Printed Electronics: Markets, Technologies, Trends

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About IDTechEx – snapshot view

IDTechEx provides Emerging Technology insight, intelligence and networking, helping clients with their critical strategic business decisions.

Global and timely analysis through:

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Since 1999 we have served clients in 80 countries from our bases in the US, UK, Germany, Korea and Japan.
IDTechEx Show! is a one of a kind event. We co-locate our topic focused events due to strong overlap across technologies, exposing you to the full relevant supply chains, customers and supplier bases. IDTechEx Show! is comprises of two-day conferences on the hottest technologies, co-located with a common exhibition.

### Key Facts

- **Topic focused** tracks
- One **common exhibition**
- **3500+** attendees
- **200+** exhibitors
- **50+** press

**ALL IN ONE PLACE**
What is Printed, Flexible, Organic Electronics?

Enabling materials and manufacturing processes...

- Metallic ink
- Organic semiconductors
- Inorganic semiconductors
- Dielectrics
- Carbon nanotubes, graphene
- Conductive polymers
- Glass, polymer, paper and steel substrates
- Flexible barrier films, adhesives, encapsulants
- Quantum dot materials
- Printing processes (inkjet, gravure, flexo, screen, rotoscreen, dip pen nanolithography, lithography)
- Vacuum deposition, spin coating, ALD, CVD, sputtering
- Sintering, curing (photonic, heat, UV, IR)

...creating these devices...

- Thin Film Transistor Circuits (TFTs)
- Memory
- Displays (OLED, e-paper, electrochromic, electrowetting, electroluminescent)
- Lighting (OLED, LED)
- Sensors (photo detectors, temperature, pressure, bioelectronic etc)
- Photovoltaics (CdTe, CIGS, DSSC, OPV)
- Batteries, supercapacitors
- Transparent conductive films
- Actuators and haptics
- RFID
- New Products
- Stretchable electronics
- Touch screens

...being exploited by these industries...

- Healthcare
- Consumer Goods
- Consumer Electronics
- Aerospace and Military
- Media & Advertising
- Architecture & the Built Environment
- Transportation

...because benefits can include...

- Low cost
- NEW FORM FACTORS
  - flexible, thin, conformal, transparent, stretchable
- TECHNICALLY SUPERIOR
  - eg better displays, readability in sunlight, PV
  - more efficient in lower light levels
  - bio-compatible
- PRODUCTION
  - Larger areas, faster production and turn around
Printed, Flexible and Organic Electronics Status

**OLED Displays**
- Organic but not printed
- Progression to flexible displays
- Little focus on simple, printed OLED displays

**2016 Total: $24.2 Bn**

<table>
<thead>
<tr>
<th>DISPLAY &amp; LIGHTING</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>e-paper displays</td>
<td>$250Mn</td>
</tr>
<tr>
<td>AC EL disp</td>
<td>$70Mn</td>
</tr>
<tr>
<td>OLED Lighting</td>
<td>&lt;$30Mn</td>
</tr>
<tr>
<td>Electrochromic disp</td>
<td>&lt;$2Mn</td>
</tr>
</tbody>
</table>

**POWER**
- Printed/thin film batteries: <$5Mn
- OPV, DSSC: <$1Mn
- Logic & memory: $8Mn

**Sensors**
- Glucose test strips are the majority of the market (20bn units)
- Rest is $83 million of different sensor types and applications

**Conductive Ink**
- PV is main market, followed by touch panel electrodes
- Overall growth 3.3% CAGR to 2020

Source: IDTechEx report “Printed, Organic & Flexible Electronics Forecasts, Players & Opportunities” www.IDTechEx.com/pe
Rise of Plastic and Flexible OLED Displays

- Plastic OLED displays are already mass produced for mobile phones and smart watches
- Main advantages are thinner and lightweight displays
How inkjet has enabled mass production

For mass production of flexible OLED, it is essential to minimize the time and cost of depositing the encapsulation layers.

Inkjet allows fast deposition of the organic materials without the need for further patterning.

The printer coats each display on the carrier motherglass but does not obstruct the edge contacts.

Inkjet printing could also be used to manufacture OLED TVs in the future.

Source: Kateeva
Innovation and Differentiation in the $120Bn Display Business

Quantum Dots help LCDs

- $500 million in 2016 for QDOT LCD to over $3 Billion in 2020
- QDOTs as an emissive display without LCD an alternative to printed OLEDs?

New Battlegrounds

- Flexible LCDs
- LEDs (which can be printed)
Come Back Reflective Displays, All is Forgiven?

- B/W E-reader sales have stabilised at around 6 million units a year
- Growth in Electronic Shelf Labels (ESLs), signage and decorative displays
- Amazon continue investing in electro-wetting technology, no products yet
- KENT Displays sell millions of reflective LCDs
- New start-ups enter: Clearink, Folium Optics, Etulipa, Bodle Technologies

Source: Folium Optics
Source: E-ink
Source: KENT Displays
Emerging printed sensors have a strong growth potential

- 20Bn Glucose test strips. Rest of the market is $83 million
- Printed gas sensors now being adopted
- Innovation opportunity: sensors with novel form factors


Source: 3PLAST project
Source: MEC and Holst Centre
Source: StretchSense
Wearable sensors with printed electronics
PV market experiencing a change of leadership at the paste and powder level.

Touch screen bezel edge market changing. Narrow bezel is the key driver of change

Many new market opportunities emerge

Antenna printing is on the up

- 3D antenna printing gaining traction and now competing head-on with LDS

- Other printing processes also already commercial

- Saving space and reducing turn-around time are key drivers

Rapid customization, material & component cost reduction, light-weighting and saving space are key drivers
Stretchable Electronics

E-textile market grows from $150 million in 2016 to over $3 billion in 2026

30x increase in amount invested in stretchable electronics companies between 2012 and 2015

Key Innovation Areas

- Stretchable Inks
- Flex to Rigid Connections
- Sensor Structures & Materials

Smart Clothing for Sports Leads The Way

Sports & Fitness

Health & medical

Wellness

Home

Industrial & military

Fashion

Other

Stretchability, washability, durability: new opportunities for ink suppliers
Printed batteries for wearables

Flexible and/or printed batteries enable wearable tech to go wearable

Large companies are now interested (Apple, LG Chem, Samsung, STMicro etc), changing the competitive landscape.

Different types of technologies, some printed, others not

Sources: Imprint Energy, Sensium Vitals, Enfucell, Blue Spark
Energy Harvesting: MW to mW

MAINLY ELECTRICAL ENGINEERING
Highest market value

100kW

Thermoelectric, Piezoelectric, Capacitive

0.01mW

MAINLY ELECTRONICS

Multimodal

Source: Hanergy

Source: Nature Energy

Source: ACS

Source: Nature Energy
New Materials Come to Market

- Conductive inks
- Quantum Dots
- Carbon nanotubes
- Perovskites
- Graphene
- Transparent conductors
- Dielectric elastomers
- Electroactive polymers
- Organic light emitters
- New uses of fluoropolymers

Source: StretchSense

Source: ISORG
Manufacturing Innovations

- 3D Printing: Rapid growth of 3D metal printing (one manufacture saw year on year growth of 97%); companies beginning to make bold acquisitions

- 3D Printed Electronics

- Rapid circuit prototyping by creating printed multilayer circuit boards on your desktop

- The next wave is manufacturing hybrid devices – such as thin flexible ICs onto thin flexible substrates, and handling many different components of different sizes

Source: Voxel8
Source: Nanodimension
Source: Uniqarta
Flexibility and performance: hybrid systems

Source: PARC and UCSD

Source: Bainisha

Source: MC10
How can we speed up commercialization?

A few companies are building ecosystems – working together and some are taking on a systems integration role.

**Supplier push**
- Great interest from suppliers of chemicals, inks, film and paper: 27%
- Production machinery and know how: 10%
- Large number of components now available:
  - EL displays
  - EC displays
  - OLED displays
  - Electrowetting
  - Electrophoretic
  - Flexible LCD
  - Sensors
  - Batteries
  - Photovoltaic cells
  - Transistors
  - Memory
  - Actuators: 60%

**User pull**
- Few integration companies or creative designers involved: 3%
- Little questioning of what users want, little market pull

**Horizontal selling**
**Vertical selling**
Recent investments / acquisitions

- LG announce significant investment in OLEDs on Plastic (potentially $8.71 billion)
- Sharp (Foxconn) will invest $570m in pilot line for OLED displays
- BOE announce potential $6.8 billion in flexible AMOLED fab
- Heliatek has secured €80m in additional funding for OPV manufacturing in Dresden
- PragmatIC has raised ~ €20m from investors including Avery Dennison
- Thinfilm invests in new production site in Silicon Valley (formerly owned by Qualcomm)
- Cambrios back in business after acquisition by TPK
Several Government-funded centers around the World

Diverse range of equipment from R&D to commercial manufacturing

Focus on hybrid electronics – many opportunities for equipment suppliers

Large EMS companies now very active with flexible/printed electronics
“...The comprehensive nature of the report saved us from spending a lot of money on market research. The report was indeed very helpful, and it covered most of the areas of opportunity that my team and I thought existed, and highlighted some other areas that we hadn't considered...“