Application of Inkjet Printing

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Outline

- Characterization of Ink Properties
- Ink Development
  - ❑ Constantan
  - ❑ Nickel
  - ❑ Particle-free Silver
  - ❑ Particle-free Copper

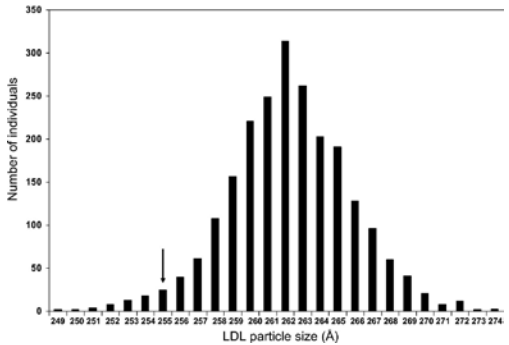
Ink Characterization Properties

Average Particle Size and Distribution

Measure the the range of the size of particles in the ink and the average size of the particles

Example: Novacentrix silver ink's average particle size is 80 um and ranges between 60 and 90 um.

Dynamic Light Scattering system

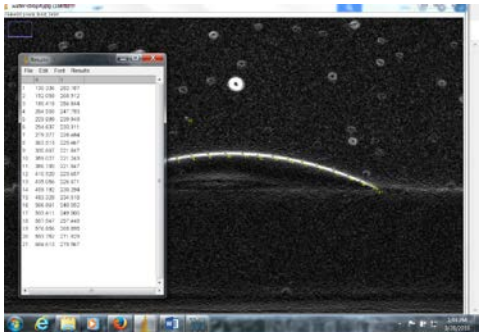


Contact Angle

Measure the contact angle between a droplet of ink and a substrate

Mostly focusing on Kapton as a substrate, because it's used most frequently

Horizontal microscope to image droplet from the side. ImageJ and Matlab to analyze image and find contact angle.



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Ink Characterization Properties

Density

Find the mass of a known volume of ink, divide mass by volume.

Effects of Filtering on Solid Loading

Use Dynamic Light Scattering system to find difference in particle size range between unfiltered and filtered ink

0.90 micron Whatman filter

Viscosity

Measured using a viscometer

Surface Tension

Measured using surface tensiometer

Platinum ring method

Thermogravimetric Analysis

Provides information on physical and chemical phenomena, such as, vaporization, sublimation, chemisorptions, and desolvation

Shelf-Life

Amount of time before the ink, in it's original bottle, is still usable for printing

Record the day the bottle was opened, and print periodically to tests inks viability

Ink Characterization Properties

Pot Life

Amount of time the ink is usable when left in an ink cartridge

Record date that ink is filled into cartridge, test viability of ink every day by printing

Visual Inspection of Ink

Use an optical/near-infrared spectrometer in the 400-1000 nm range to measure the reflectance spectrum of the ink before, while, and after being cured.

Zeta Potential

Use Zetasizer to measure zeta potential of inks

Layering/Stacking ability

Test the adhesion between multiple layers of the same inks or two layers of different inks on top of each other

Using adhesion test (Scotch tape test)

Resolution

Print the 1951 USAF resolution test chart (or similar resolution testing pattern) to determine if the ink meets the standards required to test nearly any possible pattern with acceptable accuracy.

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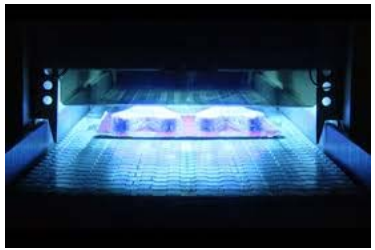
Ink Characterization Properties

Curing Time

A printed test pattern will be cured for, and at specific intervals of time, the resistance of the ink will be measured, until it reaches a point where the change in resistance is insignificant.

The amount of time it takes to reach this point will be the curing time

Testing using thermal and UV curing



Electrical Properties

Measure resistance of ink

Multimeter for basic testing

Wheatstone bridge for more accurate results

Material Compatibility

Connect wire to printed pattern using different adhesives. Test for a completed circuit

Epoxy, glue, tape, etc

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Ink Characterization Properties

Adhesion to substrate (Scotch tape test)

Apply scotch tape to a cured printed pattern and then remove tape.

If no or a small ink is removed, Passed.

If a large amount of ink is removed, Failed

Oxidation and Environmental Resistance

Place in humidity chamber for an amount of time. Test resistance.

Ink development

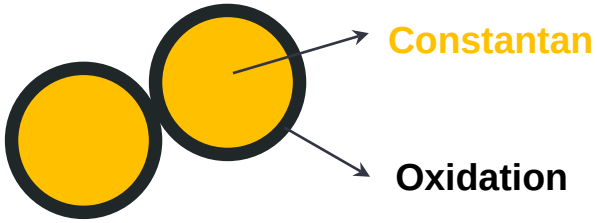
Particle ink

- Constantan ink
- Nickel ink

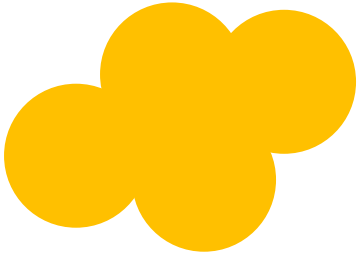
Particle-free ink

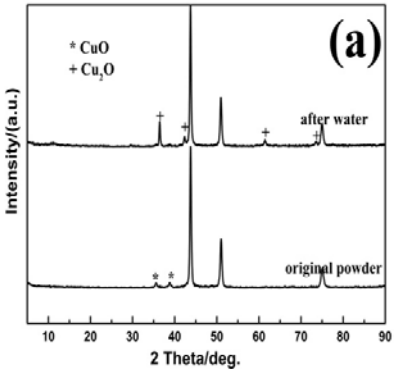
- Silver ink
- Copper ink (in process)

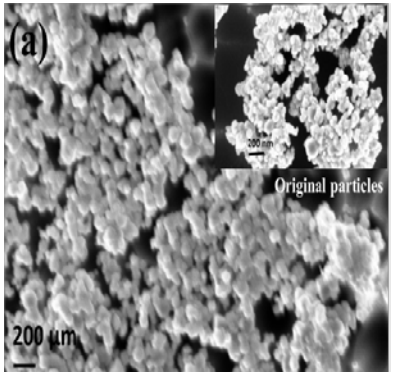
Constantan ink-formula

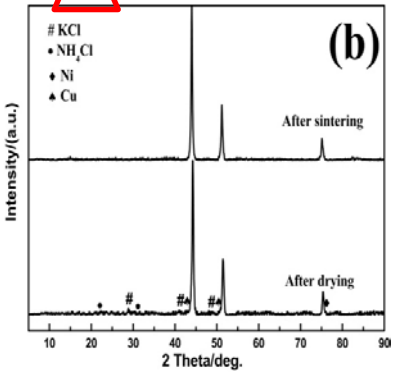


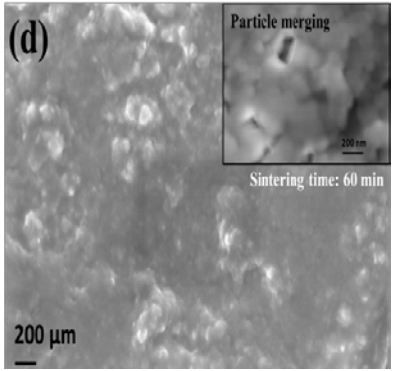
Chemical method











Oxidation has low electronical and thermal conductivity which makes it impossible to sinter constantan at low temperature

After chemical method, constantan particles have been sintered

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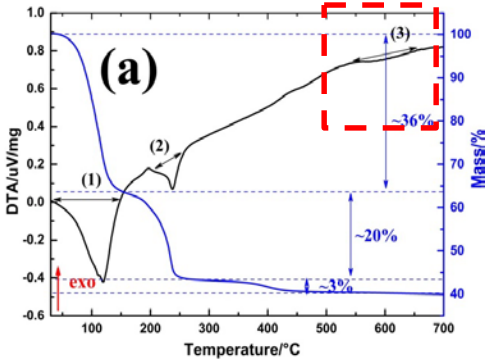
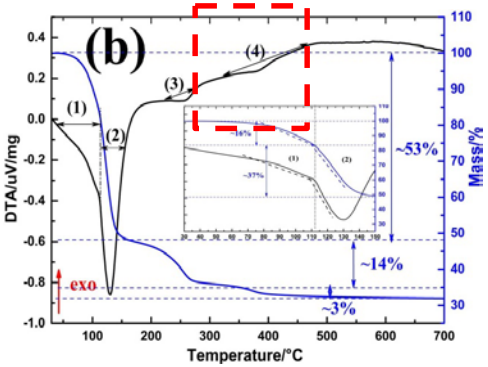
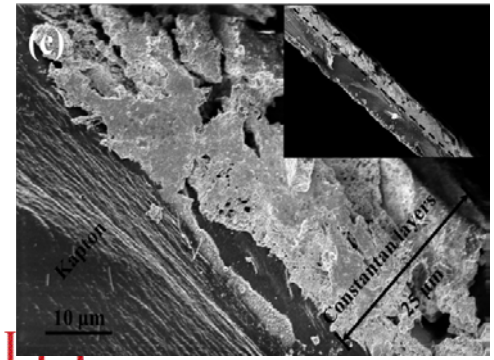
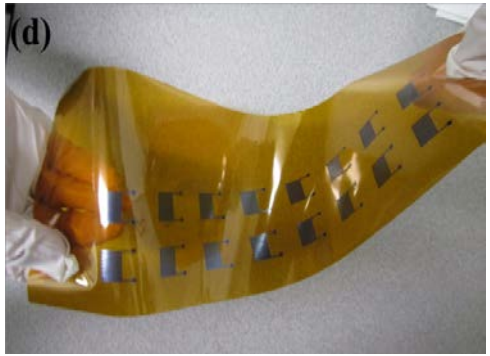
Constantan ink-properties and applications

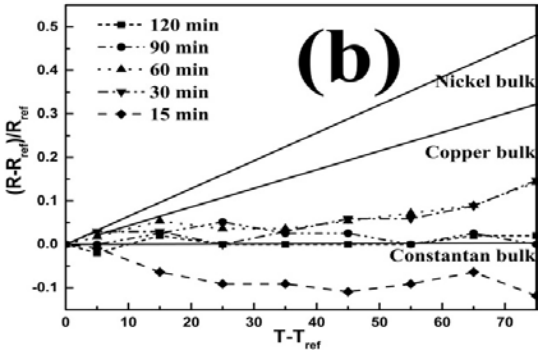




The sintering temperature drops fro m 600℃ to below 400 ℃ which is possible for the use of polymer as the substrate







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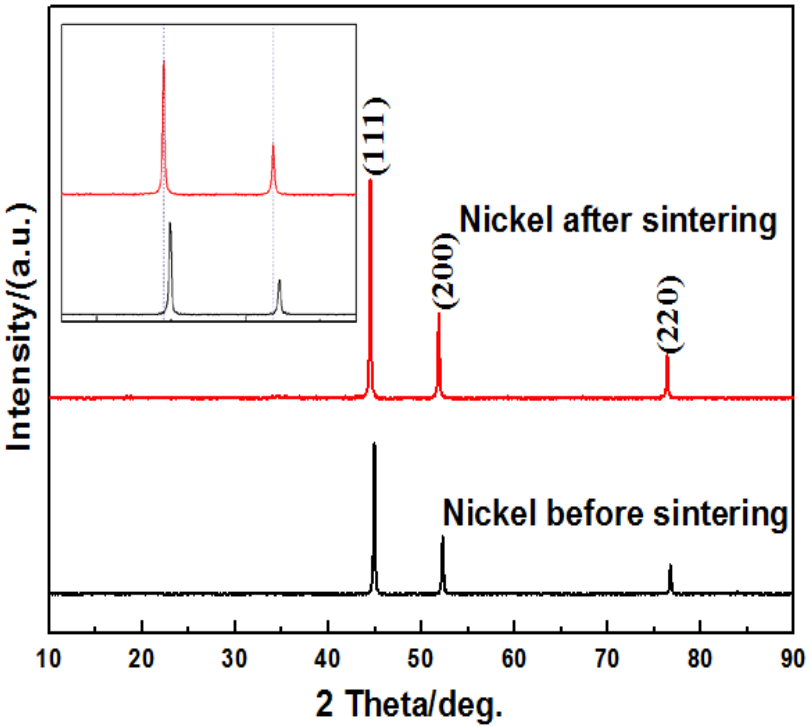
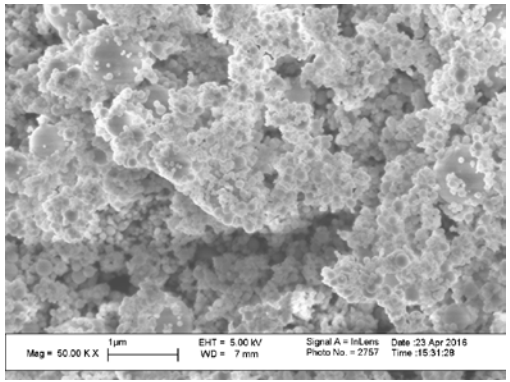
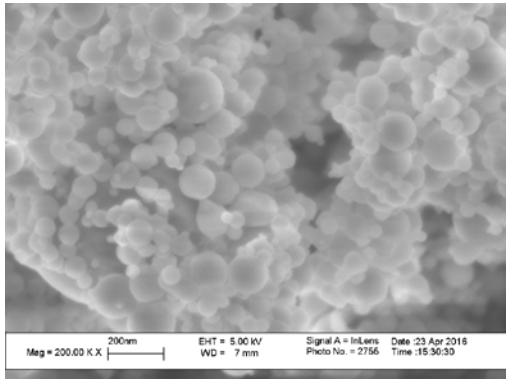
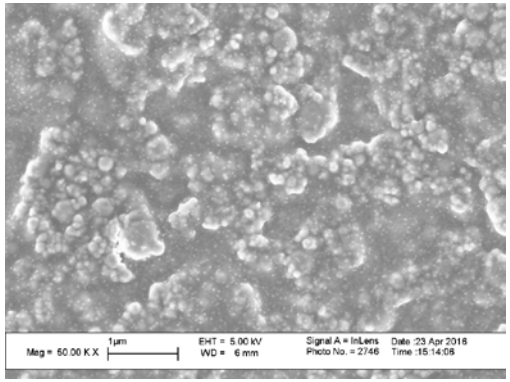
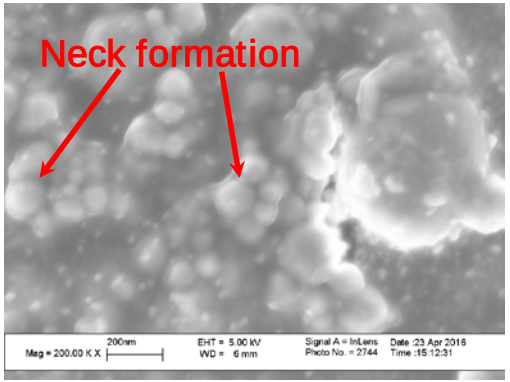
Nickel ink-formula







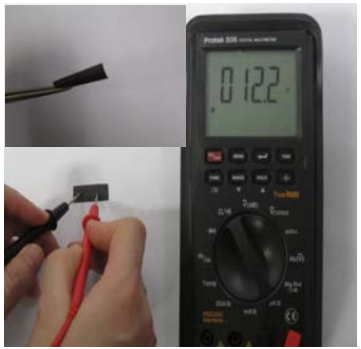


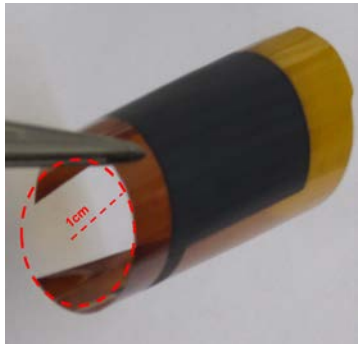


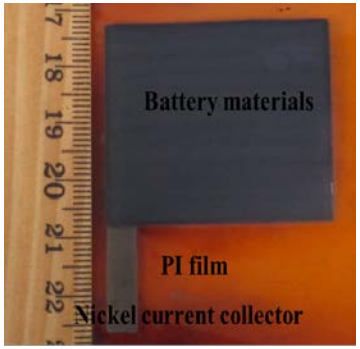
Nickel ink-properties and applications

1 Nickel can be used in the printed batteries as current collectors due to its high electrochemical stability.

- Aluminum: very hard to print due to its high chemical reactive
- Copper: can only be used in low voltage
- Silver: can only be used in low voltage
- Gold: too expensive
- Carbon: Suffer great contact resistance
- Nickel: Very stable at high voltage (lower than 4V) with acceptable resistance







2. Nickel also acts as a barrier against oxidation, which could greatly help in the production of printable circuit boards (PCBs).

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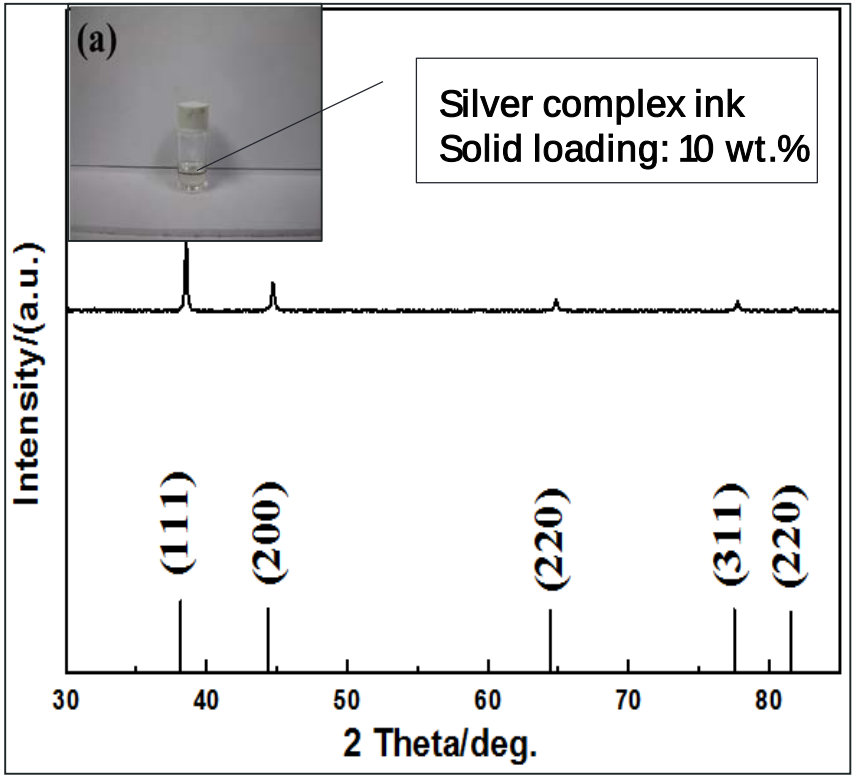
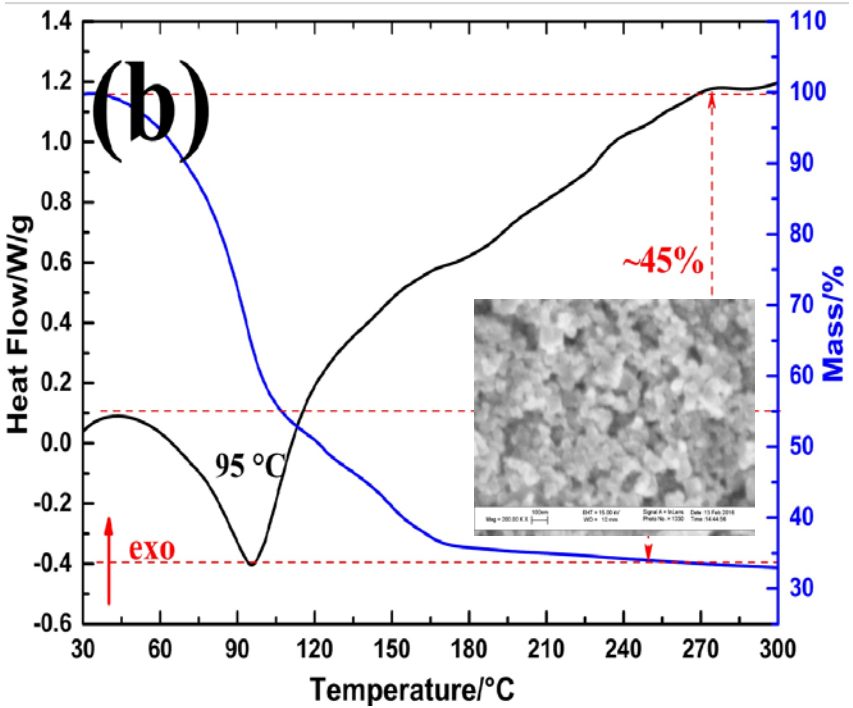
Silver ink (particle-free)-formula





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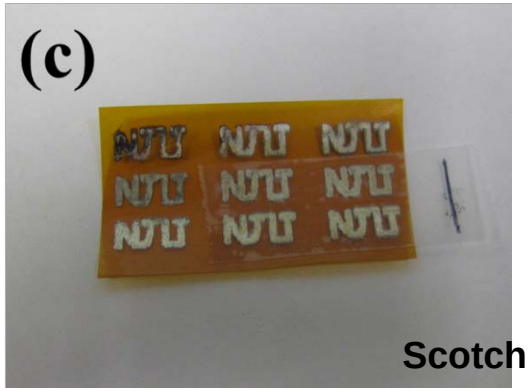
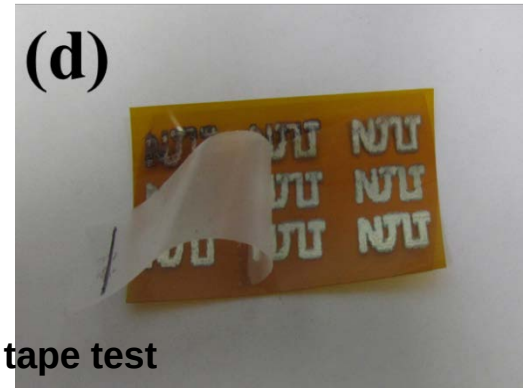
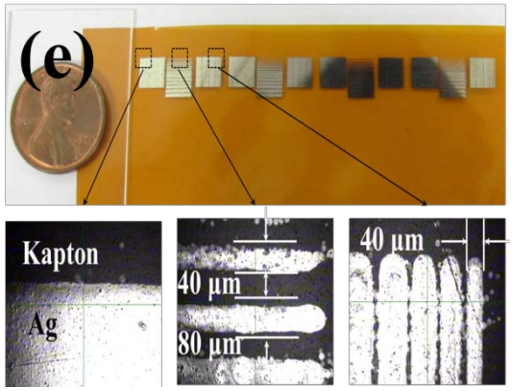
Silver ink (particle-free)-properties and applications



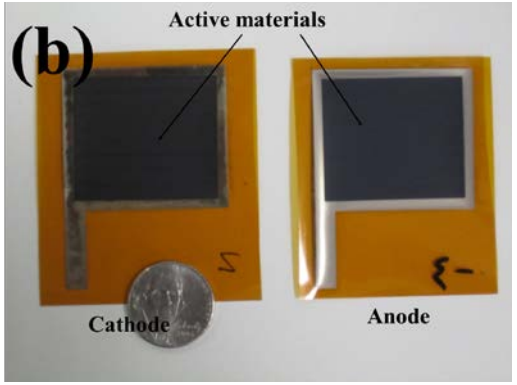


Scotch tape test



Circuit board

Electrodes



Silver current can only be used in oxygen reduction reaction batteries. It cannot be used in lithium ion batteries due to the reaction with the electrolyte at high operation potential.

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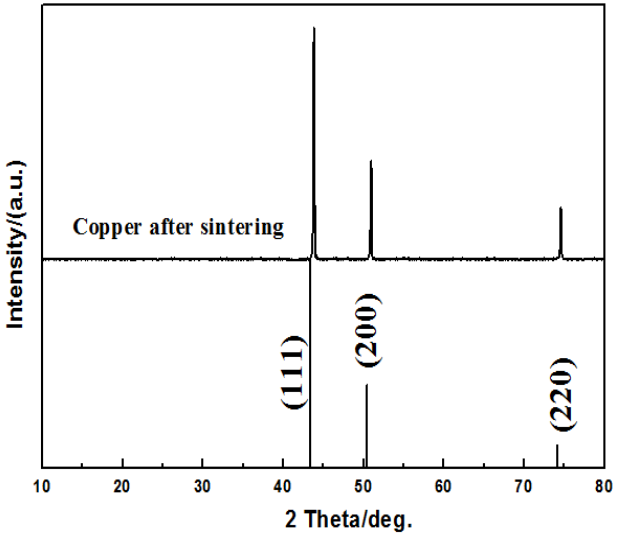
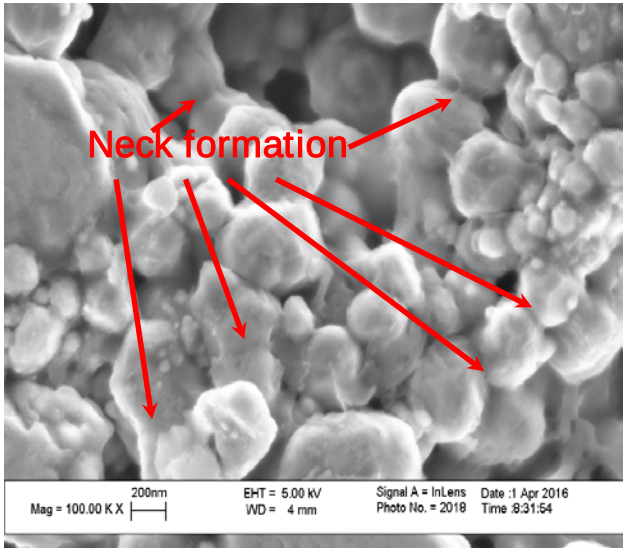
Copper ink-in process

We able to fabricate copper particle free ink, the problem is the cracks during the sintering

Solid loading: 13.7 wt.%



Copper after sintering



Copper after sintering

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Summary

- Use standardized tests to classify ink’s physical properties as well as properties before and after printing
- Developed and demonstrated inkjettable Constantan and Nickel ink for low temperature processing on plastic substrates
- Developed and demonstrated particle-free metallic inks