UV BASED CONDUCTIVE INKS FOR FLEXIBLE PRINTED ELECTRONICS

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UniPixel Inc

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Who We Are

• UniPixel is innovative in design and manufacture of Performance Engineered Films™ (PEF)

• Design, Mastering, R2R Manufacture:
  • We modify industrial base films at the micro/nano level to effect the surface geometry, chemistry, optical and/or electrical properties
  • Custom formulation of inks and coating materials

• UniBoss™ Printed Conductor Technology:
  • Involves embossed, patterned or planar films
  • Conductive lines <10µm wide, on one side & both sides of R2R films
  • Initial focus on Flexible Printed Electronic Products:
    • Multi-touch sensors for electronic displays & Touch sensors for other applications
    • Antennas - RFID, etc, Precision flex cables with reduced lead time
    • Available with a variety of coatings

• Protective Cover Films:
  • Diamond Guard™ - Clear Hard Coat, Anti-scratch, Flexible - as a cover glass replacement
  • Finger Print Resistant Film, Anti-Glare Film, Fashion Films

Major share of UniPixel Performance Engineered Films is made with UV Cure materials
Possible Solutions are Limitless…

Raised surfaces wick away fingerprints to ensure clean displays even with heavy use.

Optical microstructures increase display and lighting efficiency and improve uniformity.

Narrow Width Copper lines allow thin touch sensors to be printed at much lower cost.

Advanced MEMS display film: A 4μm conductive mesh surrounding micro-optical structures on ultra-thin film.
Printed Conductor Patterning

METHODS FOR PRINTING CONDUCTORS
- PHOTOLITHOGRAPHY / ETCH
- INK JET
- SCREEN
- GRAVURE
- FLEXOGRAPHY
- MICRO-CONTACT
- LASER PROCESSING

INKS FOR PRINTING CONDUCTORS
- Water Based, Solvent Based, Radiation Cured
  - METAL NANO PARTICLES: Ag, Cu, Au
  - CARBON NANOTUBES
  - GRAPHENE
  - CONDUCTIVE POLYMERS

UniPixel Approach –
Custom formulation of UV cure inks
**Process Parameters**

- Viscosity, Surface Tension and drying characteristics of the Ink
- Print gap, drop volume, print speed
- Film surface energy compatibility with the surface tension of the ink, the pattern to be printed - for selective wetting

**SURFACE ENERGY EFFECTS**

Embossed microstructures on PET films – Ink Jet Printed with Metal-Organic Ink

Surface Energy / Surface Tension Compatibility for Wetting characteristics
Ink Jet Printed Conductor - Selective Patterning by Surface Energy Modification

Plated Cu between lenslets - Clear lens tips

TYPICAL DIMENSIONS
Height = 4µm, Tip Diameter = 6µm

Cu on embossed lines of UV acrylate film on 125µm PET Film
Design: 4µm gap between 4µm tall, 4µm wide. Cu Line Width (µm): 3.47, 4.28, 4.05, 4.17

50X mag
• UniBoss™ is:
  • Proprietary Embossing / Micro-contact Printed Metal Conductors
    • Custom Ink Formulation
    • Minimum trace/space width: ~10µm / 20µm
    • Roll to Roll (2 mil – 10 mil PET)
      • Multiple substrates
        • Multiple metals
          • Low resistivity
            • Flexibility
              • High throughput
UniBoss™ Production Process for Ultra Fine Line Metal Patterns

Proprietary UniBoss™ Fabrication Process

1. Substrate
2. Micro-Pattern
3. Embossing Step
4. Metal
5. Metallization Step

~15µm Line

20X mag

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R2R UniBoss™ - Ultra Fine Line Metal Patterns

- ~16µm lines
  - 20X mag
  - 50X mag

- ~15µm lines, 600µm Grid
  - 20X mag

- ~17µm lines, 600µm Grid

- ~8µm line
  - 50X
R2R UniBoss™ - Ultra Fine Line Metal Patterns: <10µm Copper Lines

~8µm Conductor Lines

SEM Images

620X mag

4650X mag

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# UniBoss™
## Technical Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trace Thickness</td>
<td>≈1μm thick</td>
</tr>
<tr>
<td>Trace Width (Minimum)</td>
<td>10μm</td>
</tr>
<tr>
<td>Space (Minimum)</td>
<td>20μm</td>
</tr>
<tr>
<td>Pattern Area</td>
<td>400mm x 600mm</td>
</tr>
<tr>
<td></td>
<td>(Process scalable to larger size patterns)</td>
</tr>
<tr>
<td>Conductive Layers</td>
<td>Single or Double sided patterned conductors</td>
</tr>
<tr>
<td>Base Substrate Film</td>
<td>0.075mm (0.003in) up to 0.250mm (0.01in)</td>
</tr>
<tr>
<td></td>
<td>(Other thicknesses and film material available as custom order)</td>
</tr>
<tr>
<td>Hard Coat</td>
<td>&gt;= 6H available as laminated cover film</td>
</tr>
<tr>
<td>Adhesive Layer</td>
<td>Available</td>
</tr>
<tr>
<td>Release Liner</td>
<td>Available</td>
</tr>
<tr>
<td>Transmittance</td>
<td>up to 90+%</td>
</tr>
<tr>
<td></td>
<td>(Varies with substrate and pattern density)</td>
</tr>
<tr>
<td>Adhesion</td>
<td>Passes Scotch tape test</td>
</tr>
<tr>
<td>Operating Temperature</td>
<td>-20°C to +65°C</td>
</tr>
<tr>
<td>Trace Conductivity</td>
<td>-0.050 Ohms/sq</td>
</tr>
<tr>
<td></td>
<td>(for 1μm thick Cu, tunable for different applications)</td>
</tr>
<tr>
<td>Example Sheet Resistance</td>
<td>-6 Ohms/sq</td>
</tr>
<tr>
<td></td>
<td>(15μm line width, 1μm line thickness, 600μm grid spacing)</td>
</tr>
<tr>
<td>Base Substrate Films</td>
<td>PET*, PEN, PC*, Cellulosics*, Polyimides, Acrylics, Flexible Glass</td>
</tr>
<tr>
<td>Metals</td>
<td>Cu, Ni, Sn, Ag, Au</td>
</tr>
</tbody>
</table>
UniBoss™ Applications

Touch Sensor

Standard Configuration:

X Sensor Pattern

PET

Y Sensor Pattern

Optional Configurations:

PET

OCA

PET

PET

PET

PET

PET

PET

PET

PET

PET

12

PET = 100µm thick, OCA = 25µm thick
# Touch Sensor Technology Comparison

<table>
<thead>
<tr>
<th></th>
<th>UniBoss</th>
<th>ITO on Film</th>
<th>ITO on Glass</th>
<th>Conductive Polymer (PEDOT)</th>
<th>Carbon Nanotube</th>
<th>Ag Nanowire</th>
<th>Metal Nanoparticles</th>
<th>Thin Wire</th>
<th>Carbon Ink</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Offerings</strong></td>
<td>Patterned Film</td>
<td>Coated Film</td>
<td>Coated Glass</td>
<td>Coatings Film Ink</td>
<td>Mesh Grids Aligned Arrays</td>
<td>Nanowire Coated Films</td>
<td>Nanoparticle Coated Films (mostly Ag)</td>
<td>Thin Wire embedded in Substrate</td>
<td>Patterned Film</td>
</tr>
<tr>
<td><strong>Patterning Process</strong></td>
<td>Printing</td>
<td>Photolithography</td>
<td>Photolithography</td>
<td>Photolithography Inkjet Screen</td>
<td>Photolithography Laser Ablation</td>
<td>Photolithography Laser Ablation</td>
<td>Weaving</td>
<td>Printing</td>
<td></td>
</tr>
<tr>
<td><strong>Transmissivity</strong> <strong>(Depending on aperture)</strong></td>
<td>80% - 92%</td>
<td>81%</td>
<td>88% to 90%</td>
<td>81%</td>
<td>81%</td>
<td>90% – 91%</td>
<td>84%</td>
<td>84%</td>
<td>~75% est.</td>
</tr>
<tr>
<td><strong>Haze</strong></td>
<td>&lt;0.6%</td>
<td>1.7% to 3%</td>
<td>0.1 - 0.3%</td>
<td>1.5%</td>
<td>1.5%</td>
<td>0.9% - 1.3%</td>
<td>0.9% - 1.3%</td>
<td>0.9% - 1.3%</td>
<td>0.9% - 1.3%</td>
</tr>
<tr>
<td><strong>Color</strong></td>
<td>Black</td>
<td>Yellow</td>
<td>Greyish</td>
<td>Blue</td>
<td>Black</td>
<td>Greenish</td>
<td>Silver</td>
<td>Copper</td>
<td>Black</td>
</tr>
<tr>
<td><strong>Transparent Material</strong></td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td><strong>Resistance</strong></td>
<td>&lt;0.05 Ohms/sq</td>
<td>200 to 600 Ohms/sq</td>
<td>50 to 500 Ohms/sq</td>
<td>200 to 800 Ohms/sq</td>
<td>400 Ohms/sq</td>
<td>150 to 270 Ohms/sq</td>
<td>1 to 150 Ohms/sq</td>
<td>&lt; 0.4 Ohms/sq</td>
<td>0.4 to 1.0 Ohms/sq</td>
</tr>
<tr>
<td><strong>Flexibility</strong></td>
<td>High</td>
<td>Semi-Rigid</td>
<td>Rigid</td>
<td>Flexible</td>
<td>Flexible</td>
<td>Flexible</td>
<td>Flexible</td>
<td>Rigid Frame</td>
<td>High</td>
</tr>
<tr>
<td><strong>Feature Size</strong></td>
<td>10µm</td>
<td>1mm</td>
<td>1 mm</td>
<td>80µm to 100µm</td>
<td>1mm</td>
<td>30µm</td>
<td>20µm</td>
<td>10µm wire</td>
<td>15µm</td>
</tr>
<tr>
<td><strong>Health &amp; Safety Concerns</strong></td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Indium compounds</td>
<td>No</td>
<td>Lung damage by Ag absorption by</td>
<td>No</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td><strong>Scalability</strong></td>
<td>50” +</td>
<td>23”</td>
<td>23”</td>
<td>7”</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>105”</td>
<td>?</td>
</tr>
<tr>
<td><strong>Issues</strong></td>
<td>* Less costly to integrate in</td>
<td>* Brittle</td>
<td>* Brittle</td>
<td>* Requires toxic</td>
<td>* Requires toxic</td>
<td>* Resistance spikes at</td>
<td>* Flexing effects</td>
<td>* High heat for sintering</td>
<td>* Difficult to manufacture</td>
</tr>
</tbody>
</table>

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* All technologies require contrast management to achieve pattern invisibility

** Assumes single PET or glass substrate configuration

All data based on publically available information

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## UniBoss™ Copper compared with ITO based touch panel

<table>
<thead>
<tr>
<th>Performance Advantages</th>
<th>ITO</th>
<th>UniBoss™ Copper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower power</td>
<td>Much lower power ($P = CV^2f$)</td>
<td>(up to $1/10,000$ the capacitance)</td>
</tr>
<tr>
<td>Higher scan speed</td>
<td>$\sim 60 – 300$Hz</td>
<td>up to $10,000x$ faster scan rate</td>
</tr>
<tr>
<td>Larger form factor</td>
<td>up to $17”$</td>
<td>up to $80”$</td>
</tr>
<tr>
<td>Thinner</td>
<td>requires glass to protect from cracking</td>
<td>no glass</td>
</tr>
<tr>
<td>Lower weight</td>
<td>requires glass to protect from cracking</td>
<td>no glass</td>
</tr>
</tbody>
</table>

### Cost Advantages

**Manufacturing**

<table>
<thead>
<tr>
<th>Deposition method</th>
<th>Vacuum</th>
<th>Normal atmosphere, roll to roll</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patterning process</td>
<td>Subtractive - Batch photo-lithography</td>
<td>Additive - Roll to roll plating process</td>
</tr>
<tr>
<td></td>
<td>$(100%$ of surface area covered, $x2$ layers)</td>
<td>$(\sim1%$ area covered, $x2$ layers)</td>
</tr>
<tr>
<td>Materials</td>
<td>Indium = $$800.00/kg$</td>
<td>Cu = $$7.31/kg$</td>
</tr>
<tr>
<td></td>
<td>(Indium is $75%$ of ITO by weight)</td>
<td></td>
</tr>
<tr>
<td>Assembly</td>
<td>Silver silk screen / lamination / flex cable attach</td>
<td>Optionally, fully integrated circuit</td>
</tr>
</tbody>
</table>
• UniBoss™ brings Value-Add solutions to;
  • Transparent Touch Sensors
  • Precision flex cables with reduced lead time
  • Micro-Antenna
    • RFID, cell phones, RF, WiFi, Bluetooth, remote video, etc.
  • Transparent EMI/RFI shielding
  • OLED backside electrode grid
  • Solar electrode grid

• More under development…