Printed Electronics: State of the Art

Practitioners’ Perspectives Panel:
  • Gene Hasch, Cubbison Company
  • Mike Wagner, Butler Technologies Inc.
  • Vince Cahill, VCE Solutions
Printed Electronics (PE) uses analog printing methods, such as screen printing, or digital printing inkjet or thermal transfer to deposit conductive materials to create electrical circuits instead of a plate-up/etch-down process. PE is typically a simpler and less expensive alternative production method as compared to the etching process for making circuits.
PE Printing Methods

Analog:
- Screen Printing
- Flexography
- Gravure
- Pad Printing
- Offset Lithography
- Microcontact printing (or μCP) “Soft Lithography”

Digital:
- Nanoimprint lithography (NIL)
- Evaporation printing
- Embossing
- Ink Jet
- Thermal Transfer
- Aerosol Jet
# PE Print Methods Comparison

<table>
<thead>
<tr>
<th>Printing Technology</th>
<th>Offset</th>
<th>Flexography</th>
<th>Gravure</th>
<th>Screen</th>
<th>Inkjet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ink viscosity (Pa.s)</td>
<td>5-100; 40-100</td>
<td>0.05-0.5</td>
<td>0.01-0.2; 0.05-2</td>
<td>0.5-50</td>
<td>0.001-0.04</td>
</tr>
<tr>
<td>Layer Thickness (μm)</td>
<td>0.5-2; 0.5-1.5</td>
<td>0.04-2.5; 1-2.5</td>
<td>0.1-8; 0.1-5</td>
<td>0.015-100</td>
<td>0.05-20; 0.5-15</td>
</tr>
<tr>
<td>Feature size (μm)</td>
<td>10-50</td>
<td>80</td>
<td>75</td>
<td>20-100</td>
<td>20-50</td>
</tr>
<tr>
<td>Registration (μm)</td>
<td>10</td>
<td>200</td>
<td>20</td>
<td>25</td>
<td>5-20</td>
</tr>
<tr>
<td>Throughput (m²/s)</td>
<td>3-30</td>
<td>3-30</td>
<td>3-60</td>
<td>2-3</td>
<td>0.01-0.5</td>
</tr>
<tr>
<td>Resolution (lines/cm)</td>
<td>100-200</td>
<td>60</td>
<td>100</td>
<td>50</td>
<td>60-250</td>
</tr>
<tr>
<td>Printing Speed (m/min)</td>
<td>200-800</td>
<td>100-500</td>
<td>100-1000</td>
<td>10-15</td>
<td>15-500</td>
</tr>
</tbody>
</table>

Chart source: Diana Gregor-Svetec, in *Nanomaterials for Food Packaging*, 2018
Printed Electronics Applications

- E-Textiles
- Capacitive Touch
- Electroluminescence
- Force Sensing Resistors
- Flexible Circuits & Flexible Hybrid Electronics
- Membrane Switch & Keypads
- Biosensors & Test Strips
- Flexible Printed Heaters
- RFID & Printed Antennas
- In-mold Electronics (IME)
- Photovoltaics (PV) & Organic PV (OPV)
- Displays & Lighting
Membrane Switch Products - ECI

- Tactile & Non-tactile Keypads
- Backlit Keypads, Rubber Keypads
- PCB Based Membrane Switches & Keypads
- Flexible Printed Circuits
- Medical Sensors
- Graphic Overlays
- Labels & Nameplaes

- Biosensors: EKG & ECG, Glucose Test Strips, Drug Delivery Pads
- RFID Antennas
- Heaters
- Batteries
Cubbison Company

Gene Hasch
Director of Manufacturing Operations
IAPEC Committee Member
ASTM Committee Member

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Cubbison Company is a premiere manufacturer of product identification solutions and Printed Electronic devices.

• Founded in 1951
• Located in Youngstown, Ohio
• 30,000sq. Facility
• ISO 9001:2015 Certified
Cubbison Company - What We Provide

Products Provided:
• Nameplates, Labels, Overlays
• Membrane Switches
• Flexible Electronics
• Touch Screens
• HSS™ Touch Recognition Technology
• Biosensors

Industries Served:
• Aerospace
• Medical
• Oil & Gas
• Defense
• Transportation
• Manufacturing
• Industrial Power
Cubbison Company - Processes

Processes used:
- Screen Printing
- Digital Printing
- Pick and Place
- Laser/Digital Cutting
- Full Assembly
- Digital Testing
- Prototyping
Cubbison Company - Projects

HLM - Heart Lung Machine

• Cubbison Reverse Engineered to meet IEC 60601-1-2, 4th edition EMC electrostatic discharge standard for FDA Approval
  • Redesigning of shielding
• Prototyping through production
• Screen printed circuitry with digitally printed overlay
Membrane Switches as part of Stainless Steel Assembly

• Only producer of membrane switches with a Stainless Steel overlay
• Explosion Proof
• Class 1 Zone 0 ATEX and IECEx approved
• Applications
  • Oil and Gas, Military
Stainless Steel Overlays on Membrane Switch

- IECEx/ATEX Class 2 non-Incendive Compliant
- Meets strict ESD requirements in the field
- Applications
  - electronic instruments
  - electromechanical devices
Force Sensing Wearables

- Produce Force Sensing Resistor and combined them with wearables

- Applications
  - Medical
  - Athletic
  - Equestrian
Cubbison Company - Projects

FAA Approved Membrane Switch

• Unit tests the Passive Restraint System
• Tested to 8585
  • Highly Accelerated Life Testing
• Application
  • Aerospace
HSS Intelligent Touch Sensing

• Eliminates false and unreliable actuations

• Delivers HMI solutions that are highly dependable in the most challenging environments including
  • Extreme temperatures and humidity
  • Gloves, water, noise, cleansers and dirt

• End users benefit from higher yields and reduced downtime
Butler Technologies’ Product Lines

User Interface

Printed Electronics
Biometric Sensors and Electro-Stimulation Therapy

- Electrocardiography (ECG / EKG) printed sensors for heart rate monitoring.
- Electroencephalography (EEG) printed sensors for monitoring brain activity.
- Surface Electromyography (sEMG) printed sensors for monitoring muscle activity.
- Electrical Muscle Stimulation (EMS), often called “e-STIM” or “TENS”.
- Printed sensors for monitoring respiratory rate.

Image courtesy of: Strive
Printed Flexible Heaters

Positive Temperature Coefficient (PTC) and Fixed Resistance heaters for wearables and industrial applications.
Printed Electronics Products

Force Sensing Resistors (FSR)

Printed sensors with resistive output that are used in applications including medical, industrial, and automotive.

Pressure Mapping / Podiatry Foot Gate Analysis

Image courtesy of: sensorprod.com

Motor / Tool Speed Control

Image courtesy of: Cervis Inc.

Seat Occupancy Detection

Image courtesy of: IEE Group

Response Comparison:
Shuntmode FSR ( ) vs. ThruMode FSR ( )
**Capacitive Touch Circuits**

**Features:**
- Typically printed on Polycarbonate or Polyester film.
- Clear conductive ink used for backlit sensing pads.
- Can feature bendable, formable conductive inks.
- Attachment of SMD and Connectors.
- Can be backlit using Light Guide Film (LGF) Technology.

**Applications Include:**
- Smart Surfaces / In-Mold Electronics (IME / IMSE).
- OEM product interfaces.
- Proximity Sensors.
- Load Detection / Force Displacement.
Flexible Printed Circuits / FHE

Features:
- Fine line printing (down to 50 micron trace & space - usually ink and substrate dependent).
- Inks include: Ag, Ag/AgCl, Carbon (PTC Heater, FSR, etc.), Copper, PEDOT, CNT, Conductive Adhesive, and more.
- Substrates include: Polyester (PET), Polycarbonate (PC), Polyimide (PI), Thermoplastic Polyurethane (TPU), Synthetic Paper, etc.
- SMD attachment using conductive epoxies & encapsulants.
Lighting Effects

Various techniques can be employed to provide unique lighting effects on products:

- Light Guide Film (LGF) in combination with side-fire LEDs (white, single-color, RGB).
- Top-fire LEDs with light diffusing films.
- Top-fire LEDs with printed light diffusing patterns on the graphic layer.
- Fiber optic panels (woven or flat fiber).
- Most lighting techniques require some type of printed electronics circuit.
• In-house Graphic, Electrical and Mechanical design.
• Nearly all film positives and screens are produced in-house.
• Large-format, sheet-fed semi-automatic flat bed screen printing.
• Heated roll laminating and heat transfer of circuits to textiles.
• High-speed clamshell die-cutting and CO₂ galvo & gantry-style lasers.
• SMD attachment using Epoxy Dispensing and Pick & Place Machines.
• Crimp machines for adding solder tabs, female connectors, and snaps.
• Various life-cycle, circuitry, and force sensor test equipment.
Markets Served (Printed Electronics)

- Safety & Fire Services
  - Garment Heaters and Lighting Solutions
- Industrial Controls
  - Printed Heaters and Force Sensing Resistors
- Medical / Home Healthcare
  - Garment Heaters, Biometric Sensors, and Force Sensing Resistors
- Performance Sportswear
  - Garment Heaters, Biometric Sensors, and Force Sensing Resistors
- Transportation (Automotive, Heavy Equipment, etc.)
  - Force Sensing Resistors, Printed Heaters, and various circuits & sensors
- Military & Aerospace
  - Biometric Sensors, various printed circuits & sensors
Ralph Lauren Polo PE Heated Olympic Team Jacket

Source: Ralph Lauren
ILO - Cremieu, France

- Kohler distributed PE heating film demister-heater for bathroom mirrors
- PE heater for rear view auto mirrors
- Heated exam table covers
- PE heater films for buildings, trains, autos, ships, medical, agriculture, & industry
- Uses primarily screen, also thermal transfer
Product Applications

- RFID tags
- Anti-theft protection
- Data storage & memory
- Displays
- Visual Effects
- Monitoring
- Toys
- Batteries
- Sensors

- Keyboards & touch screens
- Membrane switches
- Photovoltaic cells (PV & OPV)
- Cellphone parts:
  - Cellphone main & GPS antennas
  - LED packaging
  - Energy storage
  - ITO jumpers
  - Multi-layer Printed Circuit Boards
  - Edge circuits
Markets for PE

• MarketersMedia projects that the global Printed Electronics Market will grow from $6.24 billion in 2018 to $11.50 billion by 2023, at a CAGR of 13.0%.

• According to a MarketsandMarkets’ report* the printed electronics market is estimated to reach $13.6 billion by 2023 from $6.8 billion in 2018 in 2018, at a CAGR of 14.92% during 2018-2023.

• Consumer electronics, healthcare, automotive, aerospace and defense, retail and consumer goods

• Automotive industry is the largest contributor in the printed electronics market with use cases, such as sensors, lighting panels, and displays. Autonomous vehicles

* Printed Electronics Market by Material (Inks and Substrates), Technology (Inkjet, Screen, Gravure, and Flexographic), Device (Sensors, Displays, Batteries, RFID tags, Lighting solutions/panels, and PV Cells), Industry, and Geography-Global Forecast to 2023
Some Key PE Producers

- Butler Technologies Inc.
- GM Nameplate
- Cubbison Company
- Techprint
- Emerald Corporation
- Accelerated Assemblies, Inc.
- Conductive Technologies Inc.
- BeBop Sensors
- Advantech U.S., Inc.
- ECI
- TeleTec Electronics Corp.
- QUAD INDUSTRIES (Belgium)
- Printed Electronics Ltd. (UK)
- Nissha GSI Technologies
- Kent Displays, Inc.
- Argil
- DuraTech Industries, Inc.
- Epec Engineered Technologies
- Thinfilm Electronics

See also: https://www.printedelectronicsnow.com/buyersguide/
Thank You

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