Thin Film Electronics ASA (“Thinfilm”):

From stand-alone memory to integrated systems

8 September 2012

Davor Sutija, CEO
Presented at ICFPE
First product: Data Storage on a Label

20-bit • rewritable • non-volatile • disposable

5¢
Thin Film Electronics ASA

Pure-play printed electronics

Public company (THIN.OL) with global reach

- Focus on low cost printed memory & logic
- Founded 1990's as subsidiary of Opticom ASA
- Listed in Oslo January 2008 (ticker: THIN.OL)
- $100 Million Market Cap

Experienced management team

CEO: Dr. Davor Sutija
- PhD UC Berkeley; Mgmt & Tech, Wharton
- Founding CEO at SiNOR AS
- SVP at FAST, a Microsoft subsidiary
- Joined Thinfilm in 2000

CTO: Dr. Christer Karlsson
- PhD from Linköping University
- Deputy Director at the National Defense Research Establishment
- Joined Thinfilm in 2011

CFO: Torgrim Takle
- 6+ years in McKinsey & Company, managing corporate finance related projects
- Joined Thinfilm in 2011

North Am: Jennifer Ernst
- 20 Years Business Development and Marketing at PARC, a Xerox company
- 9 Years in printed electronics
- MBA from Santa Clara Univ.

Japan: Dr. Jiro Kasahara
- PhD from Waseda University, Tokyo
- Established Sony Fusion Domain Laboratory where he led the development of molecular and organic electronics
How it Works

Voltage is applied to the electrode

20V
0V
-20V

0V

Thinfilm Electronics confidential
Signal levels from R2R produced cells

Red dots indicate polarization by ferro-electric capacitance

Blue dots indicate polarization by bulk capacitance

Green lines indicate polarization due to leakage currents

Data from 5500 cells printed roll-to-roll
Rewritability and Retention

Reading and Re-Writing Memories

Reading and Writing at RT
No effect of storage at 60/80 C
Introducing PE in Toys & Games

► Right proving ground
  - High-volume, cost-sensitive consumer applications
  - Require safety and robustness (e.g. Patent-pending dual-layer protection)
San Francisco Exploratorium
March 1, 2012

VentureBeat
“Interactive adventure game wows Exploratorium crowds”
Thinfilm Product Progression
From Memory to Integrated Systems

**Memory**
- Standalone memory for toys and games

**Memory + Logic**
- Addressable memory for integration

**Integrated Systems**
- Sensor tags
- Display tags
- RFID & NFC
Thinfilm Addressable Memory

Key Milestones

- Program began early 2011
- Demonstrated October 2011
- Memory + Decoder = First printed memory + logic
- First building block for integrated systems
- FlexTech Innovation Award – February 2012
- IDTechEx Product Development Award – April 2012
- Technology Transfer in progress
Why "CMOS" TFTs?

- Reduce pad count
- Add product functionality
  - Read and store sensor data
  - Memory for display info
  - Wireless write and read

Why "CMOS"?
- Reduce power consumption
- Good product reliability and stability
Demonstration of addressable array memory

- Memory 12 WL x 2 BL (24 bits)
- Actual memory cell area ca 0.24 mm²
- Pads (large black rectangles) only for testing
- Decoder + passgates used to address the memory
- Done utilizing OTFTs

- Senseamplifier and waveform generation using external electronics
Using the decoder to address memory cells

Decoder logic:
1) Select a specific row
2) Pass enough voltage to switch memory polarization

Decoder allows $2^N$ fan-out, essential for scaling arrays

<table>
<thead>
<tr>
<th>N input</th>
<th>$2^N$ output</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>7</td>
<td>128</td>
</tr>
<tr>
<td>10</td>
<td>1024</td>
</tr>
</tbody>
</table>
Reading and Writing to Passive Arrays

The "V/3" Protocol

**READING DATA**

<table>
<thead>
<tr>
<th>AdWL</th>
<th>BL</th>
<th>BL</th>
<th>BL</th>
<th>BL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>V=0</td>
</tr>
<tr>
<td>V=0</td>
<td>V=0</td>
<td>V=0</td>
<td>V=0</td>
<td>V=0</td>
</tr>
</tbody>
</table>

**WRITING BACK NEW DATA**

<table>
<thead>
<tr>
<th>AdWL</th>
<th>BL</th>
<th>BL</th>
<th>BL</th>
<th>BL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>V=2V_d/3</td>
</tr>
<tr>
<td>V=2V_d/3</td>
<td>V=0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V=2V_d/3</td>
<td>V=2V_d/3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Voltage

Read/erase cycle

Write cycle

Adressed WL

All other Word Lines (Rows)

Bit Lines (Columns)

Time

Writing 0

Writing 1
Write and read of the memory

Oscilloscope traces

- Successful write and read!
- 0: large signal
- 1: small signal
- Memory tolerant to non-perfect waveforms
Processing of OTFTs

► Inkjetted electrodes
  ► Source, drain and gate
► Inkjetted semiconductors
► Global dielectric
► Design rule
  ► Linewidth=65 um (LW)
  ► Spacing=35 um (LS)
  ► Registration accuracy 20 um (RA)
Printed integrated systems

Example of tag types (integrated systems)

Sensor tag (temperature)

Dynamic price display

Wireless rewritable tag (towards NFC/RFID)

Smart Tags

Memory

- Thinfilm proprietary

Logic

- Co-development and exclusive license

Sensor

- Signed agreement with PST Sensors

Display

- Licensed leading low-cost display

Battery

- Secured privileged access to custom battery

Antenna

- Internal development and numerous external options
Smart Packaging – Why now?
The “Internet of Things”: a Megatrend

Gartner Identifies Top 10 Strategic Technologies
“...there has been an acceleration in the number and types of things that are being connected and in the technologies for identifying, sensing and communicating. These technologies are reaching critical mass and an economic tipping point over the next few years” October, 2011

IDC Intelligent Systems: The Next Big Opportunity
“The evolution of embedded systems from fixed function and disconnected systems to intelligent systems continues to gain momentum and puts intelligent systems on track to bring the Internet of Things to reality” September, 2011

McKinsey & Company The Internet of Things
“More objects are becoming embedded with sensors and gaining the ability to communicate. The resulting information networks promise to create new business models, improve business processes, and reduce costs and risks” McKinsey Quarterly, 2010

Commercial agreement with packaging giant Bemis

Bemis Company, Inc.

Forbes
“Thinfilm Pairs Up With Packaging Giant Bemis to Create Labels That Know Things”

- Global leader in flexible packaging
- 2011 net sales of $5.3 billion
- Innovation driven S&P company
Packaging & promotion applications

From...
- Pricing
  - Electronic shelf labels ($3-4/label)
  - Manual re-pricing of perishable goods

- Packaging
  - “Static” consumer packaged goods and POS displays
  - Existing technology too expensive

- Monitoring
  - Color changing labels
  - Data loggers only affordable per pallet

To...
- Dynamic/smart price display
  - Reduces manual labor, food waste

- Interactive packaging and POS displays
  - Adds functionality and differentiation

- Printed smart tags with sensors
  - Improves safety of food, pharmaceutical products
  - Reduces waste
Q&A