Functional Ink Systems for “In Mold Electronics”

The Next Generation Human-Machine Interfaces

Microcircuit Materials
DuPont Has Evolved Over Two Centuries

1800 – 1850
1802 – E.I. DUPONT
1805 – CORE VALUES
1804 – FIRST POWDER MILL
1880 – FIRST DYNAMITE
1903 – EXPERIMENTAL STATION
1915 – PLASTICS
1917 – MAKING DYES
1918 – EXPERIMENTAL STATION
1935 – NYLON®
1936 – LUCITE®
1949 – ENGINEERING POLYMERS
1923 – CELLOPHANE®
1924 – RAYON®
1924 – FILMS BUSINESS BEGINS
1928 – CHEMICAL EXPANSION
1932 – DYNAMITE EXPANSION
1939 – E.I. DUPONT
1942 – E.I. DUPONT
1949 – ENGINEERING POLYMERS
1952 – MYLAR®
1955 – TYVEK®
1962 – LYCRA®
1965 – KEVLAR®
1967 – NOMEX®
1972 – ELECTRONICS EXPANSION
1966 – TYVEK®
1967 – NOMEX®
1972 – ELECTRONICS EXPANSION
1961 – TEDLAR®
1962 – LYCRA®
1965 – KEVLAR®
1986 – CORIAN®
2000 – SORONA® BIO BASED POLYMER
1966 – TYVEK®
1967 – NOMEX®
1972 – ELECTRONICS EXPANSION
1999 – ACQUIRES PIONEER HI-BRED
2000 – SOLAE JOINT VENTURE
2003 – SOLAE JOINT VENTURE
2001 – ACQUIRES DANISCO
2011 – ACQUIRES DANISCO
2002 – ACQUIRES 100% OF SOLAE
2013 – COMPLETES SALE OF PERFORMANCE COATINGS BUSINESS
2015 – SPIN-OFF OF CHEMOURS
2017 – DUPONT and DOW CHEMICALS have merged INTO DowDuPont
2019 – Split into 3 independent companies

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Electronics & Imaging Advanced Materials

Business Development: Science + Market Needs → Innovation
Microcircuit Materials Traditional Business

Over 50 years of experience in the development, manufacture and sale of specialized “Thick Film Compositions” (Pastes / Inks) for the Printed Electronics Industry

Core Technologies:
- Fine Powders
- Ceramic Science
- Glass Science
- Coating Technology
- Polymer Science
- Photopolymer Technology
- Dispersions
- Rheology
- Tape Casting

Products:
High & Low Temperature Screen Printable Pastes:
- Conductors
- Resistors
- Dielectrics

Major Traditional Applications:
- Automotive
- Photovoltaic
- Bio-Medical
- Power Supply
- MTS
- EL
- RFID

Over 50 years of experience in the development, manufacture and sale of specialized “Thick Film Compositions” (Pastes / Inks) for the Printed Electronics Industry.

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Automotive Interiors History – Past
Automotive Interiors History – Recent
Automotive Interiors History – Present
Automotive Interiors History – Future
Actually there is however a major limitation:

PCBs are flat & rigid constraining the design options and the intelligent function effectiveness…

What if I could encapsulate intelligence and functionality directly into 3D surfaces?
Example: HMI Control Panel

**Traditional Design Example**

Surface plastics (Foil visual finish and molded plastic)

Flex for capacitive switch

Light pipes

Full width rigid PCB

**Design Properties**
- Assembly depth: 25+ mm
- Numerous components
- Multiple manual assembly processes
- Complex electrical connections
- Mature technologies

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**Surface Encapsulated Design Example**

Foil with visual finish

Printed circuitry, SMD LEDs and ICs on IML foil

Injection-molded plastic

**Design Properties**
- Wall thickness: ~3 mm
- 50-70% weight reduction
- Sensors in surface structure
- Environmentally-protected electronics
- Consolidated electrical connections
- Single-component solution
Example: Overhead Console

Before (mechanical button)  
After (capacitive touch)

<table>
<thead>
<tr>
<th></th>
<th>Conventional assembly</th>
<th>IME version</th>
<th>Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>650 g</td>
<td>150 g</td>
<td>77% lighter</td>
</tr>
<tr>
<td>Assembly depth</td>
<td>45 mm</td>
<td>3 mm (un-form)</td>
<td>93% less depth</td>
</tr>
<tr>
<td>Mechanical parts</td>
<td>64 parts</td>
<td>2</td>
<td>96% less parts</td>
</tr>
<tr>
<td>PCBA size</td>
<td>10 x 4 cm</td>
<td>10 x 3 cm</td>
<td>25% smaller area</td>
</tr>
</tbody>
</table>

Source: Tactotek
Intelligent Surfaces Potential

Integration of:

• Electronic circuits: Electrical connections, shielding, etc…

• Interfaces: Capacitive switches, curved touch surfaces etc…

• Sensors: Antennas, proximity and gesture detectors, etc…

• Electronic components: LEDs, ICs, etc…

• Screens: OLEDs…?
The Ready To Use Solution

Introducing “In Mold Electronics”
IME in 3 Basic Steps

In Mold Electronics refers to Printed Electronic Circuitry on a polymer film substrate which successively undergoes a thermoforming and an injection moulding process. The circuit remains functional as the conducting tracks contour the 3D shape.

This technology is an extension and addition to IMD / FIM (In Mold Decoration / Film Insert Moulding) with base technology from the 1990’s. It combines films, graphics and electronics to form a 3D aesthetical, functional, fully integrated part.
IME – Typical Manufacturing Process

Substrate

Screen printing

Graphic inks

Ag / Functional inks

Protection layer(s)

PC / Other film

~ 200-300 um

Drying

Drying

Drying

Film Insert Molding

Thermoforming

Cut & trim

Injection molding

Device assembly

Electronic components

- Vacuum or high air pressure
- > 150 °C

~ 275-325°C

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IME Benefits
Versatile technology with features that lead to immediate benefits

Up To 70% Lighter
Elimination of mechanical buttons, sliders and wires. IME part can be as slim as 2mm thick!

New Design Freedom
Enable 3D modern Smart Surfaces design with continuous surfaces

Up To 40% Assembly Time Reduction
Switches, LEDs and components embedded in structure significantly reduced parts for assembly

Highly Touch Sensitive
Capacitive switches are printed directly on device surface

Durability
Injection molded part protects components from vibration and environment

Up To 30% Less Cost
Simpler and more efficient production
Enabling Technology

Why has this not been possible before and how is this achieved now?

Through the developments of new, specially formulated functional inks
Paste / Inks Constituents

Key elements of a polymeric IME paste composition

**Polymer**
- Elastic / Stretchable
- Good adhesion to PC
- Withstands high temperatures

**Solvent**
- Solubilises the polymer
- Good screen print properties
- Compatible with PC & graphic inks

**Filler**

**IME functional ink**

Conductor: Ag, Carbon, etc.

Dielectrics: different for under / over print, cross-over, etc.

- Compatibility with substrates / graphic inks / and among DuPont IME ink portfolio
- Balance of viscosity, good printing properties
- Balance for conductivity & ability to stretch
- Good adhesion and temperature resistance to withstand “wash out” during injection moulding process
## IME Product Portfolio – Dielectrics

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
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</table>
| **Silver Conductor** | ME602 - PC friendly & for over-printing on graphic inks  
|               | ME603 - PC compatible & improved Ag show-through  
|               | ME101 - For RFID Antenna, NFC enable (reduced elongation)                   |
| **Conductive Adhesive** | ME902 - For attach component, thermoformable, good adhesion                  |
| **Transparent Conductor** | ME801 - Good conductivity, high light transmission >90%                      |
| **Carbon Conductor** | ME201 - Overprint for connectors & to inhibit Ag migration                    |
IME Product Portfolio – Dielectrics

Protection Encapsulant
ME772 - White Over-print protection – solvent based
ME780 - Clear Over-print protection – solvent based, good abrasion with UV protection

Crossover Dielectric
ME778 - Reduced pinhole, stable BDV at elongation
ME779 - Wide process window (oven or belt drier)
DuPont IME Active Collaborations

To provide an IME solution to the Industry - from paste to final functional device - we know there are challenges related to materials and processes:

Collaboration with technology leaders and specialized innovators is therefore essential

<table>
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<tr>
<th>Printing</th>
<th>Thermoforming</th>
<th>Solutions &amp; Know-How</th>
</tr>
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<tbody>
<tr>
<td>• Pröll - Graphic Inks</td>
<td>• Niebling - High Pressure</td>
<td>• Various companies - specializing in IME</td>
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Application Development Resource

• Holst Centre – Hybrid Printed Electronics cluster WP7 Platform (In Mould Electronics)
IME – Summary / Conclusions

• **Versatile technology**
  • In Mold Electronics is ideally suited to quickly develop “intelligent surface” solutions by fitting existing IMD / FIM products and processes

• **Novel dedicated ink technology and complete suite of materials**
  • New functional ink chemistries for conductors, dielectrics, carbons and adhesives complying with the typical IMD / FIM substrates, stretching and thermal / mechanical process conditions

• **Robust and reliable technology and products**
  • Proved environmental test performance and thermal cycling resistance

• **Ongoing technical work**
  • New generation of improved conductors and dielectrics
  • Layers stack up design
  • Generation of additional reliability data