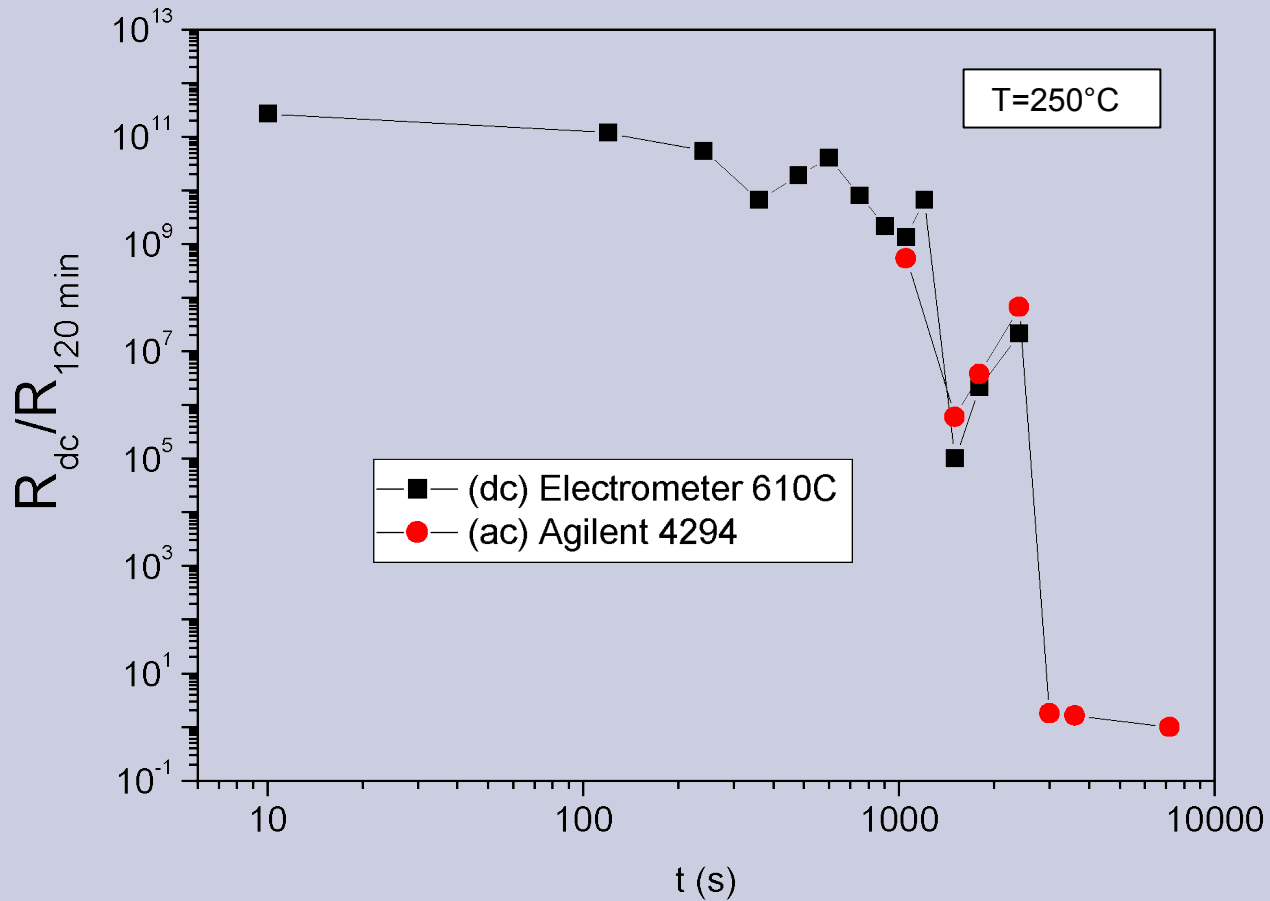




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Sintering Process

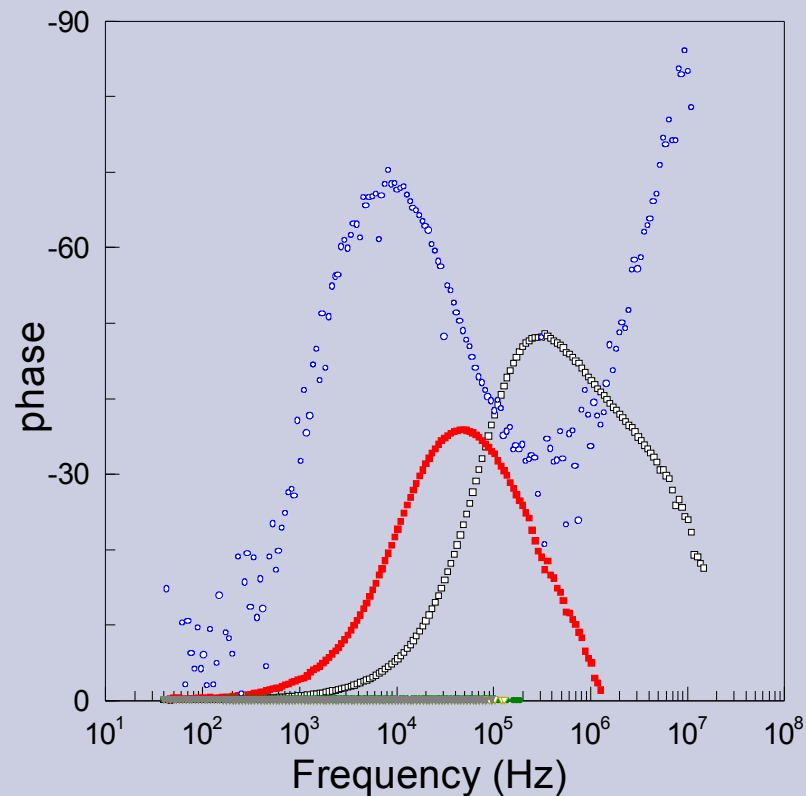
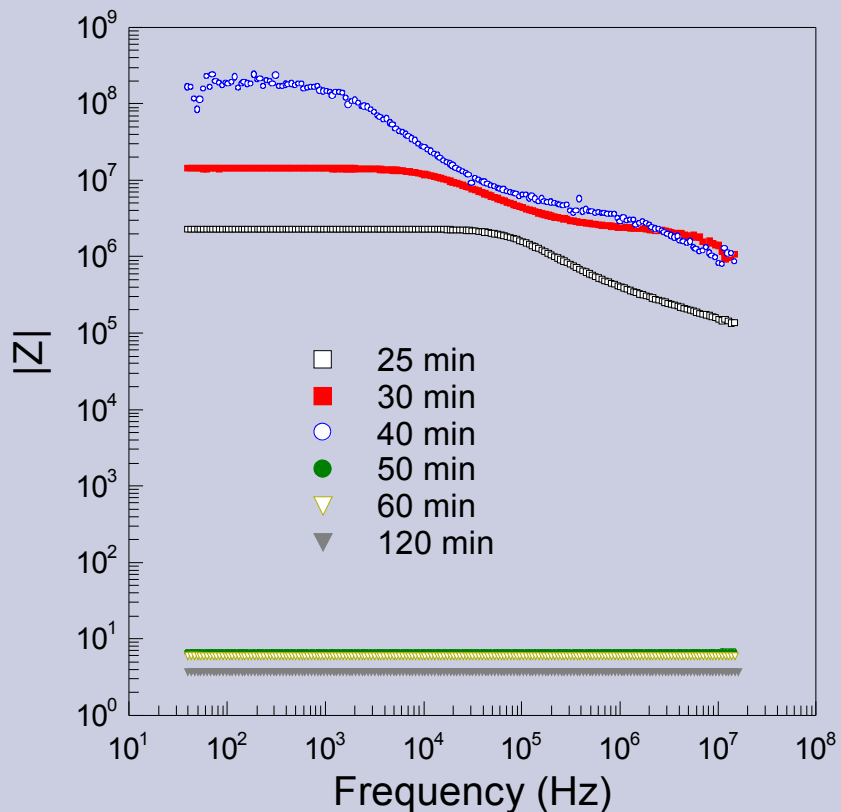




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Sintering Process



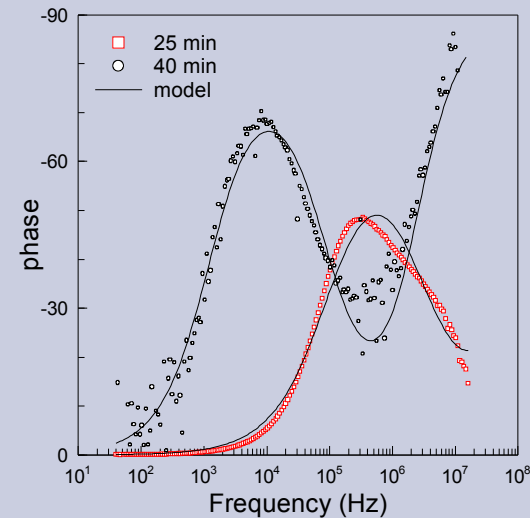
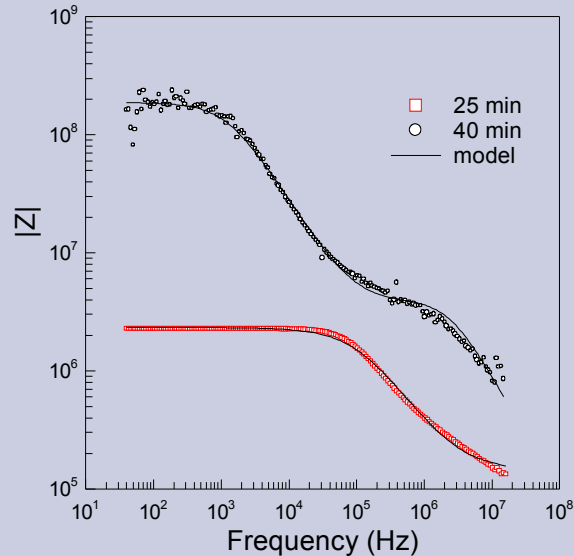
Impedance absolute value and phase of printed layer in different time of heating process at 250°C in the air atmosphere



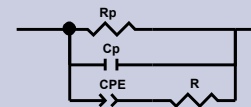
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Sintering Process



Impedance absolute value and phase of printed layer for 25 and 40 minutes of heating at 250°C 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

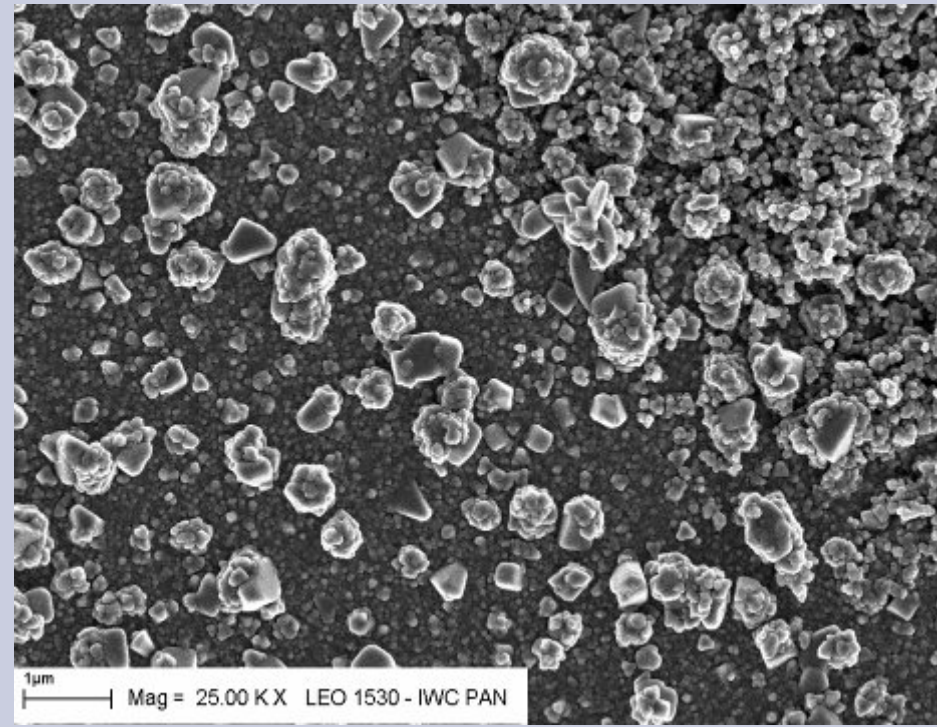
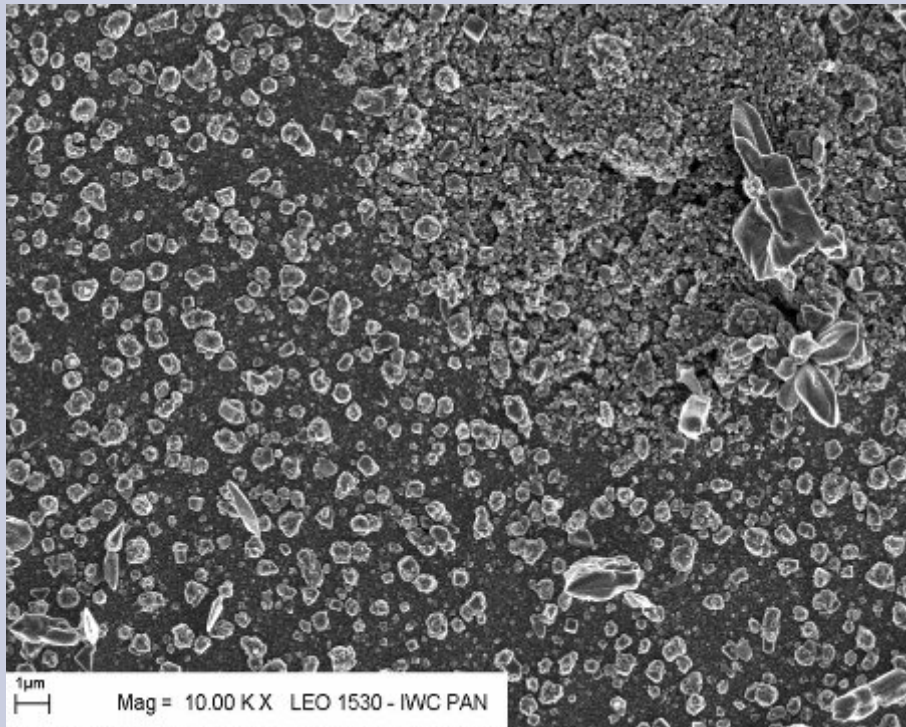
Chi-Squared: 0,070926
 Weighted Sum of Squares: 24,328
 Run Fitting / All Data Points (1 - 174)



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After sintering

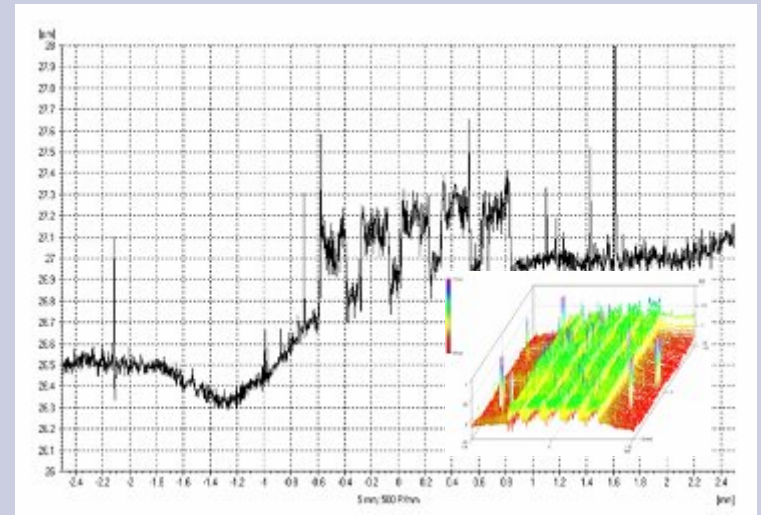
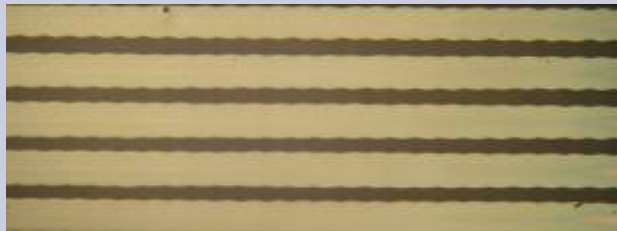
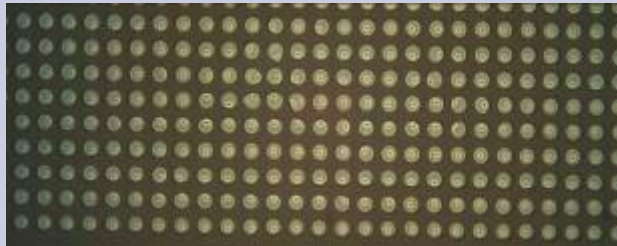




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Electrically Conductive Structures



Measured resistivity - no higher like $3 \cdot 10^{-5} \Omega\text{cm}$ (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.*

