IARIGAI 2015 Helsinki, Finland



Session 2A Printed functionality 1

Improving the Electrical Performance and Mechanical Properties of Conductive Ink on Thin Compound Substrate

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IAD – What we do...

- 1. Starting point & motivation
- 2. Comparison of investigated processes
- 3. Electrical and morphological evaluation
- 4. Summary and outlook

PRINTED FUNCTIONALITY

some examples...







Carbon/Ag-ink

Capacitive devices – Touchpad, sensors...



Printed thermogenerators, PhD Topic

Resistive devices



Printed (rechargeable) batteries



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EQUIPMENT

Everything in-house...



Various equipment for screen printing: EKRA Printing machines, Binder Oven, Berbertec screen tensioner, open air plasma by Plasmatreat, UV&IR curing, Alicona microscope...

Printed Batteries

Flapping technology







- Separator inbetween (printed or assembled)
- Barrier properties by substrate and sealing





Printed Batteries

Flapping technology





- Key advantage: freedom of design, flexibility, scaling...
- Adapting to device requirements (voltage)

Starting point & motivation



MOTIVATION Need for proper substrate



Compound substrate glued to carrier with frame pattern or full area

- Improving processability and stability of substrate
- Use in printed batteries
- Compound substrate made of PE-AI-PET
- Barrier for functional materials
- ~ 100 µm thickness
- Drawbacks: Weldability of substr., poor printability
- Both aspects are adressed in this work

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PROCESSES Tools

2. Comparison of investigated processes



- Printing on PE side
- Alternatives to oven curing
- Alternative to open air plasma pre-treatment
- Improving adhesion via sublayer
- Improving performance (morphological & electrical)
- Investigation of heat pressing, hot stamping, oven curing



PROCESSES Key to conductivity



Principle of percolation, electrical pathways (Banfield 2000)

- Printing inks contain several (unwanted) ingredients
- Evaporation of solvent(s) and additives in ink by heating
- Densification of functional particles
- Alternatives to oven?

Hochschule der Medien

Comparison

Electrical conductivity



- Dependency of conductivity on temperature
- Dependency of conductivity on pressing time
- Conclusion: Increasing conductivity with increasing T and t
- Comparable with oven processing (15 min @ 120 $^{\circ}$ C)
- No improvement t > 15 sec
- About 86 % reduced resistance





- In general: Great improvement by thermal processing
- Best results by heat stamping, shortest processing time
- But: Impact on surface

Electrical and morphological evaluation

Comparison

Surface morphology



Heat Press Effect on Thickness Effect on Mean-Roughness 1.41 1.42 15.6 14.5 14.9 1.21 Mean roughness in µm 13.1 т Thicknessin µm 10.2 10.2 0.91 9.2 9.3 **Hot Stamping Hot Pressing** 2 Sample 1 3 4 ■ Before Pressing □ After Pressing Heat Press at 120°C for 15s

- Decreasing thickness of layer due to heat pressing
- From 13-15 μm to 9-10 μm
- Decreasing surface roughness



Comparison

Surface morphology





- a) heat press b) hot stamp
- Observation of densification of particles
- Increasing conductivity
- Surface roughness is decreasing
- But: Heavy impact of stamp in printed layers
- Heat press seems to be promising tool

Comparison

Adhesion test



Cross-Cut-Test: Removed Squares



- Adhesion on surface of Plasma samples very good
- Temperature dependant adhesion
- Depending on gluing area
- But: Test variations due manual scratching
- Tape test: only passed for Plasma treated samples

Impact of creasing

Impact of Creasing on Ohmic Resistance



- Impact on conductivity of silver layer -
- Avoiding increase in resistance is current topic of research



& outlook



- Goal: Screen printing on compound Substrate, used in printed batteries
- Alternatives to oven curing and improvement of adhesion on substrate
- Hot press and hot stamping improve the electrical properties greatly
- UV-ink improves mechanical properties of substrate
- Further research: ideal temperature and time
- Temporary fixation to carrier substrate
- Sealing of batteries (alternatives?)
- Avoiding conductivity decrease due to creasing
- Evaluation of further compound subtrates

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Thank you for your attention!

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