

Inkjet printed oxide electrode films for solid oxide fuel cell fabrication – part I: ink development

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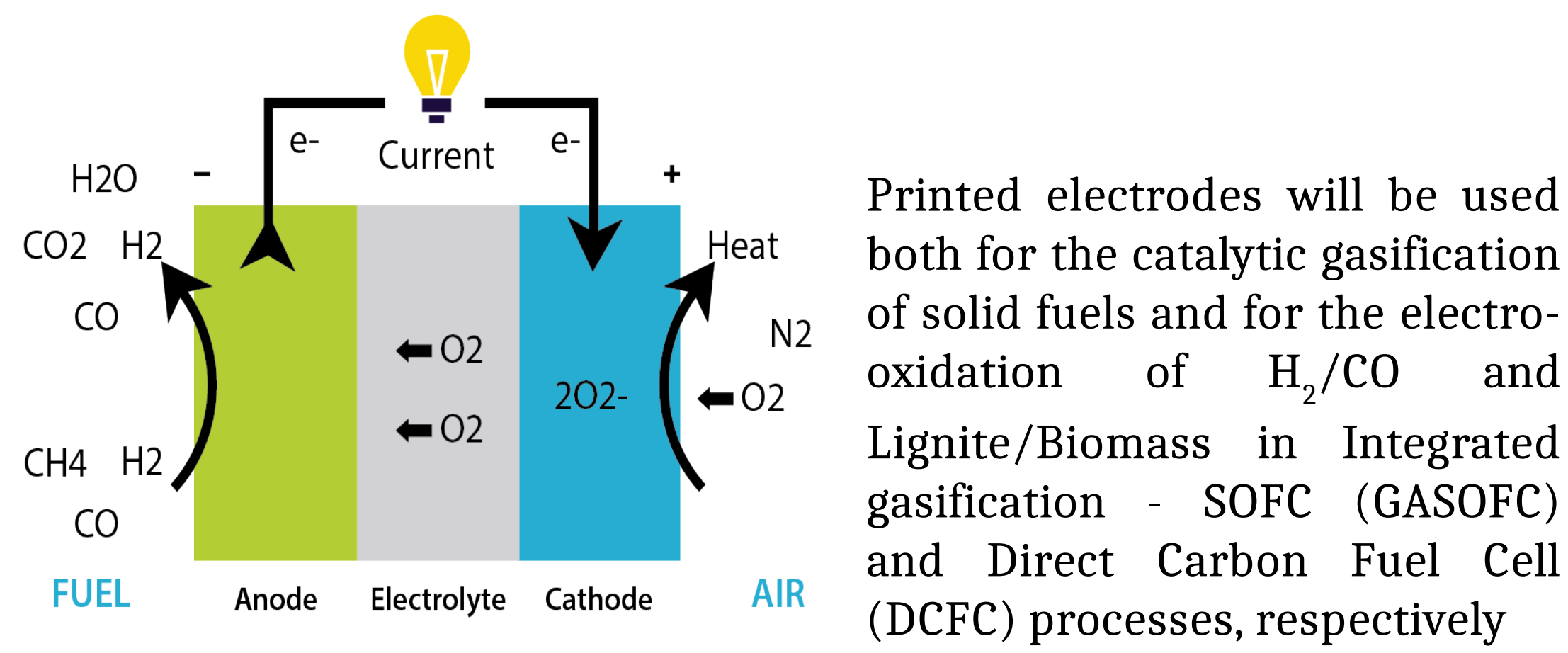
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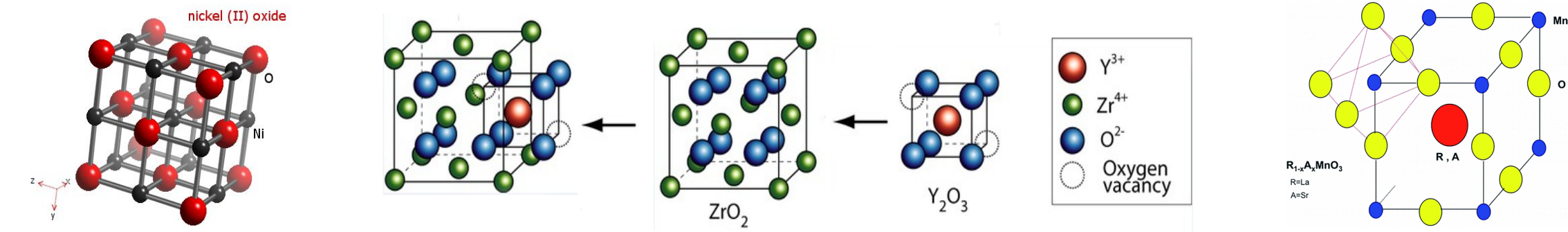
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Solid Oxide Fuel Cells

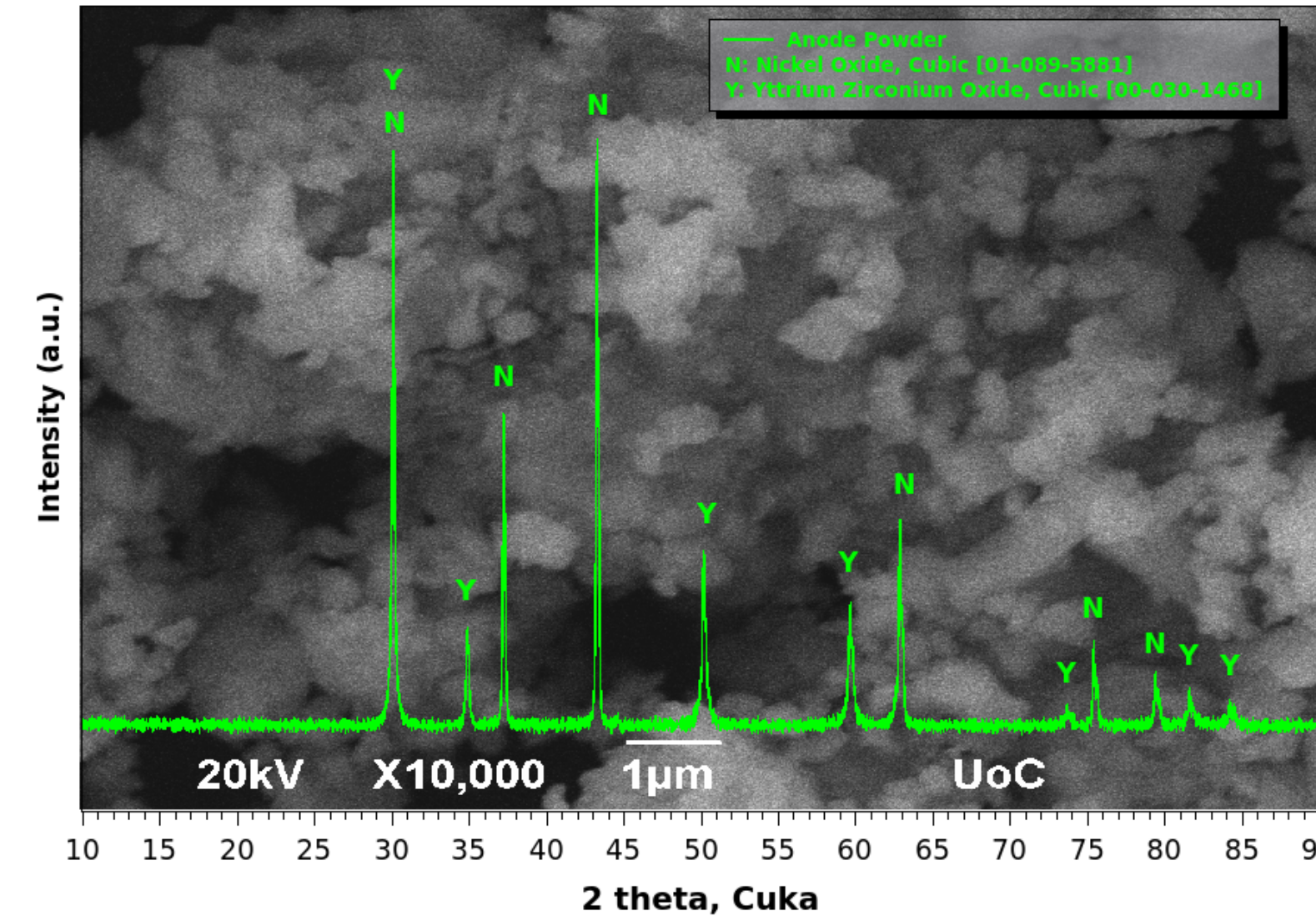


Printed electrodes will be used both for the catalytic gasification of solid fuels and for the electro-oxidation of H_2/CO and Lignite/Biomass in Integrated gasification - SOFC (GASOFC) and Direct Carbon Fuel Cell (DCFC) processes, respectively

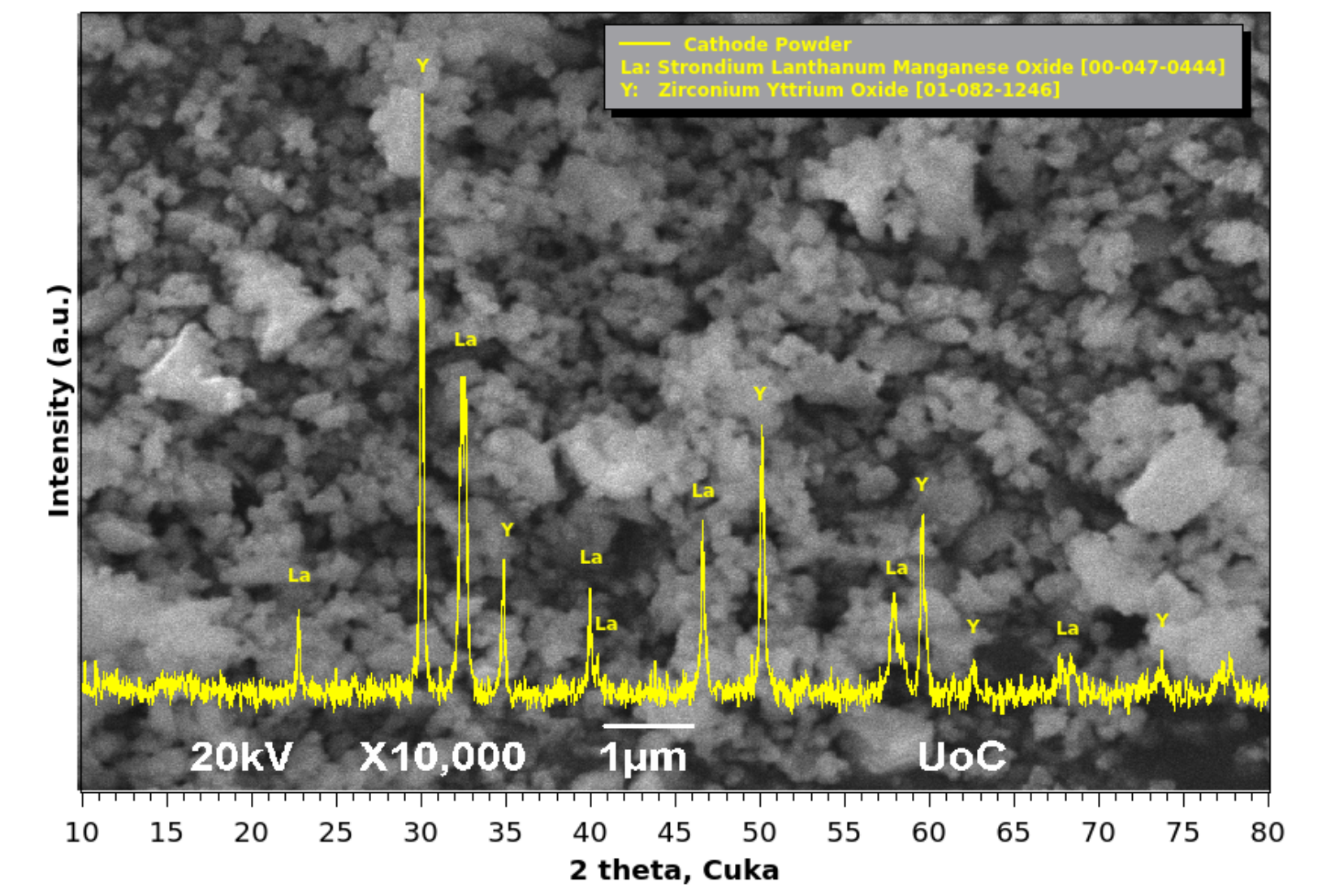


Electrode powders properties

Anode material: NiO/YSZ
As obtained

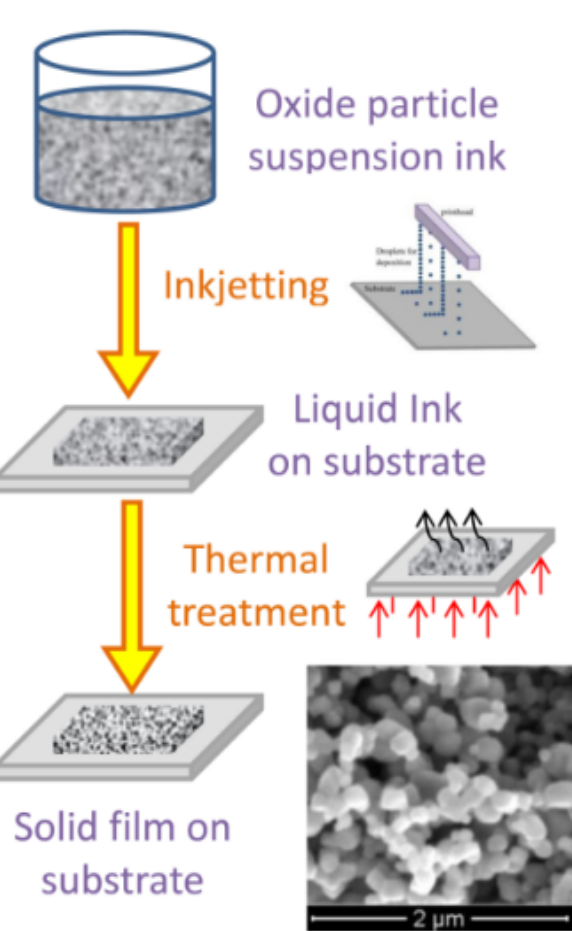


Cathode material: LSM/YSZ
Ball milled at 700rpm for 30 min



Ink development of inkjet inks

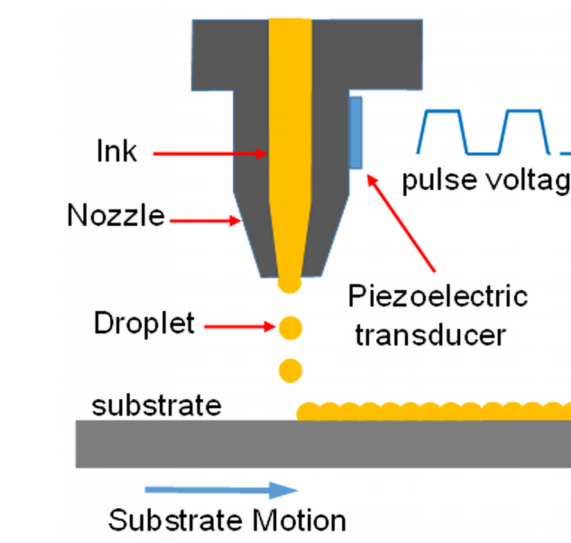
Water-based Inks Composition				
Ink code	H ₂ O	Ethanol	powder loading	Polyvinylpyrrolidone
WI-1	80 vol%	20 vol%	1 wt%	10 wt%
WI-2	80 vol%	20 vol%	3 wt%	10 wt%
WI-3	80 vol%	20 vol%	1 wt%	30 wt%
WI-4	80 vol%	20 vol%	3 wt%	30 wt%
PG-based Inks Composition				
Ink code	Propylene Glycol	Butanol	powder loading	Triethanolamine
NI-4	80 vol%	20 vol%	5 wt%	1 vol%
NI-5	80 vol%	20 vol%	5 wt%	2 vol%
NI-6	70 vol%	30 vol%	5 wt%	1 vol%
NI-7	70 vol%	30 vol%	5 wt%	2 vol%



Water-based Inks Composition				
Ink code	H ₂ O	Ethanol	powder loading	Polyvinylpyrrolidone
WI-2	80 vol%	20 vol%	3 wt%	10 wt%
WI-7	80 vol%	20 vol%	5 wt%	10 wt%
WI-5	70 vol%	30 vol%	3 wt%	10 wt%
WI-8	70 vol%	30 vol%	5 wt%	10 wt%
PG-based Inks Composition				
Ink code	Propylene Glycol	Butanol	powder loading	Triethanolamine
NI-4	80 vol%	20 vol%	5 wt%	1 vol%
NI-5	80 vol%	20 vol%	5 wt%	2 vol%
NI-6	70 vol%	30 vol%	5 wt%	1 vol%
NI-7	70 vol%	30 vol%	5 wt%	2 vol%

Inkjet Printing Deposition

Inkjet printing deposition is a mask-less and automated approach on thin film fabrication, based on the drop generation of the developed active material ink.

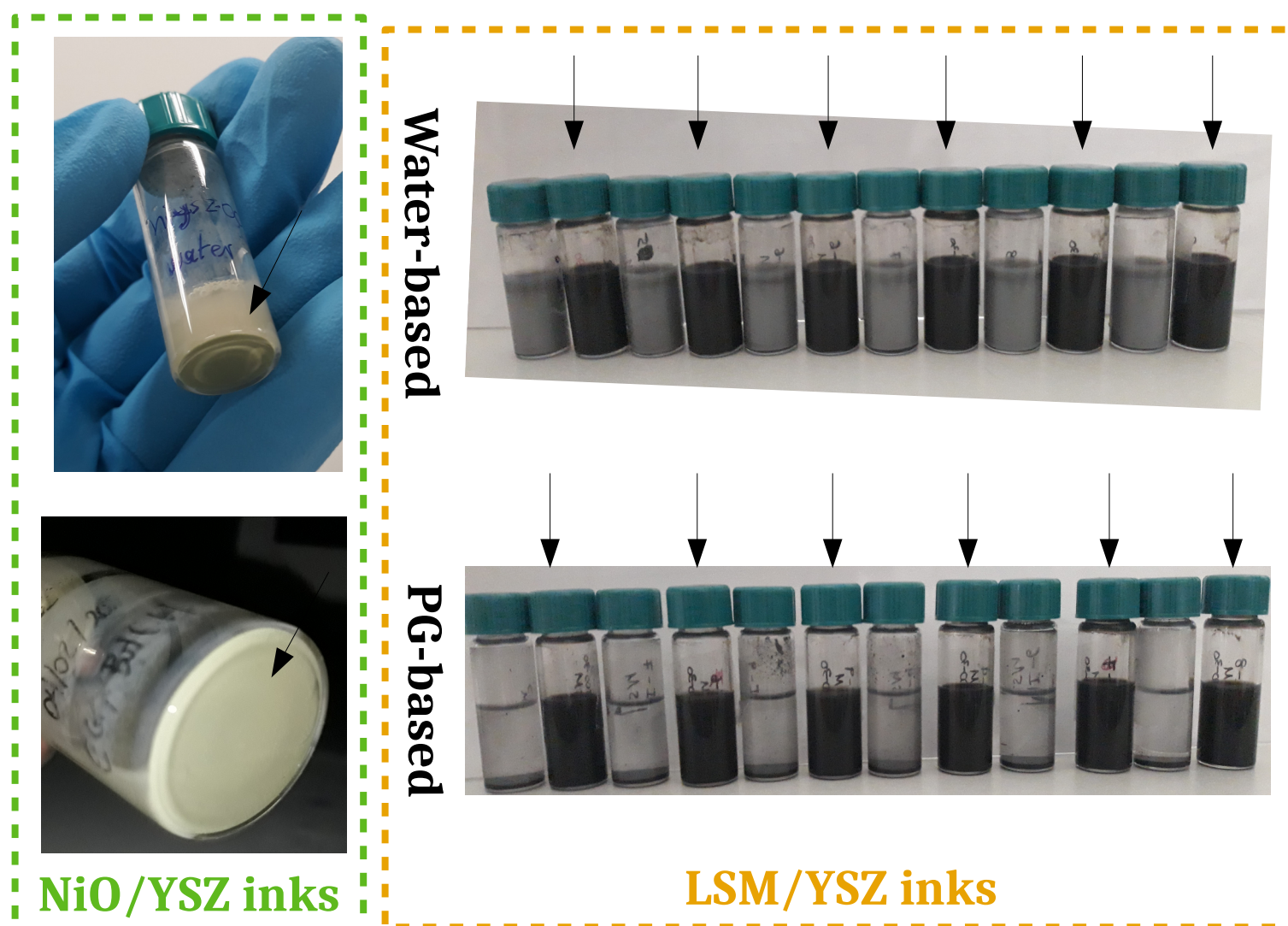


Recommended inkjet ink properties:

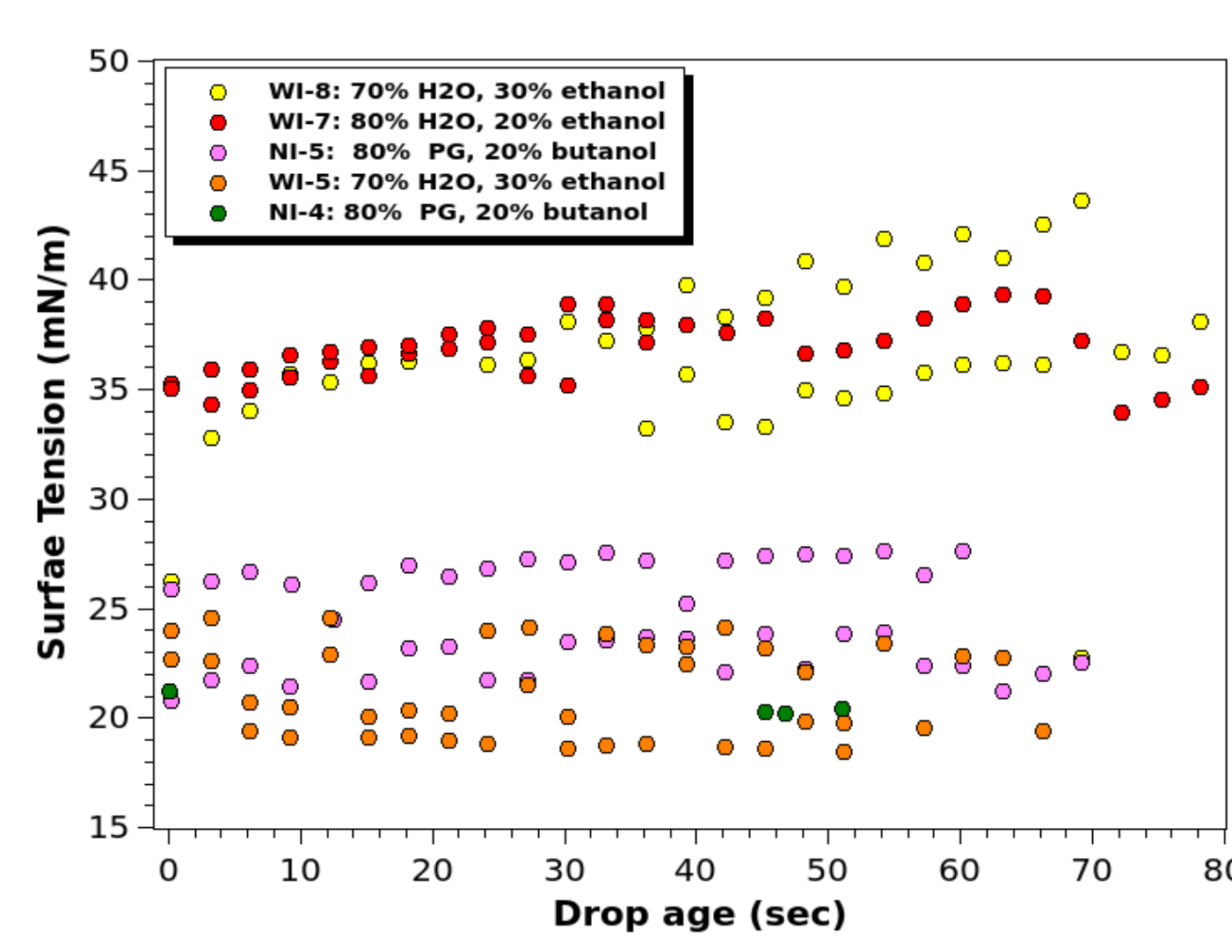
Particles diameter	less than 400 nm
Viscosity	about 12 mPa·s
Surface Tension	28 – 33 mN/m
pH	4 – 9

Particle dispersion properties

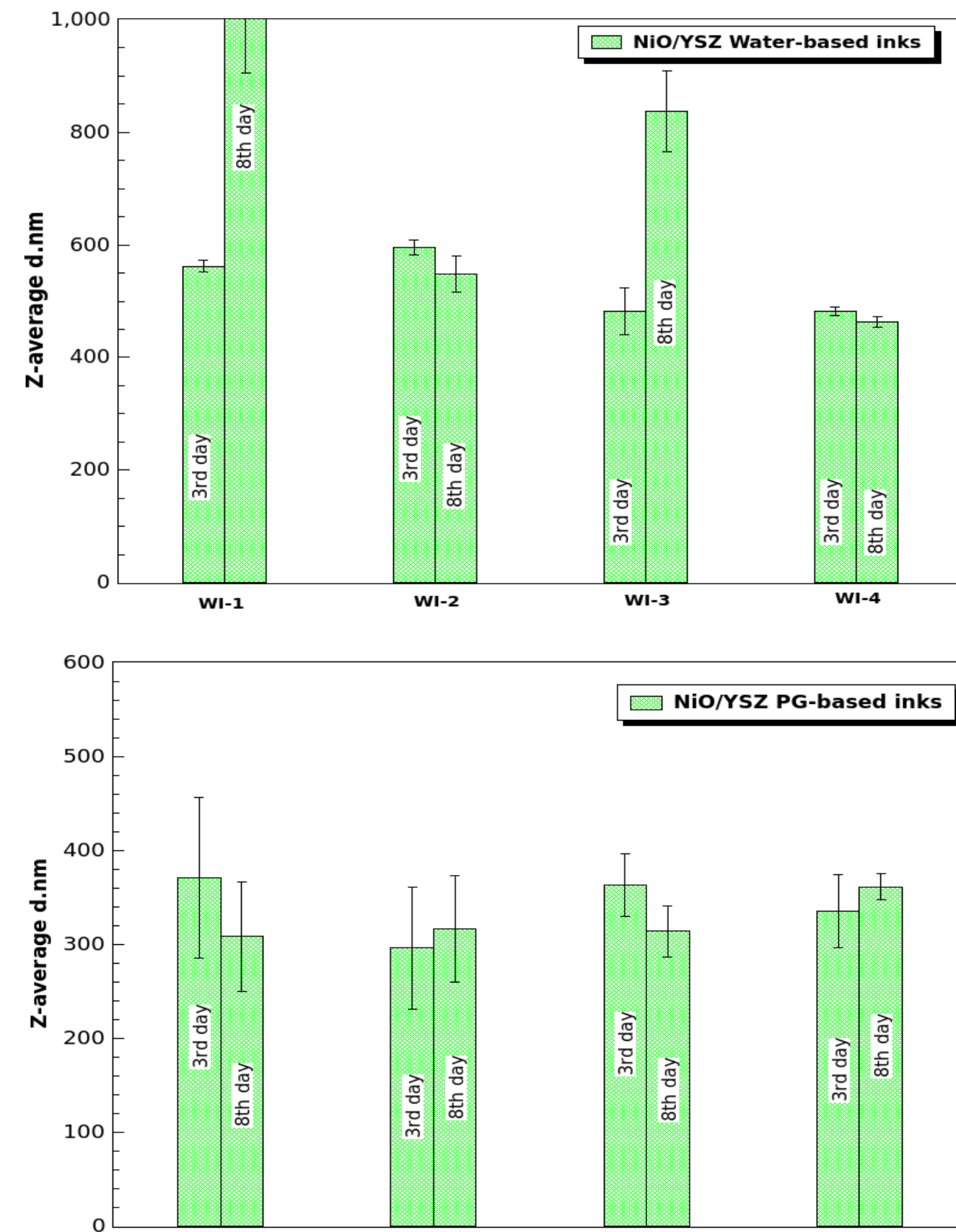
The effect of powder ball-milling



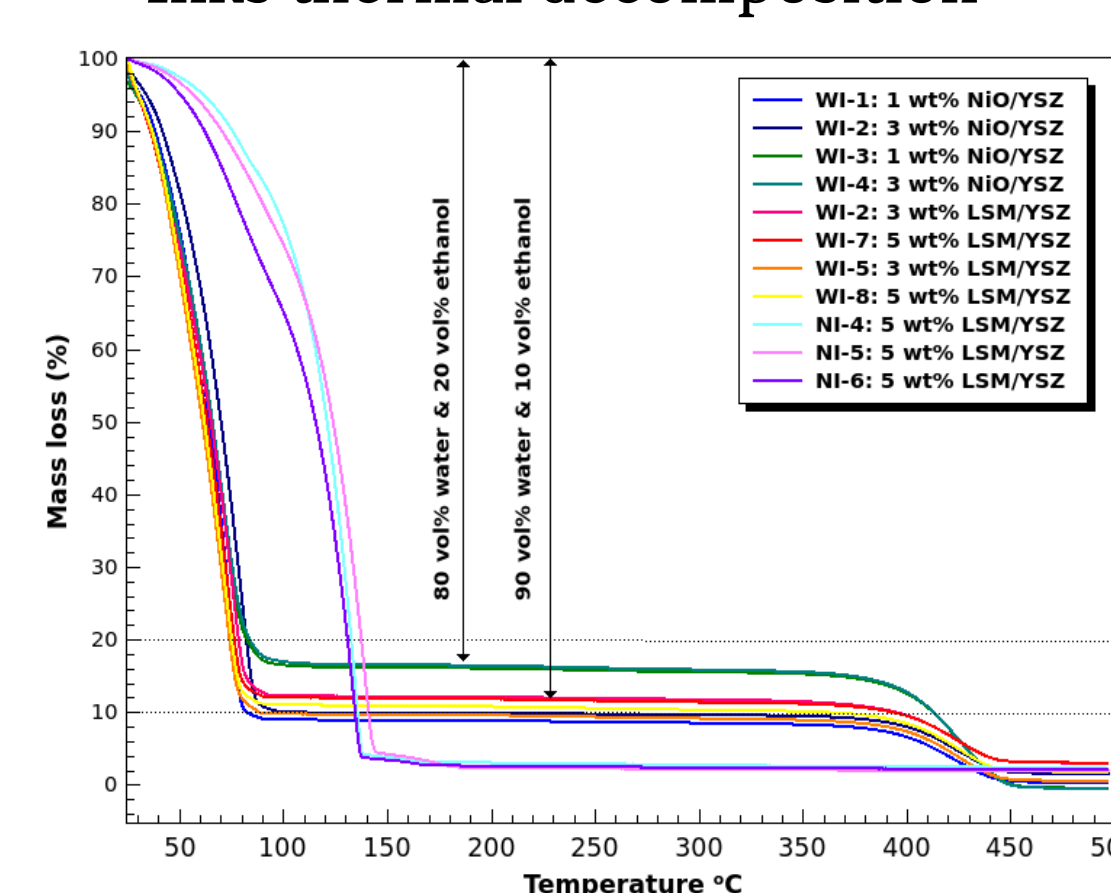
Inks surface tension over time



Particle size over storage



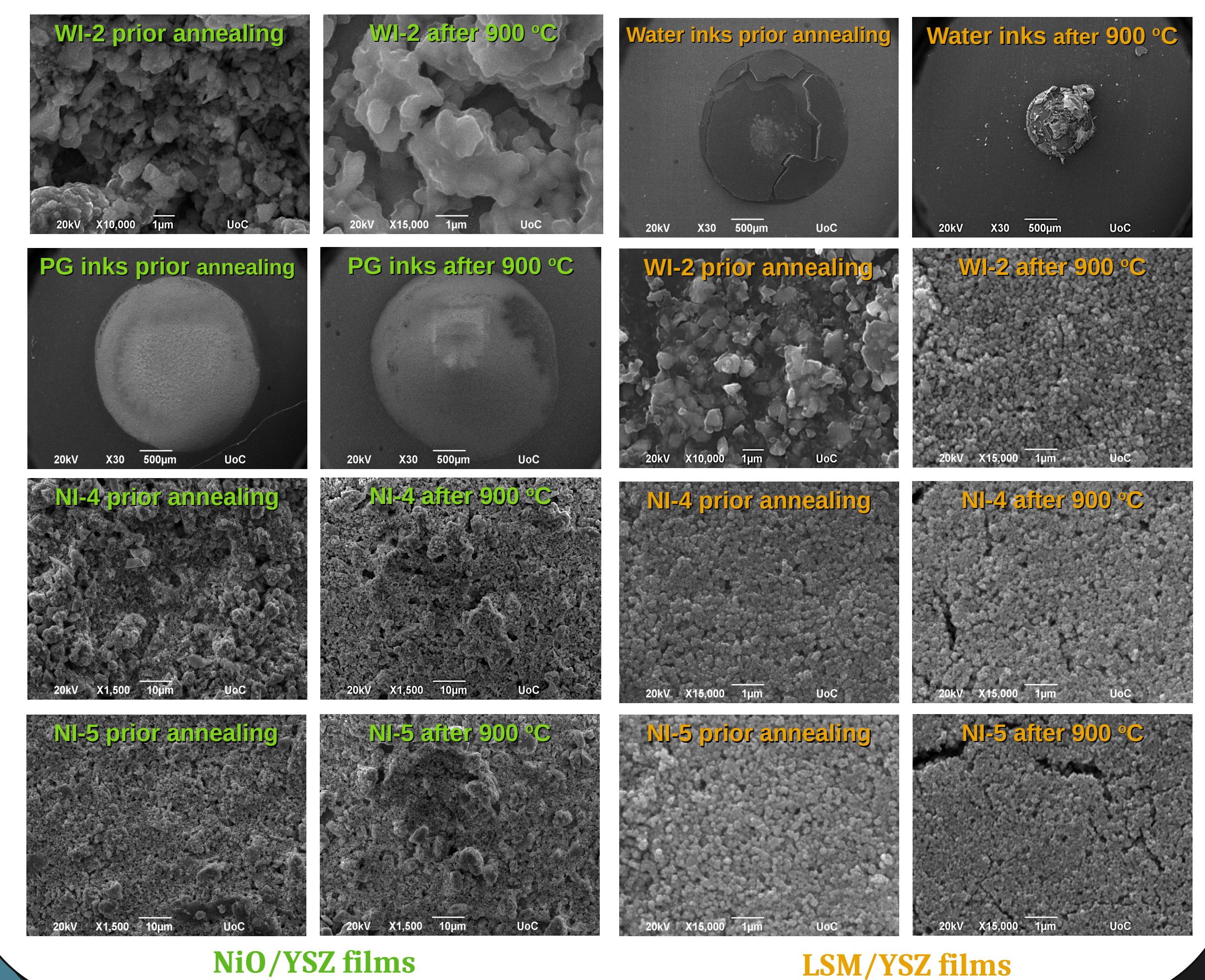
Inks thermal decomposition



Optimal inks properties

Ink code	NI-4 LSM/YSZ	NI-5 LSM/YSZ	WI-4 NiO/YSZ
Viscosity (30 °C)	16.694	18.48	23.288
Surface Tension (mN/m)	21 to 20	28 to 20	-
Density (g/cm ³)	1.0426	1.0384	1.0354
Particles d. (nm)	< 200	< 200	< 500

Deposited thin films morphology



Conclusions

- Progress on the ink development of anode and cathode materials for inkjet printing deposition of SOFC
- A novel series of inks were tested on normal storage conditions, with the inks with ball-milled powders exhibiting week-long dispersion stability
- Optimization of composition for the LSM/YSZ ball-milled ink, with adequate characteristics for use in inkjet printing
- Water-based inks of both materials are much less stable than the PG-based
- Annealing of the water-based films, leads to massive cracking and destruction of films
- Annealing of the PG-based films, leads to denser films with sintered nanoparticle interfaces, formation of small cracks on the layer, and alteration of the film porosity

References

- (1) Mater. Res. Soc. Symp. Proc., 2013, 1547, 13–20
- (2) WebElements, <https://www.webelements.com>, accessed May 2019
- (3) University of Cambridge –<http://www.doitpoms.ac.uk/tlplib/fuel-cells/printall.php>
- (4) RSC Adv., 2015, 5, 60254–60263