Opportunities for Gravure in Printed Electronic Applications

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www.wmich.edu/engineer/cape
CAPE
where University meets Industry

Established in 2008

Purpose: to advance the field of printed electronics by facilitating the research and development of materials and printing processes

12 faculty and their students

Multidisciplinary team:
- Material Science, Electrical Engineering, Paper and Printing Science and Engineering, Physics, Chemical Engineering, Mechanical Engineering, Chemistry

Established partnership network with industry and other universities

Parkview Campus at Business Technology and Research Park
343,000-square-foot facility completed in 2003

College of Engineering and Applied Sciences (CEAS), Kalamazoo, MI
What is Printed Electronics?

- Printed electronics (PE) is an emerging industry that uses different printing technologies to manufacture electronic components and devices of various functionality and complexity.

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[Image: PolyIC 2008](image-url)
Materials and Device Components

- Conductors
- Semiconductors
- Dielectrics (insulators)
- Other materials
  - Substrates
  - Barrier materials

Passive Components
- Conductors (wires)
- Resistors
- Capacitors
- Inductors (coils)

Active Components
- Transistors
- Pixels (LCD, LED ...)

Materials and Device Components:
- Conductive inks: Ag, Au, Cu, LCC
- Resistor inks: RuO2, C
- Dielectric inks
- Ferrite inks
- Clear conductors: ITO, NTO ...
- Semiconductors: polymers, inorganic
Current electronics manufacturing technology

- Monocrystal silicon wafers are the main substrate used for producing integrated circuits (ICs).

- Produced in clean rooms using photolithography techniques.
Photolithography Process vs. Printing process

- Surface Preparation
- Coating (Spin Casting)
- Pre-Bake (Soft Bake)
- Alignment
- Exposure
- Development
- Post-Bake (Hard Bake)
- Processing Using the Photoresist as a Masking Film
- Stripping and Post Processing Cleaning (Ashing)

- Ink preparation
- Ink deposition (printing)
- Ink drying
- Encapsulation packaging; and final testing

*Several of these process steps are repeated several times – production may exceed 100 processing steps.*
Graphic Printing is NOT Electronic Printing

- For PE - traditional printing processes have limitations
  - resolution (printing of fine features $\approx 5 \, \mu m$)
  - registration (alignment) layer-to-layer
  - ink film uniformity
Functional Inks are NOT Graphic Inks

- Solvent systems are different
- Solids loading is different
- Drying properties are different
- Press stability is different
- Environmental stability is different

Term “functional” – added to differentiate graphic arts inks that provide visual attributes from inks that provide intrinsic bulk electrical, thermal, chemical, or optical properties.
Why Gravure Process?

- Premier printing process – very high quality and stability (consistent print) over time.
- High resolution printing and layer-to-layer registration
- Mechanically simple – less process variables.
- Image carrier - engraved cylinder - Solvent compatibility - broader material sets
- Printing directly from engraved cells onto substrate.
- Variety of substrates.
- Broad range of particle size inks
- 3D printing
Other printing processes

- **InkJet** - Depositing very thin layers (5-500 nm). Resolution limitations, drop placement accuracy and slower production speeds make it less applicable for PE fabrication.

- **Screen** - printable inks typically contain large particles and therefore, printed ink film is very often thick and rough. Low resolution print.

- **Flexography** - “Halo” effect, which is caused by improper impression pressure settings, leads to excessive ink build up on the edges of printed features. Sensitivity of flexographic plates to organic solvents. Most of the available plate materials tend to swell and distort upon contact with the solvents.

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Initial Plate | PM Acetate | Tetraline | Xylene | Toluene
---|---|---|---|---
![Initial Plate](image1.jpg) | ![PM Acetate](image2.jpg) | ![Tetraline](image3.jpg) | ![Xylene](image4.jpg) | ![Toluene](image5.jpg)
Comparison of Printing Methods

Resolution

Ink Film Thickness

CAPE data provided to Serenius E., Daetwyler R&D
3D Printing

Dry Ink Thickness to 50+ µm

X & Y Axis - Screening

150 dpi

750 dpi

Z Axis - Depth

120° Unique Shapes

90° Stylus

© Daetwyler R&D
μStar Engraving from Daetwyler R&D

High Resolution Examples

5 microns
AccuPress™ - Precision Gravure Printer

- Layer-to-Layer Registration
- Precision Components
- Multi-Axis System
- Error Correction
- Custom Enhancements
- MicroEngraving™ (5 µm feature 2.5µm spacing)
- Print Area 300 x 300 mm
So what are the opportunities?

The market for printed and potentially printed electronics in 2020

- **OLED Display & Lighting**: $19 billion
- **Photovoltaics**: $17 billion (Excluding CdTe and Conventional Silicon)
- **Transistors**: $8 Billion
- **Other inks**: $2 billion
- **Sensors**: $1.6 billion
- **E-paper displays**: $6 billion
- **Inorganic Electroluminescent displays**: $0.4 billion
- **Others**: $2.75 billion (Batteries, other displays etc)

*Source: IDTechEx*

**83% Predominately Printed**

**75% Flexible**

Image Sources: PolyIC, OEA, GE, E-ink, Konarka, Commec, Add-Vision, Toppan Forms
Promise of Printed Electronics

It’s ultimately about cost reduction
Printed = Mass production by the roll
Printed = A flexible and tunable process
Printed = New markets and applications

Printed electronics on flexible substrates creates new market opportunities.
Research at CAPE

- Optimization of printing processes
- Correlation of printing parameters to electrical performance
  - main focus on high-volume printing – lab and pilot scale
  - gravure, flexography, but also inkjet and screen printing

Gravure engraving resolution and line quality

- 240 lpi
- 280 lpi

Engraving Quality

Printing speeds 100-400 fpm

Engraving Parameters

- 200 lpi (154μm)
- 300 lpi (90μm)
- 400 lpi (60μm)

Flexo (top) and gravure (bottom) printing of conductive inks at WMU Printing Pilot Plant

Printed RF antennas
Thank You

Contact Information

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“Electrifying” the Printing Industry