Roll-to-Roll Manufacturing of Advanced Touch Panel Devices

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Web Coating Group, AEP,
Applied Materials

Aimcal Europe, Prague, Czech Republic
Date: 11th June, 2012
Outline

- Applied Materials & The Mobility Age
- Touch Panel Production Equipment
- Current 150 Ω/□ Invisible ITO Performance
- Towards 100 Ω/□ Invisible ITO for Film Based Devices
- Influence of Scaling & Cathode Type on Productivity & CoO
- Summary
The Most Exciting Industries on Earth

**Semiconductor**

- **20,000,000x** reduction in COST PER TRANSISTOR in 30 years\(^1\)

**Display**

- **20x** reduction in COST PER AREA in 15 years\(^2\)

**Solar**

- **5x** reduction in COST PER WATT in 4 years\(^3\)

At 1976 transistor prices, an iPod® would have cost $3.2B

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1 Source: SIA, IC Knowledge LLC
2 Source: Display Search, Nikkei BP, Applied Materials
3 Source: Photon Consulting 2012
Mega Trends

The Mobility Age

Clean Energy
Enabling Mobility Age

More Transistors

New Architectures

Performance at Low Power

Moore’s Law Scaling

3D Transistors

Mobile End Markets
Mobility Creating “Fourth Wave” in Displays

- Laptop PC
- Desktop Monitor
- Large Screen TV
- Smart Phones and Tablets

LCD Revenue ($B)

- '95
- '96
- '97
- '98
- '99
- '00
- '01
- '02
- '03
- '04
- '05
- '06
- '07
- '08
- '09
- '10
- '11
- '12
- '13F
Opportunities in Mobile Displays

MOBILE
High-resolution
Thin and light
Rugged
Low power
Interactivity
Touch
Expanding portfolio to grow in new segments
## Mobile Application Demand Driving New Technologies

### SmartPhone and Tablet Demand

<table>
<thead>
<tr>
<th>Units (M)</th>
<th>2010</th>
<th>2012</th>
<th>2015</th>
<th>CAGR*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smartphone</td>
<td>297</td>
<td>685</td>
<td>1,254</td>
<td>33%</td>
</tr>
<tr>
<td>Tablets</td>
<td>18</td>
<td>109</td>
<td>225</td>
<td>67%</td>
</tr>
</tbody>
</table>

### CAGR* (area)

- Smartphone: 44%
- Tablets: 70%

Source: DisplaySearch, Applied Materials
Applied Inside Tablet PC

**Display**
Enabled by Applied Materials’ PE-CVD, PVD, Test, and Roll-to-Roll Equipment (>30% of tablet BOM*)

**Semiconductor**
Enabled by Applied Materials’ Silicon Systems Equipment - Microprocessor
- 256MB DRAM
- 16GB MLC NAND Flash
I/O Controller
Multi-Touch Controller (>20% of tablet BOM*)

Source: iFixit, UBS, Applied Materials

* Refers to % of Bill of Materials processed by Applied Materials equipment
SmartWeb™ Product

**System for Lab and Pilot production**
- Web Width: 400 – 600 – 800mm
- 3 Cathodes Per Drum
- 1 or 2 Drum System

**SmartWeb SL**

**System for Mass Production**
- Web Width: 1000 – 1400mm
- 6 Cathodes Per Drum
- 1 or 2 Drum System

**SmartWeb XL**
SmartWeb™ Modular Platform Architecture

Expansion Module Option
(thermal process or backside cathodes)

Primary Process Module
(up to 6 cathodes around temp controlled drum)

Unwinder Module

Interleaf Take-Up Option

Load Locks

Standardized interfaces for wide variety of cathode choices

Separately pumped process zones for excellent gas separation Option

Rewinder Module

Interleaf Pay-Out Option
Inline Process Monitoring & Control Necessary for Yield Enhancement in R2R!
Wide Variety of High Performance Sources

- High Utilization DC Planar Cathodes
- Super-High Utilization DC Rotatable Cathodes
- TwinMag™ Planar AC Cathodes for Dielectrics
- TwinMag Rotatable AC Cathodes for Dielectrics
- In-situ Pre-Clean/Pre-Treatment Sources

Delivering Flexible Process Capability
Rotary Cathode Technology for TP

- Continuous Target Rotation Ensures Clean Target Surface
  - Minimized Particle Buildup and Emission
    - Dramatically Reduced ITO Nodule Density
  - Maximized Process Stability and Target Utilization (> 80 %)
## Improving CoO & Performance

<table>
<thead>
<tr>
<th>Material</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Si</td>
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<tr>
<td>NbOx</td>
<td></td>
</tr>
<tr>
<td>ITO</td>
<td></td>
</tr>
<tr>
<td>MoNb</td>
<td></td>
</tr>
<tr>
<td>AlNd</td>
<td></td>
</tr>
</tbody>
</table>

### Cost Down

- **TU > 80%**

### Reduces Material Costs, Particles & Maintenance!
SmartWeb Highlights

- **Field Proven Technology**
  - Highest Install Base in Industry
  - Industry Leading Platform Serving Digital Resistive & Projective Capacitive Markets
  - Sputter up Configuration to Eliminate Particulate Incorporation

- **Best in Class Substrate Handling**
  - Minimized Number of Guide Rollers in Contact with the Coated Surface
  - Perfect Roller Parallelism

- **Superior Cathode Technology**
  - Demonstrated Process Stability
  - Best in Class Gas Separation
  - Best in Class Productivity
  - Multi Process Flexibility
  - Closed Loop Control
Invisible ITO (For Projective Capacitive Touch)

- Optical Matching Required for Patterned ITO Electrodes

Good Index Matching (Invisibility) Possible for Thin ITO Layers
## Benchmark Invisible-ITO™ on R2R HC-PET

<table>
<thead>
<tr>
<th>Rs (Ohm/Sqr)</th>
<th>Ty ITO (%)</th>
<th>b*</th>
<th>Ty no ITO (%)</th>
<th>b*</th>
<th>Ry ITO (%)</th>
<th>Ry no ITO (%)</th>
<th>Delta R / % (420-700nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>270</td>
<td>89.5</td>
<td>0.6</td>
<td>89.4</td>
<td>0.8</td>
<td>9.6</td>
<td>9.4</td>
<td>&lt; 0.7</td>
</tr>
<tr>
<td>200</td>
<td>88.7</td>
<td>0.85</td>
<td>89</td>
<td>0.9</td>
<td>11.4</td>
<td>10.7</td>
<td>&lt; 1.3</td>
</tr>
<tr>
<td>150</td>
<td>89.9</td>
<td>0.8</td>
<td>90.0</td>
<td>0.3</td>
<td>9.3</td>
<td>9.6</td>
<td>&lt; 1.8</td>
</tr>
</tbody>
</table>

### Notes:
- **Polymer (e.g. HC-PET)**: Invisibility Layers
- **TCO (e.g. ITO)**: Required for 5-10” PCT Devices-Trend Moving to 100 Ω/□ for > 10”

**Graph:** Transmission and Reflection 150 Ω/Sq invisible ITO

150 Ω/□ Required for 5-10” PCT Devices-Trend Moving to 100 Ω/□ for > 10”
Leading the Way to 100 Ohm/Sq.

- Improved ITO Performance for High Performance
  - Low Resistivity = Lower Thickness
  - Higher Transmission
  - Reduction in Reflection Difference & $b^*$

- ITO Resistivity Stability Before & After Annealing
  - Resistivity & Transmission Function of In/Sn Ratio* (O Vacancies & Sn$^{4+}$ Dopants)
  - Free electron concentration* maximized with 90% $\text{In}_2\text{O}_3$ /10% $\text{SnO}_2$
  - Carrier Density & Mobility Modulated During Anneal Process ($\text{SnO}_2$ Clustering)*

- Enhanced ITO Uniformity Required to Maximize Yield
  - High Performance Cathode Technology

Process Optimization for 100 Ohm/Sq.

- Metallic Working Points Provide Route to Lower Resistivity Material

Influence of Annealing/Lamination

- Anneal Process Typically Performed During Lamination Step
- Annealing Increases Charge Carrier Density & Hall Mobility*
  - Oxygen Vacancies Created by Desorption of Oxygen from Bulk Film $\rightarrow \rho \ & \ Rs \downarrow$
  - Interstitial/GB Oxygen Removed (Reduction in Density of Electron Traps)
  - Bulk Defect Density Reduction/Removal of Lattice Defects $\rightarrow Ty \ & \ \sigma \uparrow \rho \ & \ Rs \downarrow$

\[ \sigma = -Nq\mu \]

Significant Savings in Simple ITO

- Calculation Example:- R2R Invisible ITO Layer Stack 200 Ω/□

Remark:
Target Prices Depend Strongly on Yearly Consumption
Productivity & Cost Optimization

- Impact of Scaling & Cathode Technology
  - Calculation Example:- R2R Invisible ITO Layer Stack 200 Ω/□

- Expected Productivity Improvement by Scaling
  - 2 Drum vs 1 Drum
  - Significant Gain with Use of DC Rotatable Cathode Technology

- Cost/Area Cannot be Driven Down by Scaling Only
  - CoO Limited by ITO Cost
  - DC Target Utilization Dramatically Improved Using Rotatable Technology
Reinforcing a Touch-Panel World

- AMAT Offers Production Solutions for Foil Based Touch Panel Sensor Architectures
- Key Focus to Increase Scale and Reduce Cost
- Superior Cathode and Inline Metrology Technology Available to Maximize Yield
- 150 Ω/□ at 90 % Transmission Current Standard for 7-10“ Tablet Displays → Trend Moving to 100 Ω/□ for > 10 “
- Solutions Available to Increase Product Value for Both User and Touch Panel Manufacturer
- Prepared for Next Generation Touch Devices, Today
Reinforcing Touch-Panel World!

Turning innovations into industries.™

ありがとうございました
감사합니다
謝謝
Thank You
Danke Schön
Turning innovations into industries.
Choosing Substrate & Value Proposition

Scratch Resistant
Large Area
Narrow Bezel → Glass

Rigid plastic

Film

Shatterproof
Lightweight
Quick to Market

Flexibility

Lower CapEx

Thickness/Weight Reduction

Optical Performance

Film Conductivity

Hardness, Durability

AKT Aristo TWIN™

Dynamic Deposition
Glass and Rigid
Substrates

SmartWeb™

Roll-to-Roll Deposition
Polymer Film & Flexible Substrates

Key Manufacturing Requirements:
Process Freedom, Configuration Flexibility, Optimum Layer Properties
Recent R2R/Display Milestones:

- Released Higher Rate Planar Cathode Technology (*Productivity & CoO*)
- Qualified Multiple Target Suppliers Inclusive Rotary ITO (*Productivity & CoO*)
- Released Improved SiO₂ Process Closed Loop Control (*Yield*)
- Improved R2R ITO Resistivity to Meet 150 Ω/□ Demand (*End Product Value*)
- Invisible ITO BKM for Film Based Tablet Devices (*End Product Value*)
New Aristo Highlights

- Field Proven Technology
  - More Than 40 Systems for PCT Installed

- Rotary Target PVD Technology
  - Process Stability Even with Reactive Processes
  - Superior Particle Performance
  - Extended Uptime Due to High Target Utilization
  - Lowest ITO Resistivity
  - High Productivity
  - Superior Yield
Delivering Manufacturing Scale Driving Lower Costs

**FIRST**

Cost Per Transistor
20,000,000x cost reduction over 30 years\(^1\)

**THEN**

Cost Per Area
20x cost reduction over 15 years\(^2\)

**NOW**

Cost Per Watt
Toward grid parity

AT 1976 TRANSISTOR PRICES AN iPOD® WOULD HAVE COST $3.2B

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1 Source: SIA, IC Knowledge LLC
2 Source: Display Search, Nikkei BP, Applied Materials
This is Applied Materials official corporate overview last updated as of February 16, 2012.

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Make your presentation highly interactive.

Engage with your audience before you start your presentation and keep checking in that they are getting the information they need from you and from Applied Materials.
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Turning Innovations into Industries™

Presenter
Title
Applied Materials

Date
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AGENDA

Applied Materials Business Overview

Key Trends

Business Segments
VISION

We apply nanomanufacturing technology to improve the way people live.
WHAT WE DO

We make the **equipment** that makes the components that change the world.
Enabling and Accelerating Innovation

**Applied Materials** is the global leader providing innovative equipment, services and software to the semiconductor, flat panel display and solar photovoltaic industries.

**OUR STRENGTHS**

Thin film engineering
Commercializing sophisticated systems
Global reach
What Others Are Saying

- NEWSWEEK Magazine's Top Greenest Companies
- Ranks No. 3 in industry on FORTUNE Magazine's World's Most Admired Companies List
- Ranks Among Corporate Responsibility's 2011 "100 Best Corporate Citizens"
- Computerworld's 100 Best Places to Work in Information Technology
- Award of International Trade from the Ministry of Economic Affairs, Taiwan
- Modern Photovoltaics 2011 Top Ten Innovative PV Equipment Suppliers and PV TOP 50
- Named one of the Most Innovative Companies in the World
- SOHU.com Green Gold Nomination
- "Computerworld's 100 Best Places to Work in Information Technology"
The Global Strength of Applied

<table>
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<tr>
<th>Stock Ticker:</th>
<th>Nasdaq: AMAT</th>
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<tbody>
<tr>
<td>Market Cap:</td>
<td>$16.8 billion</td>
</tr>
<tr>
<td>Fiscal 2011 Revenue:</td>
<td>$10.5 billion</td>
</tr>
<tr>
<td>Fiscal 2011 R&amp;D:</td>
<td>$1.1 billion</td>
</tr>
<tr>
<td>Founded:</td>
<td>November 10, 1967</td>
</tr>
<tr>
<td>Headquarters:</td>
<td>Santa Clara, California</td>
</tr>
<tr>
<td>Global Presence:</td>
<td>87 locations in 19 countries</td>
</tr>
<tr>
<td>Fortune 500 Ranking:</td>
<td>259</td>
</tr>
<tr>
<td>RD&amp;E and/or Manufacturing Centers:</td>
<td>China, Germany, Israel, Italy, Singapore, Switzerland, Taiwan, United States</td>
</tr>
<tr>
<td>Employees:</td>
<td>~14,600 worldwide</td>
</tr>
<tr>
<td>Patents:</td>
<td>~9,500 issued</td>
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</tbody>
</table>

* Information as of Q1’12 except FY’11 amounts
  Fiscal year-end  October 30, 2011
Global Scale and Reach

More than $1Billion invested annually in RD&E
FY’11 Net Sales

$10.5 Billion Total

BY SEGMENT
- Silicon Systems Group: 51%
- Energy and Environmental Solutions: 19%
- Applied Global Services: 23%
- Display: 7%

BY REGION
- China: 24%
- Korea: 12%
- Taiwan: 20%
- Japan: 9%
- Europe: 11%
- North America: 19%

Fiscal year ended October 31, 2011
The Most Exciting Industries on Earth

Semiconductor

20,000,000x reduction in COST PER TRANSISTOR in 30 years

Display

20x reduction in COST PER AREA in 15 years

Solar

5x reduction in COST PER WATT in 4 years

At 1976 transistor prices, an iPod would have cost $3.2B

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3 Source: Photon Consulting 2012
Mega Trends

The Mobility Age

Clean Energy
Enabling Mobility Age

- More Transistors
  - Moore’s Law Scaling

- New Architectures
  - 3D Transistors

- Performance at Low Power
  - Mobile End Markets
Key Vectors for the Mobile Space

- Lower Power
  - New transistor architectures
  - Mobile DRAM

- Speed and Performance
  - Multi-core designs
  - Combo chip functionality
  - SSD cache
  - 2.5D interposer
Mobility Demands Ultra-Low Chip Power

All day battery life
Idle power
Instant on
New form factors
Always connected
Active power
High definition displays
Video playback
Multi-tasking
Audio playback
Eight hours talk time
One week standby time
Mobility Creating “Fourth Wave” in Displays

<table>
<thead>
<tr>
<th>Year</th>
<th>Laptop PC</th>
<th>Desktop Monitor</th>
<th>Large Screen TV</th>
<th>Smart Phones and Tablets</th>
</tr>
</thead>
<tbody>
<tr>
<td>'95</td>
<td></td>
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<td>'13F</td>
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</tbody>
</table>
Opportunities in Mobile Displays

Smartphones and tablets
Hi-resolution LCD
OLED
Smartphone to large and 3D
Touch everything
E-reader
Solar Learning Curve Accelerating

Source: Navigant Consulting, NREL, Solarbuzz, pvXchange, Morgan Stanley, New Energy Finance
Business Segments

- Semiconductor
- Display
- Energy and Environmental Solutions
- Applied Global Services
Semiconductor

Global leader in innovative equipment for the manufacture of advanced semiconductors

Systems are mainstay of virtually every advanced semiconductor factory

Leading position in majority of advanced chip processes

Launched 16 new products in 2011

* Source: Gartner, April 2011

Global expansion of consumer base will drive demand for mobile PCs, smart phones and other types of consumer electronics
Accelerating Innovation

- **Deposition**
- **Metals**
- **Inspection**
- **Plating**
- **Thermal**
- **Planarization**
- **Etch**
- **Implant**

**Collaborate earlier and deeper**
with customers on inflections

**Provide the broadest suite of solutions**
with unmatched integration benefits

**Extend the technology roadmap**
with fast cadence in product innovation

**Drive to atomic precision on interfaces**
with multi-chamber platforms

**Enable faster learning**
with Maydan Technology Center
Display

#1 in TFT-LCD equipment and services

Extending core equipment technology into new mobility segments

The equipment we build uses scale to help make flat panel TVs more than 20% larger each year without price increase

* Source: Gartner, April 2011

Exploring emerging display technologies, such as touch panel, flexible substrate and OLED which will drive the future of the screen
## Display Product Landscape

<table>
<thead>
<tr>
<th>Major End Products</th>
<th>Core Applications</th>
<th>Applied Materials Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>TV</td>
<td>CVD Array</td>
<td>PECVD</td>
</tr>
<tr>
<td>Monitor and Notebook</td>
<td>Array Test</td>
<td>EBT</td>
</tr>
<tr>
<td>Mobile phone</td>
<td>PVD Array</td>
<td>PiVot™</td>
</tr>
<tr>
<td></td>
<td>PVD Color Filter</td>
<td>New Aristo Color Filter</td>
</tr>
<tr>
<td>New TV</td>
<td>+ LTPS</td>
<td>KPX CVD</td>
</tr>
<tr>
<td>Tablet</td>
<td>+ Metal Oxide</td>
<td>CVD Metal Oxide</td>
</tr>
<tr>
<td>Smart Phone</td>
<td></td>
<td>PiVot Metal Oxide</td>
</tr>
<tr>
<td>Other High-performance Mobile</td>
<td>+ Touch</td>
<td>New Aristo Touch Panel PVD SmartWeb®</td>
</tr>
</tbody>
</table>

Expanding Portfolio to Grow in New Segments
Energy and Environmental Solutions

#1 PV Equipment Provider*

Powering the c-Si Roadmap
Driving down cost/watt and balance of system (BOS)

- Advanced cell technologies
- Both scale and technology
  - Greater efficiency
- Lower production costs
  - Grid parity

* Source: VLSI Research 2010

Accelerating global photovoltaic (PV) adoption by delivering cost-effective solutions that integrate technology, equipment and materials to improve factory productivity and increase cell efficiency.
PV Manufacturing Solutions Leadership

- Increased cell efficiencies
- Higher productivity
- Advanced automation
- Advanced Vision System
- Modular platform

Applied HCT Wafering Systems
- Best in class yield
- Highest productivity
- Thinner wafers
- Consumables reduction
- Upgradeable platform

Applied Baccini™ Cell Systems
- Increased cell efficiencies
- Higher productivity
- Advanced automation
- Advanced Vision System
- Modular platform

#1 Equipment Provider

Source: Ranked by VLSI
Helping customers lower costs, improve equipment and fab performance and maximize return on assets

Broad, flexible portfolio for custom solutions

Advanced predictive and diagnostic technologies

Innovative technology extension and conversion

World-class expertise and knowledge-base systems

Optimizing efficiency of semiconductor, display and solar factories through integrated services, spares, equipment and automation software.
Applied Global Services
Service, Equipment & Automation Software

FAB SERVICES
Supporting > 30,000 tools with ~3,000 field engineers
Innovative, flexible service solutions
   FabVantage™ benchmarking and assessments

EQUIPMENT
200mm semi, legacy solar and display,
Subfab dedicated R&D for emerging technology applications,
Comprehensive technology, productivity upgrades

FACTORY AUTOMATION SOFTWARE
Manufacturing Execution Systems (MES)
Equipment and Process Control (EES)
Batch Scheduling (SmartSched™)
We’re ready for incredible things. Whatever the next breakthrough, we are ready to provide the manufacturing solutions to make innovative ideas a reality.
Turning Innovations into Industries™

Presenter Name
email address

Learn more. Visit amat.com
Evolution of the Display Industry

1st Wave
- Laptop PC

2nd Wave
- Desktop Monitor

3rd Wave
- Large Screen TV

4th Wave
- Mobility

New Environment
- Mobility Focus
- No Gen Scaling
- Multiple Smaller Gens
- New Technologies
- Apple Influence
- Increasing Touch!

Source: Display Search, AKT
Exciting Times for PCT

Evolution of PCT Driven by:
- Cost Reduction
- Weight & Thickness Reduction
- Optical Appearance Improvement
- Reduced Energy Consumption

Apple iPad2

Samsung 7” Galaxy Tab

iPhone 4 Retina LCD

Galaxy 4.3” OLED

Nintendo 3DS

Dell 17” touch notebook

Amazon Kindle
Supporting a Multi-Player Value Chain

Touch Panel Value Chain

Source (value chain): Cypress Perform, 2008
Key Vectors for the Mobile Space

Lower Power

New transistor architectures
Mobile DRAM

Speed and Performance

Multi-core designs
Combo chip functionality
SSD cache
2.5D interposer
Mobility Demands Ultra-Low Chip Power

All day battery life
Idle power
Instant on
New form factors
Always connected
Active power
High definition displays
Video playback
Multi-tasking
Audio playback
Eight hours talk time
One week standby time
Opportunities in Mobile Displays

MOBILE
- High-resolution
- Thin and light
- Low power
- Interactivity
Opportunities in Mobile Displays

MOBILE
High-resolution
Thin and light
Low power
Interactivity
Growth Led by Projective Capacitive TP

- Total Area CAGR ~ 23%
- Projective Capacitive Touch Panel CAGR ~ 35%
  - By 2017, Projective Capacitive May Account for ~70% of Total Area

Source: DisplaySearch, July 2011

Key Driver of Growth
Cost Reduction!
Projective Capacitive Touch Panel

- **Construction**
  - Touch changes dielectric environment of x-y-capacitor
  - Some E-field lines are "projected" beyond the cover sheet

- **Size:** 3.5" to 30"

- **Advantages**
  - High durability and high optical quality
  - Multi-touch capability
  - Unaffected by surface debris or contamination

- **Disadvantages**
  - High cost touch technology
  - Finger or tethered pen use only

- **Market Trends**
  - Mobile, tablet and high end devices
  - Rapidly increasing market penetration
End Market Requirements Driving New Display Technology Adoption

**MOBILE**
- High-resolution
- Thin and light
- Low power
- Interactivity

**TV**
- Large size
- High-resolution
- Vivid color
- 3D
- Value

**TECHNOLOGY SOLUTIONS**
- α-Si LCD
- High-res LCD
- OLED

**TRANSISTOR SOLUTIONS**
- Metal Oxide
- LTPS

**EQUIPMENT OPPORTUNITY (vs. α-Si)**
- 1.3X
- 2X
Touch Sensor Technology Concepts

### Electronics
- \( \Delta V \)
  - Analogue Resistive Touch (ART)
  - Digital Resistive Touch (DRT)
  - Voltage Sensing (in-cell)
- \( \Delta I \)
  - Surface Capacitive Touch (SCT)
  - Reversing Ramped Field Capacitive (RRFC)
- \( \Delta C \)
  - Projected Capacitive Touch (PCT)
  - Charge-Sensing (in-cell or on-cell)

### Optics
- RF
  - Electromagnetic Resonance (EMR/Digitizer)
- IR
  - IR-LED & Detector Array (traditional IR)
  - Digital Waveguide Touch (DWT)
- Vis
  - Photo Sensor
  - Camera Based (as in-cell)

### Acoustics
- \( \Delta t \)
  - Surface Acoustic Waves (SAW)
- \( \{A(t)\} \)
  - Dispersive Signal Touch (DST)
  - Acoustic Pulse Recognition (APR)

### Mechanics
- \( \Delta F \)
  - Force Sensing

### TF-based technologies
- Interactions and combinations of technologies