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Ink Characterization and Gravure/Flexographic Printing Quality Analysis

THE UNIVERSITY OF NEW MEXICO

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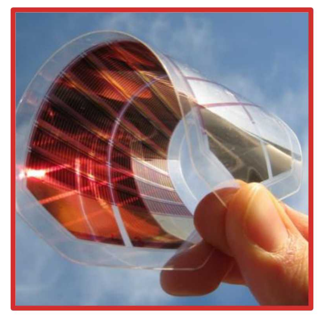
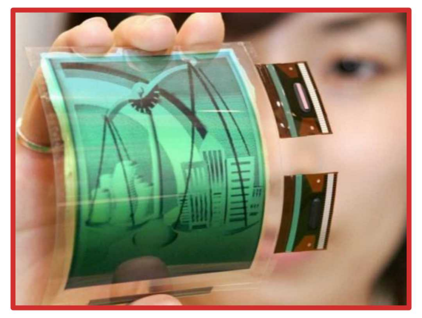
Printing Flexible Electronics

- Gravure and flexographic printing are high-throughput, precision processes drawing renewed interest for the production of low-cost, large-area, flexible electronics systems. They are compatible with a wide range of materials, including colloidal inks and low-molecular weight polymers and capable of sub-5μm features at speeds greater than 1m/s. Like most coating and printing methods, defects manifest in the form of particle aggregation, pin holes, ribbing, etc. that must be overcome with fine tuning of the ink/substrate properties and process parameters.
- This study focuses on new conductive inks formulated to play to the strengths of these processes: high resolution, high speed, and superior pattern fidelity. Promising inks must have sufficiently small particle size, be of low viscosity, have a high affinity for substrate adhesion, malleable when dry, and exhibit the properties intended after solidified. In search of such inks, several formulations are characterized via rheological studies, particulate size and distribution, zeta potential, and contact angle measurements and then printed on various substrates at high speed.
- The quality of the printed features is analyzed with an assessment of the feature uniformity, property performance, and defect occurrence.

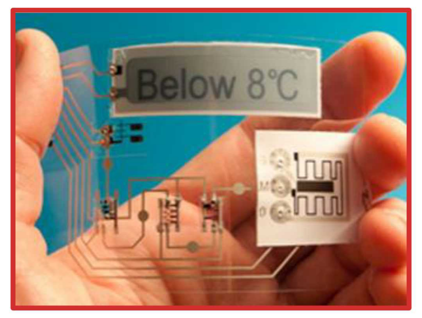


ORGANIC PHOTOVOLTAICS



FLEXIBLE SCREENS

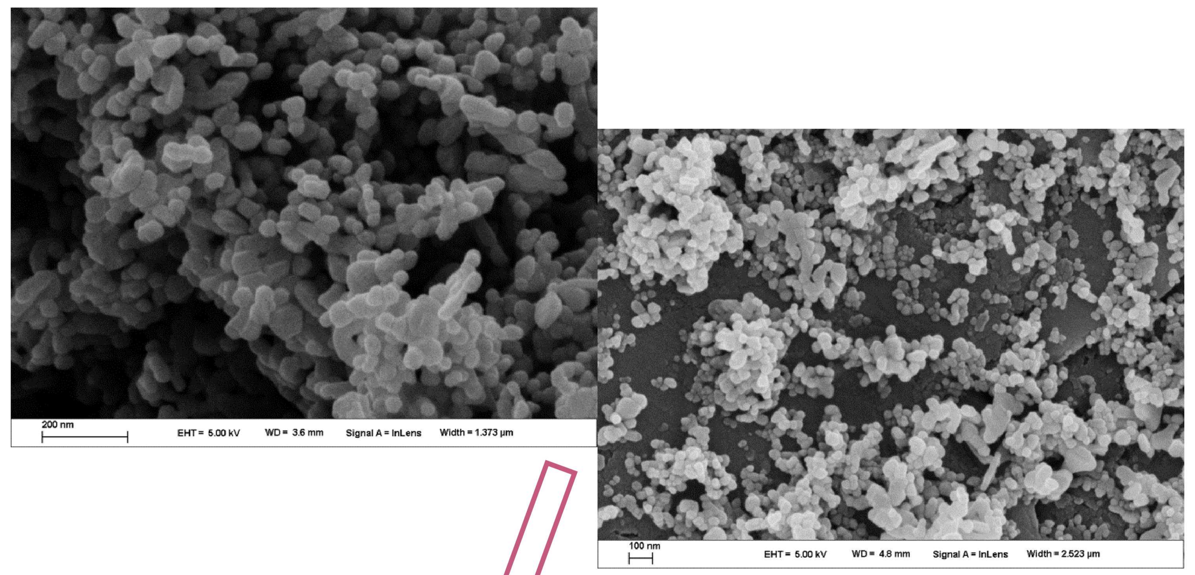
SOLID STATE LIGHTING



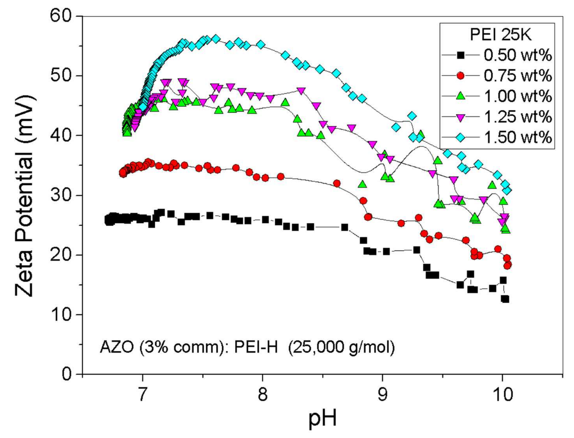
PRINTED ELECTRONICS

Ink Particle Formulation

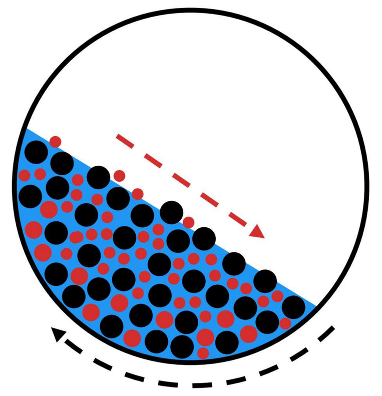
- Scanning electron micrographs (SEM) of Aluminum-doped Zinc Oxide powder produced via combustion spray has small primary crystallites but experiences agglomeration and must be milled to achieve size on order of a hundred nanometers



- Zeta potential of the powder with its surface activated by PEI (25k) in water shows that the PEI develops a positive surface charge with an optimal pH of 7.2 to 7.5 at 1.50 wt% to the AZO



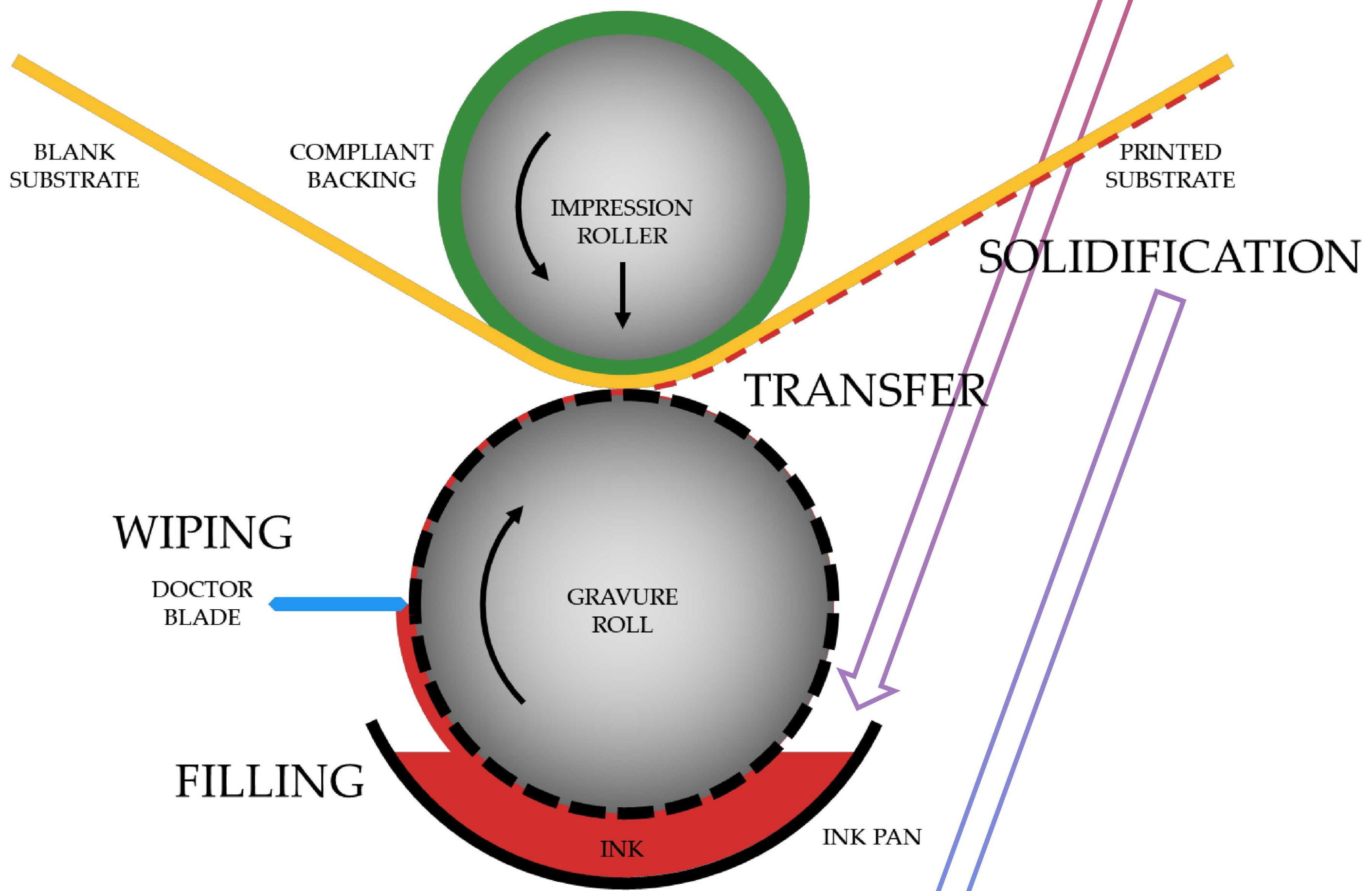
- Surface activated AZO particle size reduced via ball milling with ceramic media to a target size 100 – 200nm



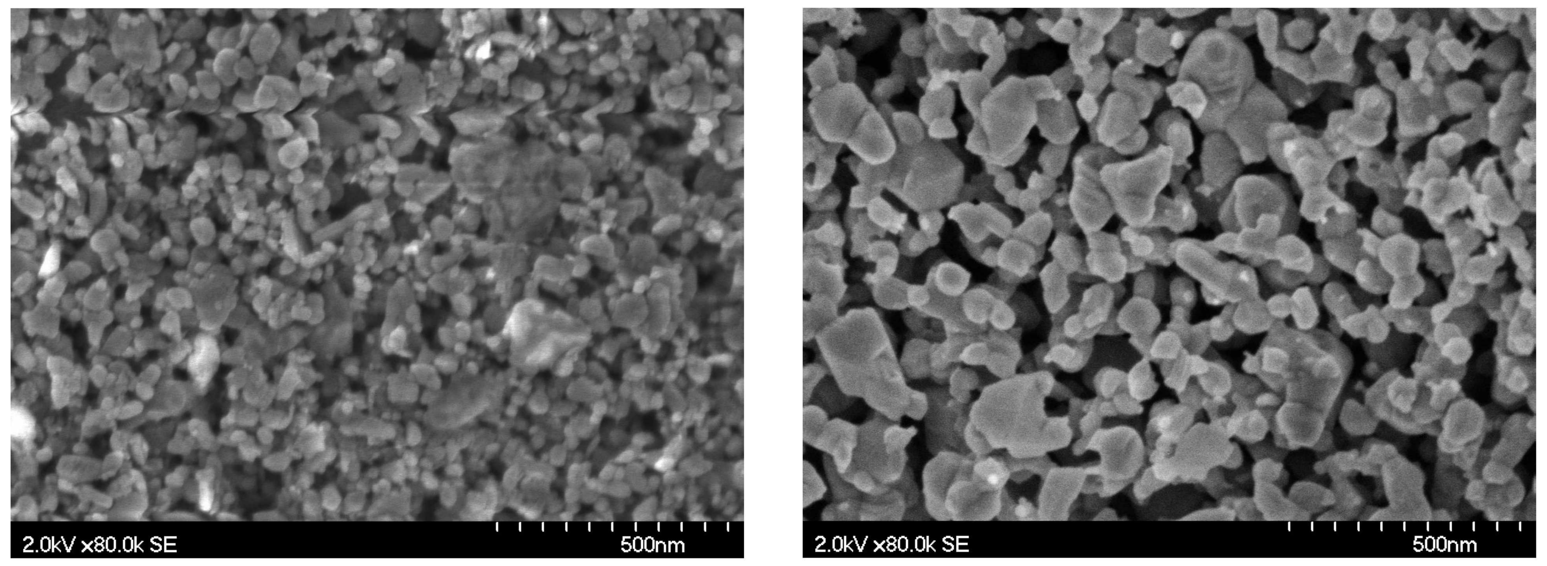
Gravure and Flexographic Printing

- Printing process is a factor of 4 steps:
  - Filling
    - Cells submerged in ink
    - Ink flows into cells
    - Excess flows out and back
  - Wiping
    - Excess wiped away by flexible blade
    - Pressure applied to blade
  - Transfer
    - Substrate pressed against patterned roller with matched speed
    - Ink wets substrate and spreads
    - Ink transferred as substrate is separated
  - Solidification
    - Ink solidifies via drying, curing, phase change, sintering, or densification

- Utilized RK Printing Proofer in gravure configuration



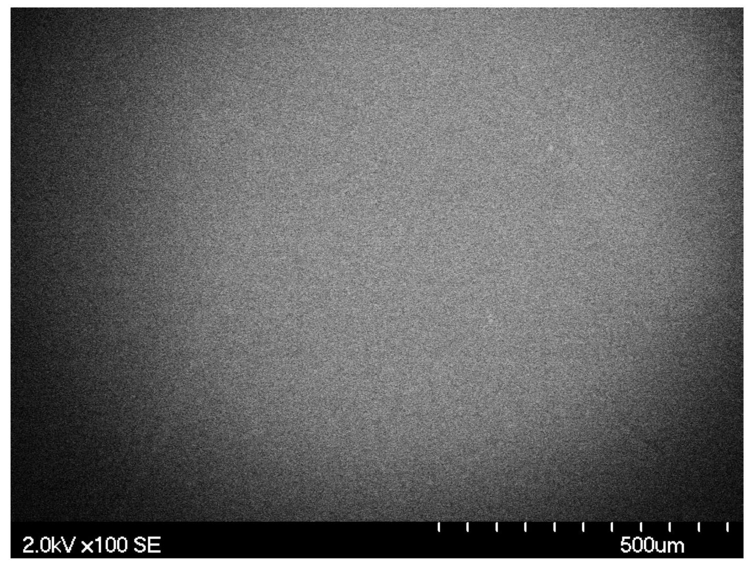
Print Sintering and Uniformity



FILM COATING PRE-SINTERING

FILM COATING PRE-SINTERING

- Thermogravimetric analysis (TGA) showed that the solvents and then binder were released at 125° and 350°, respectively
- SEM micrographs taken before and after sintering showed that the solvents and binders are evenly removed from the system but left voids

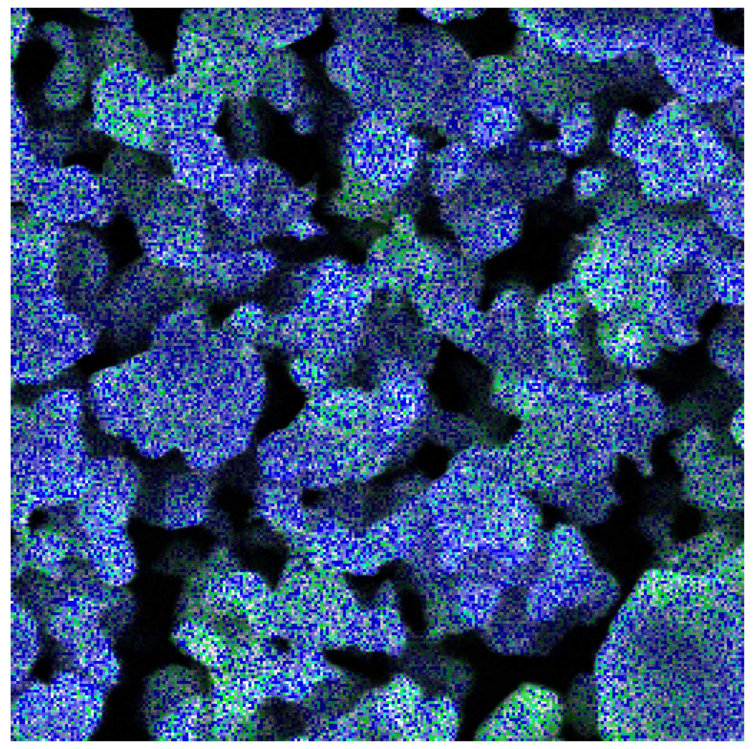


- Larger scale SEM image displaying the uniformity of the film after sinter and slow cool without the development of cracks in the film

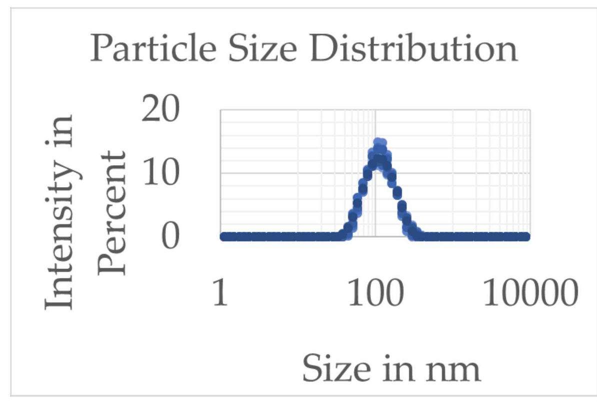
- Energy dispersive x-ray spectroscopy (EDS) shows the uniform doping of the Aluminum in the Zinc Oxide film facilitating in the electron hole pathways necessary for conductor or semi-conductor properties

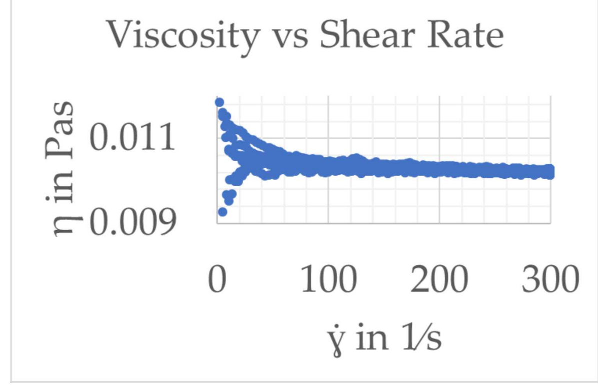
ZINC OXIDE

ALUMINUM

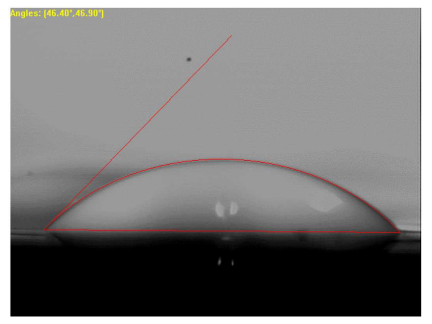


Ink Printability Tuning and Characterization

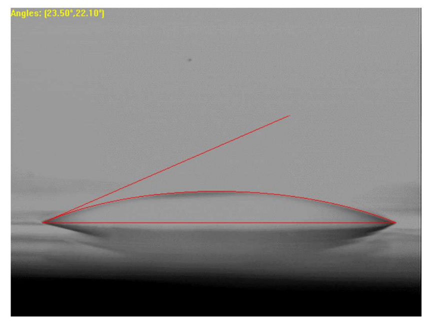




- Ink formulation used: AZO (5 wt%), Water (45 wt%), Dowanol DPM (35 wt%), Isopropyl Alcohol (13.91 wt%), Hydroxypropyl Cellulose (1 wt%), Dynol 960 (0.09 wt%)
- Contact angle measurement of the AZO ink formulation on untreated and plasma treated Kapton. A lower contact angle was measured for the treated Kapton which experienced less de-wetting after printing
- Dynol 960 surfactant was added to the formulation to enhance the wetting affinity of the ink even further



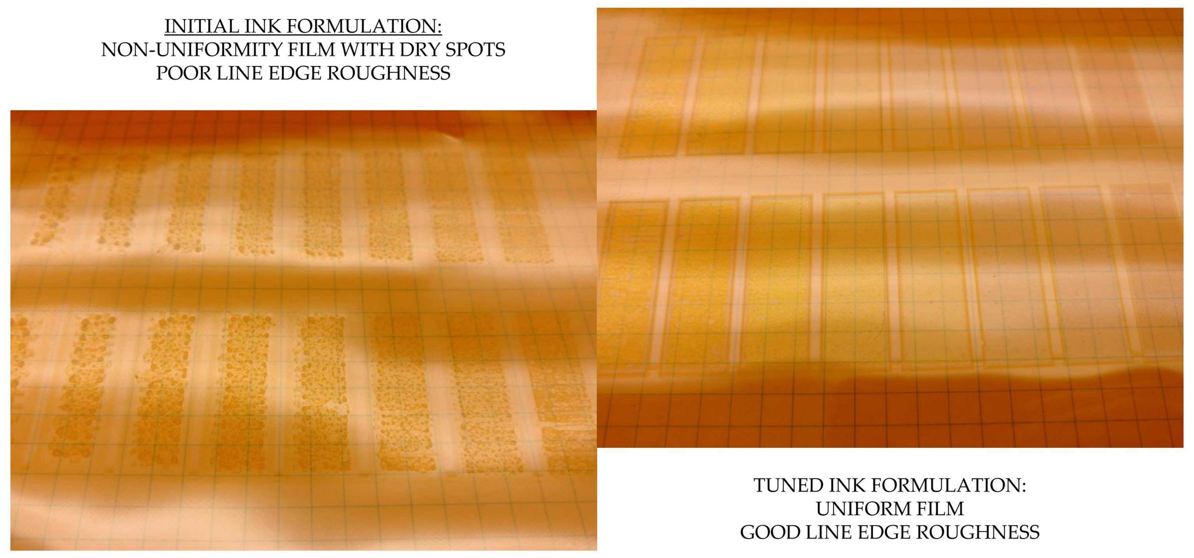
AZO INK ON UNTREATED KAPTON



AZO INK ON PLASMA TREATED KAPTON

AZO INK ON PLASMA TREATED KAPTON WITH ADDED SURFACTANT

INITIAL INK FORMULATION:
NON-UNIFORMITY FILM WITH DRY SPOTS
POOR LINE EDGE ROUGHNESS



TUNED INK FORMULATION:
UNIFORM FILM
GOOD LINE EDGE ROUGHNESS

- Printability of the ink was assessed with a patch coating pattern of varying gravure cell density from 60 – 100% and 60 line/cm
- Uniformity in the patch thickness was the primary indicator along with a sharp line edge roughness

Acknowledgements

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NASCENT NANOMANUFACTURING SYSTEMS FOR MOBILE COMPUTING AND MOBILE ENERGY TECHNOLOGIES

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