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Influence of different type protective layer on silver metallic nanoparticles for Ink-Jet printing technique

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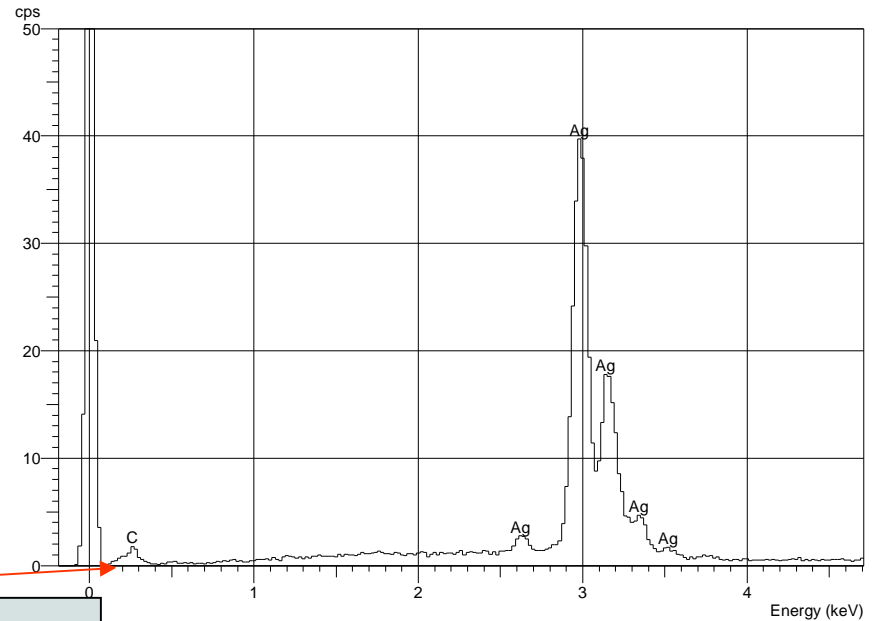
Role of Protection Layer

Protection layer around of nAg particles is builded on them during each type of reaction of producing nano Ag size stuctures.

Role of protection layer is to be the barrier against nAg particles agglomeration process and making stable colloids without sedimentation phenomena.

Protection layers have mostly nature with organic type of chemicals.

On EDX graph is typical picture of nAg analysis



Carbon peak from organic protection layer

Amepox R&D Works With Nanosilver Powder

For preparing nAg with particles less 10 nm, Amepox is working with thermal decomposition of silver type chemicals.



Raw material



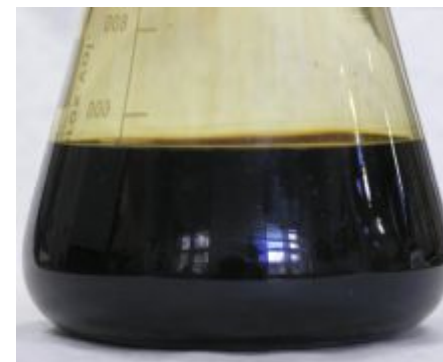
Reactor chamber



Nanosilver



Nanosilver after washing and drying process

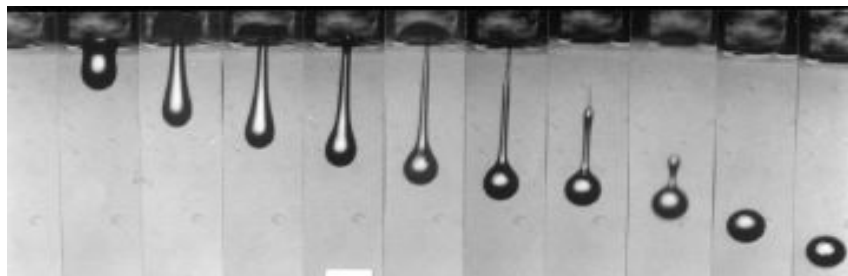


nAg suspension - INK

Ink Jet System – General Info

Nozzle diameter	10-100 μm
Droplet volume	10 – 500 picoliters
Drop speed	1,5-2,5 m/s
Drop rate*	2000/s
Max. Throughput	0.5 $\mu\text{l/s}$
Viscosity range	0,5 – 20 mPas (unheated) 20-10000 mPas (heated)

** depending on the liquid and capilar diameter*

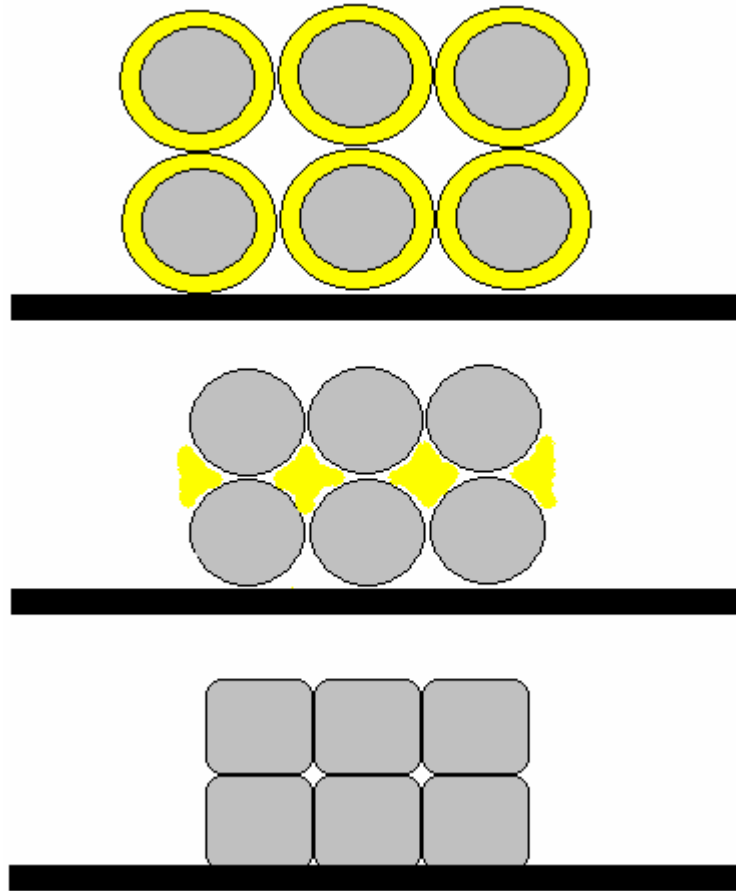


Slow Motion Shoot NanoInk by Ink Jet Dispenser



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Role of Protection Layer on nAg - Filler For EC Inks



Keeping up nAg fillers without sedimentation effect.



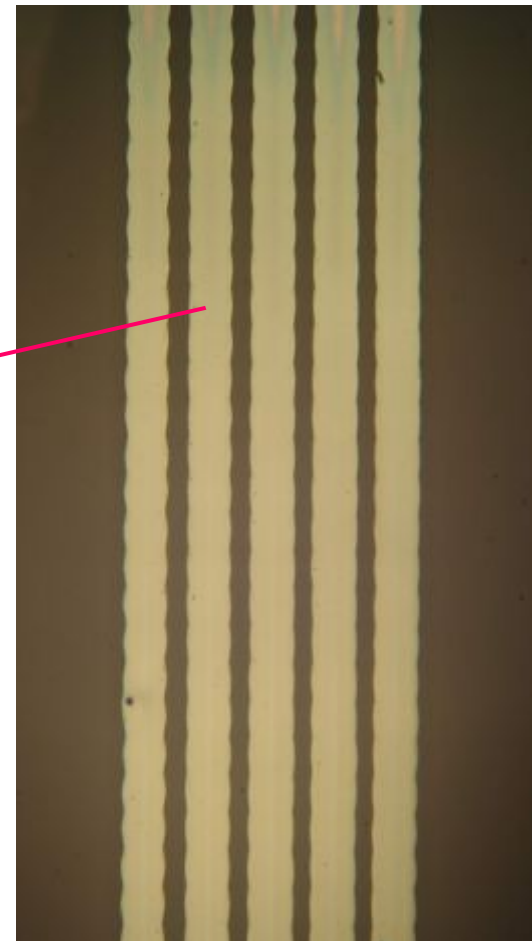
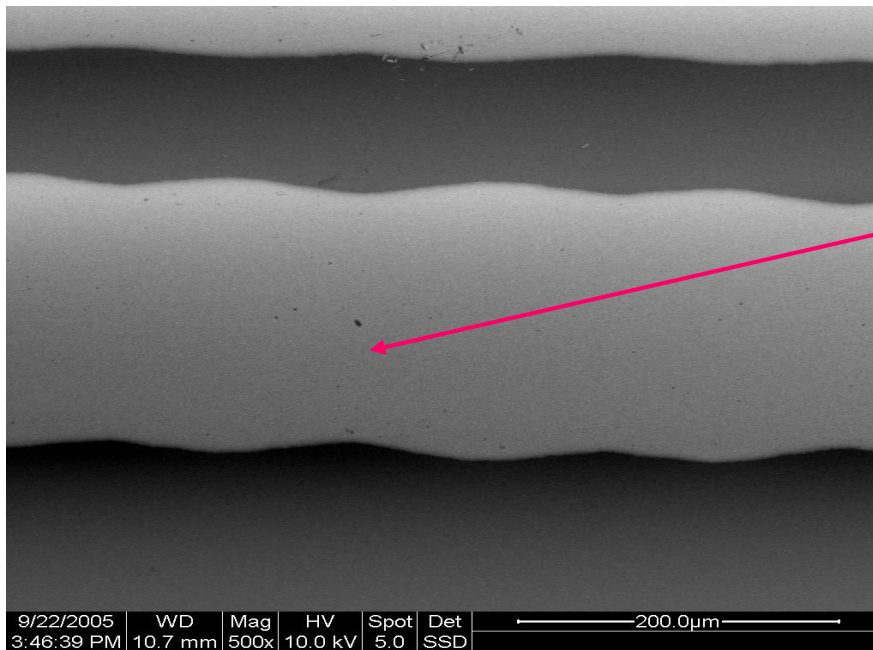
Heating process for removal protection layers



After removing protection layer nAg sintering process is possible

Application of EC Inks

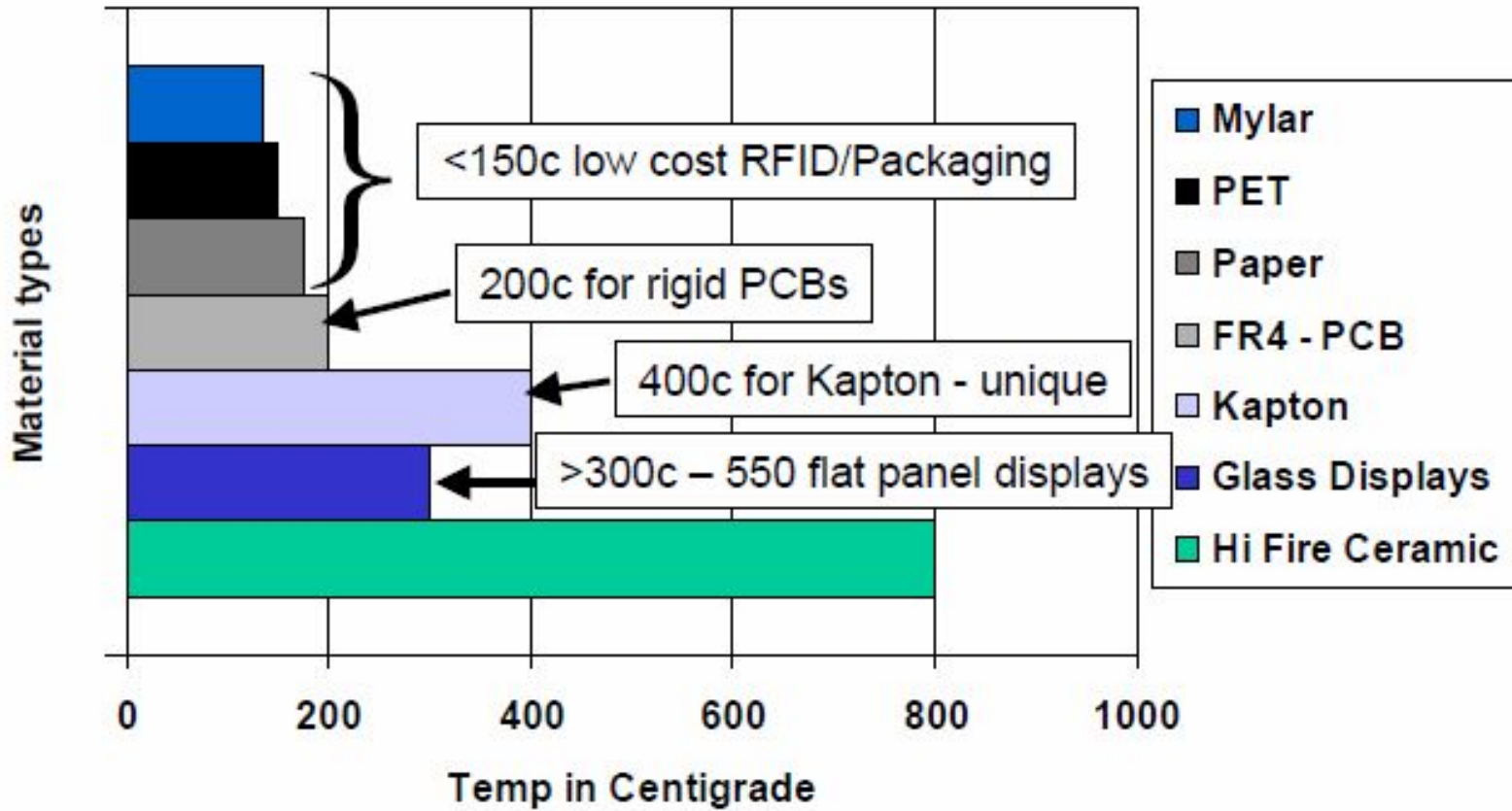
Electronic applications requirements are, that structures made with nAg powder fillers has to be highly electrical conductive with very stable conductive value after „curing” process – similar like bulk silver material.



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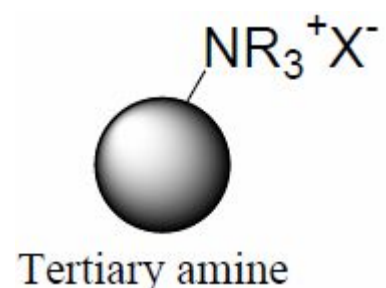
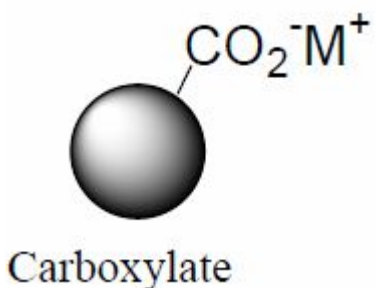
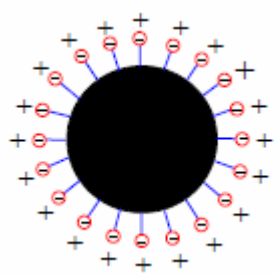
Application of EC Inks

Ink processing temperature for various substrates

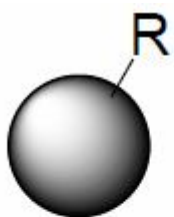
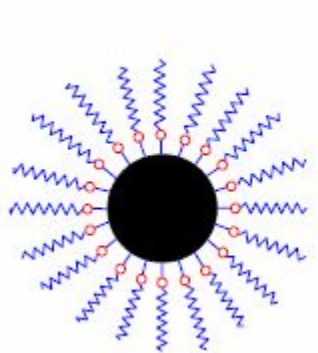


Protective coatings examples

Charged (*electrostatic*):



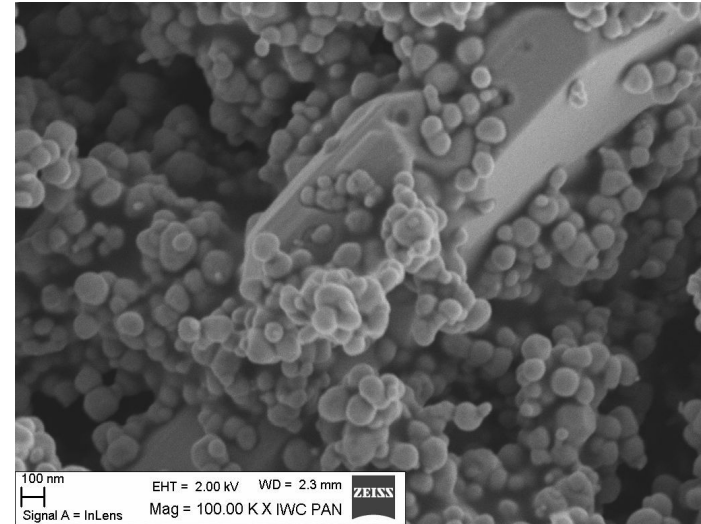
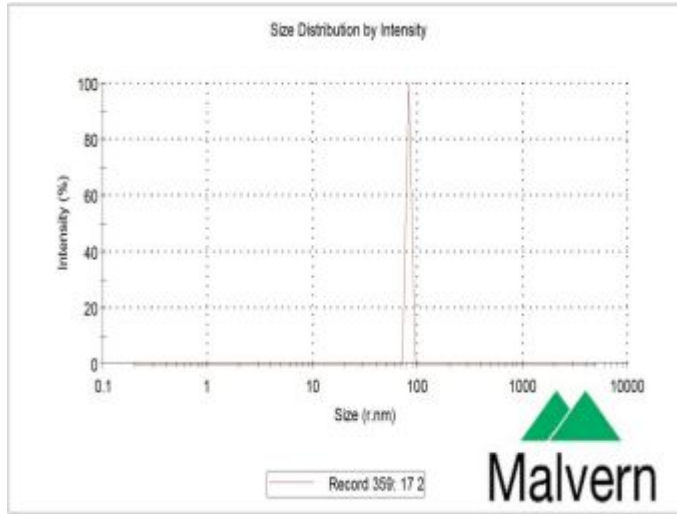
Polymer (*steric - chemical*):



R: acrylic, polystyrene, PEO, PPO, etc

Metallic NanoSilver as a Filler for Ink Preparation

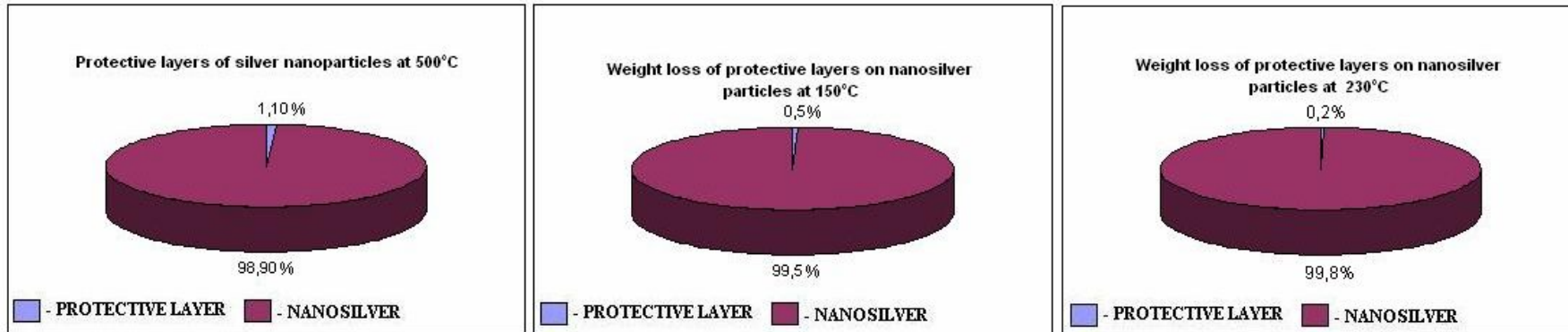
Nanosilver with carboxylate protective coating - Ag1 size 80-100nm (*electrostatic*)



Measurement of particle size „Malvern“ (Courtesy Polish Academy of Sciences)

SEM picture nAg particles (Courtesy Polish Academy of Sciences)

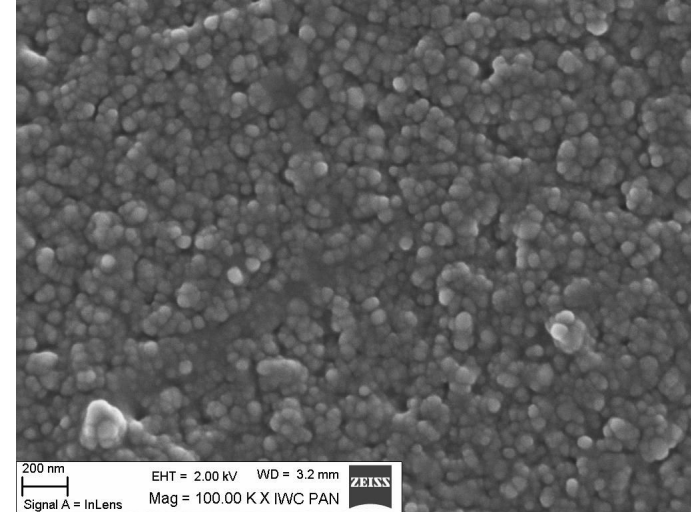
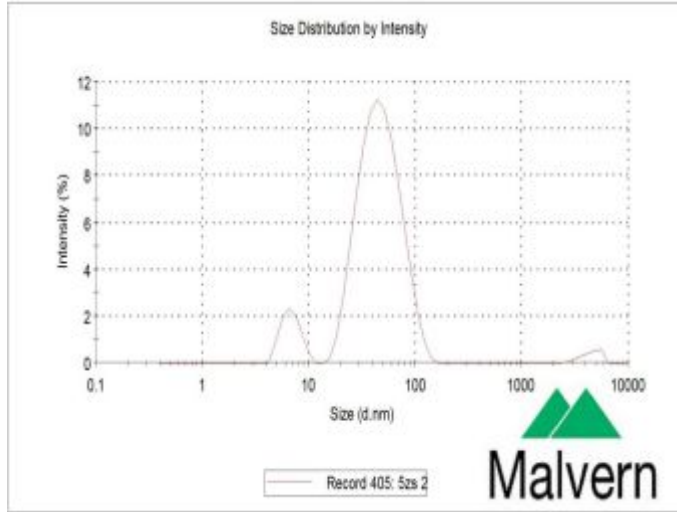
The dynamics of removing carboxylate coating at 150 °C and 230 °C as a function of time of Ag1



Purity analysis of Ag1: content of carboxylate coating - 1,1 %, removal of carboxylate coating at 230 °C & 1 hour - 0,8 %, removal of carboxylate coating at 150 °C & 1 hour - 0,6 %

Metallic NanoSilver as a Filler for Ink Preparation

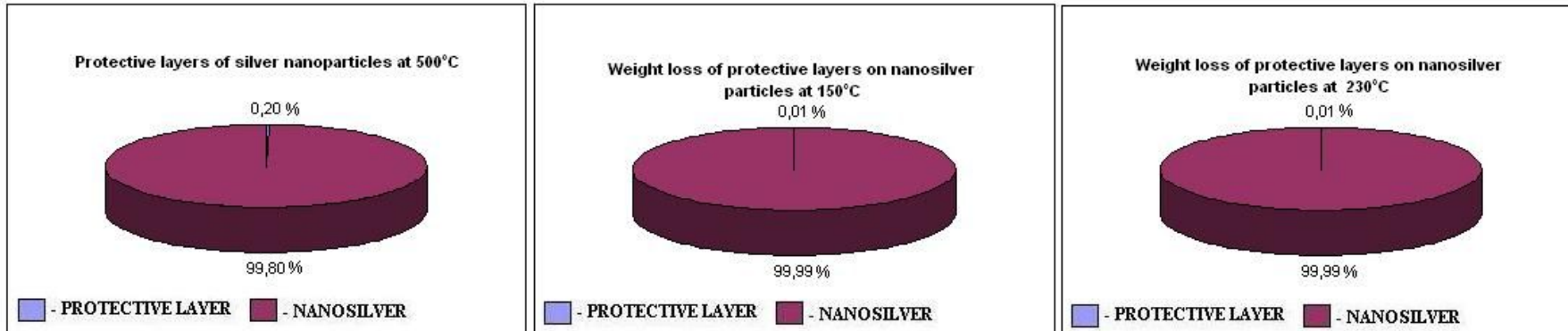
Nanosilver with amine protective coating – Ag₂ size ab. 50 nm (*electrostatic*)



Measurement of particle size „Malvern“ (Courtesy Polish Academy of Sciences)

SEM picture nAg particles (Courtesy Polish Academy of Sciences)

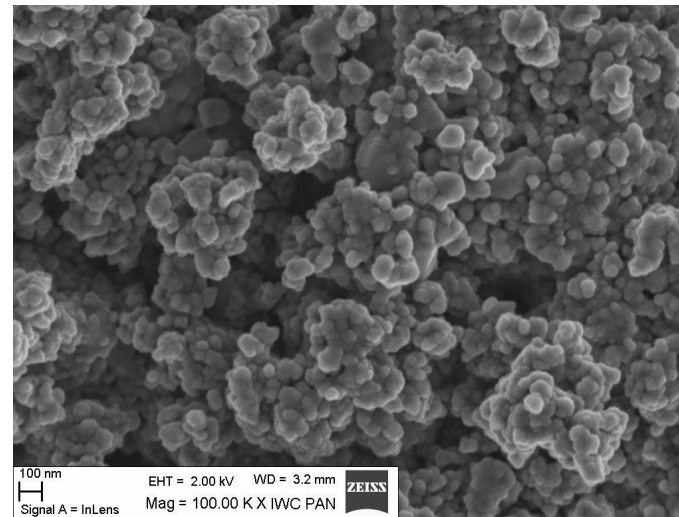
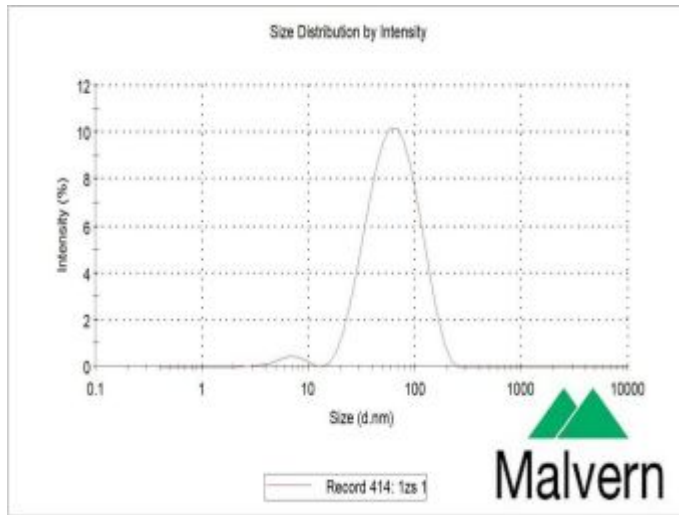
The dynamics of removing amine coating at 150 °C and 230 °C as a function of time of Ag₂



Purity analysis of Ag₂: content of amine coating – 0,2 %, removal of amine coating at 230 °C & 1 hour – 0,19 %, removal of amine coating at 150 °C & 1 hour – 0,19 %

Metallic NanoSilver as a Filler for Ink Preparation

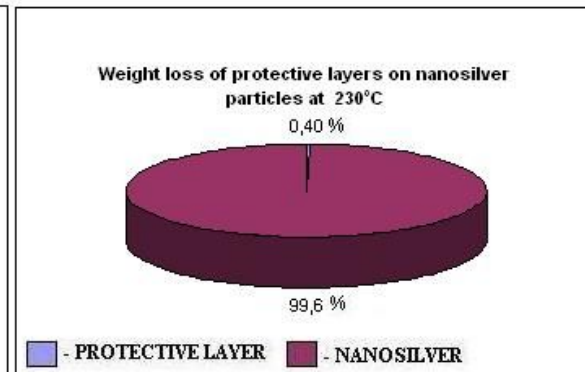
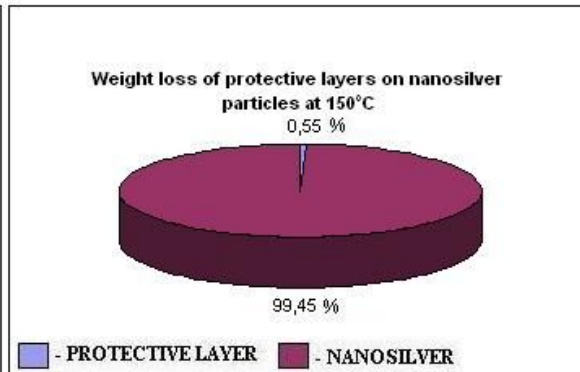
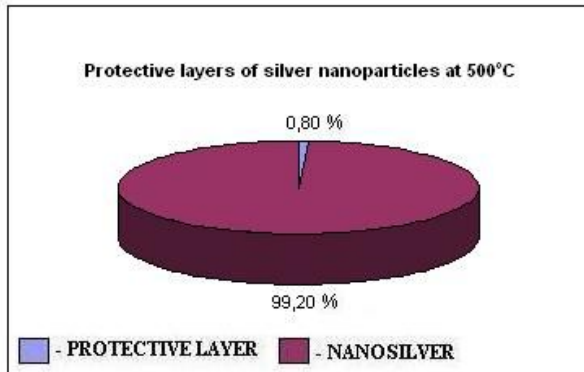
Nanosilver with polymer protective coating - Ag₃ size 50-70 nm (*chemical*)



Measurement of particle size „Malvern“ (Courtesy Polish Academy of Sciences)

SEM picture nAg particles (Courtesy Polish Academy of Sciences)

The dynamics of removing polymer coating at 150 °C and 230 °C as a function of time of Ag₃



Purity analysis of Ag₃: content of polymer coating - 0,8 %, removal of polymer coating at 230 °C & 1 hour - 0,4 %, removal of polymer coating at 150 °C & 1 hour - 0,25 %

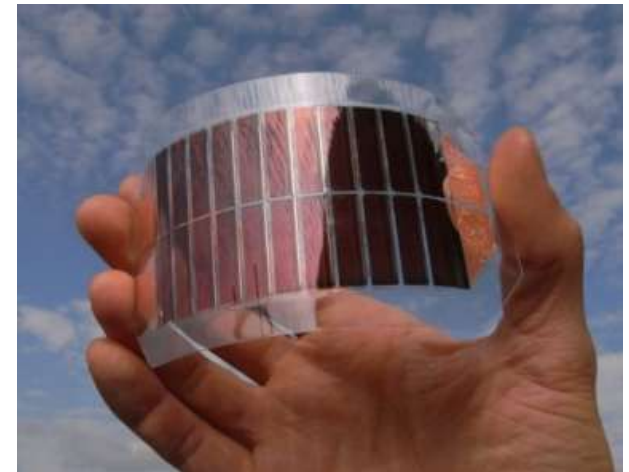
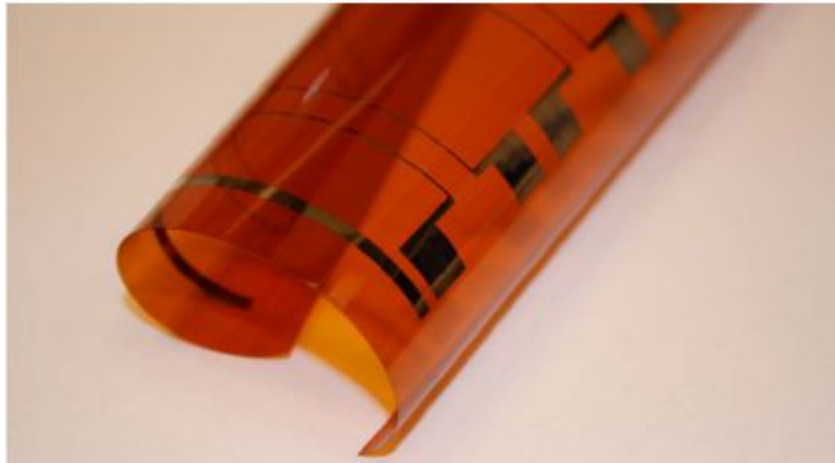
Summary:

- Example of three nanosilvers with different kinds of protective layers were presented.
- The particles diameter was in range 50 - 100 nm and each kind of studied nanosilver with carboxylate, amine and polymer protective materials were uniformly distribution.
- The maximum protection material volume for low temperature nanoink should be in the range of about 1.1 - 1.5% bw.
- Removing the protection layer is the key for obtaining good and stable conductive properties.
- Amepox R&D works is connected with developing new types of nano silver with different sizes and protective layers and their influence on electrically conductive ink properties.

Actual and future research

The low temperature ink base properties:

- Low sintering temperature - 120 - 150 °C
- Low viscosity - 2 - 15 mPas
- Sizes of silver - 30 - 60 nm
- Content of silver - up to 20 %
- Very good printability on flexible and and low temp. substrates.



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Thank you for your attention.



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