Innovations in Touch Sensing
SID 2012 - Session M-3

Bob Mackey
Synaptics
Principal Scientist
Outline

- Overview of Touch Sensing Technologies
- Why Capacitive?
- Sensing is Part of a Complex System
- Where is the Sensor?
- What Is (or Should) the Sensor be Made Of?
- Summary
Overview of Touch Sensing Technologies
Worldwide Touchscreen Shipments Continue to Increase

Worldwide Touchscreen Unit Shipments

Source: iSuppli

25% CAGR
Premium segment: Thinness, Industrial Design, Performance and Features most important decision criteria
Entry-level segment: total touch system cost driving decisions

Source: IMS Research, Jeffries, IDC 2011; SYNA Estimates
Overview of Touch Sensing Technologies

- Resistive
  - 4-wire
  - 5-wire
  - Matrix

- Capacitive
  - Surface
  - Projected
    - Trans-Capacitance (Mutual)
    - Absolute-Capacitance (Self)

- Acoustic
  - SAW
  - Bending wave

- Optical
  - Frustrated Internal Reflection
  - Above-surface (IR)
Touch Sensing Market Drivers

**Powerful Computing, Wireless, & Graphics Technology**

**Data-Rich Information Available Anytime, Anywhere**

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Synaptics Customized Human Interface Solutions

- Advanced User Interfaces
- New Usage Models
- Sleek Industrial Designs
Capacitive Families

- Surface Capacitive
- Projected Capacitive
  - Absolute capacitive (aka “self-capacitance”)
  - Trans-Capacitive (aka “mutual capacitance”)
Capacitive Sensing Families

- Surface Capacitive

- Projected Capacitive
  - Absolute capacitive (aka “self-capacitance”)

- Trans-Capacitive (aka “mutual capacitance”)

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In-Cell Capacitive Touch-Display Integration

Session 37: Projected-Capacitive Touch Panels
Wednesday (6/6) / 3:30 PM - 4:50 PM / Room 210A

37.1 - An In-cell Capable Capacitive Touch-Screen Controller With 41-dB SNR and Integrated Display Driver IC for 480 x 864 LTPS Displays
(3:30 PM - 3:50 PM)

Sony Xperia
Tablet Computers

Samsung

Huawei
Why Capacitive?
Advantages of a Capacitive Solution

- **Poor optics** due to internal air gap and reflections
- **Limited UI**, having no **multi-finger capability** such as Pinch
- **Moving parts** – requires maintenance as unit starts to wear down
- **Annoying to users**
  - Requires recalibration on a regular basis
  - Becomes non-responsive at temperature extremes
  - Needs constant finger pressure for scrolling gestures – finger must travel up and over Spacer Dots

- **Superior touch performance**
  - Tunable sensitivity and highly responsive
- **Feature rich** gesture support
  - 10 or more finger recognition
- **Durable**
  - Resistant to: Vandalism, Scratches, and Shock/Vibration
  - Mounted under glass or plastic
- **Optically CLEAR**
  - Sensor pattern invisible to the naked eye
  - High transmission rates, low reflectance, low haze, high color purity
- **Thin** and near **borderless** design
- **Accommodating** to various types of cover lens
Touch Processing

- Control sensor electrodes to generate raw data
  - Noise avoidance via multiple techniques: Frequency Shifting, CDM, etc…
- Process data to convert to Image data
- Derive and report data about finger touches (position, width, gestures)

\[(x, y, w, z)_1\]
\[(x, y, w, z)_2\]
\[(x, y, w, z)_3\]

Data Acquisition
- Tx signals generated
- Rx conversion via A/D
- Noise avoidance

Frame Processing
- Collect and Scale Capacitance
- Remove Common Mode Noise
- Gain Compensate
- Apply Thresholds

Object Processing
- Segmentation
- Track Objects
- Classify Objects
- Calculate and Report Positions
Gesture Interpretation ➔ Computer Actions

**Tap and Double Tap.**
- Light touch action – selects application

**Flick**
- Next Page of Icons, Fast directory search, Next Photo etc. ..

**Scrolling**
- Slider for message forward, volume, contrast, directory search control etc..

**Proximity detection**
- LCD screen wake up

**Multi Finger gestures**
- Pinch for zoom
- 2 Finger rotate (photo rotate)
- Two finger flick
- Bring up new menu
- Simple games
Human In-The-Loop

Data Acquisition

Frame Processing

F1 = (x, y, w, z)_1
F2 = (x, y, w, z)_2

Object Processing

Gesture Interpretation

User Action

User Perception

Computer Output

Computer Action

"Zoom"

"Pinch"
Touch “Language”

Windows 8 Touch Language

- Press and hold to learn
- Tap for primary action
- Slide to pan
- Swipe to select
- Pinch and stretch to zoom
- Swipe from edge for system and app commands
- Turn to rotate

Windows 8 Modern TouchPad Gestures (Core Seven Gestures)

- Mouse Cursor Manipulation
- Primary Button Click/Tap, Double Click/Double Tap
- 2F Scrolling w/inertial scrolling
- 2F Pinch Zoom
- Right Edge Swipe (Charsms Bar)
- Top Edge Swipe (Application Bar)
- Left Edge Swipe (Previous App)

Additional Synaptics Windows 8 TouchPad Gestures

- 2F TwistRotate (Next/Previous)
- 3F Flick (App Control)
- 4F Flick (OS Desktop and App Control)
- 2F Right Click Modern (Secondary Button)
- 1F Right Click Classic (Secondary Button)
Direct and Indirect Gestures

Windows 8 Touch Language

Direct / Touchscreen

- Press and hold to learn
- Tap for primary action
- Slide to pan
- Swipe to select
- Pinch and stretch to zoom
- Swipe from edge for system and app commands
- Turn to rotate

Windows 8 Modern TouchPad Gestures (Core Seven Gestures)

- Mouse Cursor Manipulation
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+ Additional Synaptics Windows 8 TouchPad Gestures

- 2F Twist Rotate
- 3F Flick (Next/Previous)
- 4F Flick (OS Desktop and App Control)
- 2F Right Click Modern (Secondary Button)
- 1F Right Click Classic (Secondary Button)
Where is the capacitive sensor?
Where is the capacitive sensor?
Where is the capacitive sensor?

Sensor-On-Lens

Thinner Design
Discrete Sensor Eliminated

Cover Lens
Display
Phone Body
Where is the capacitive sensor?

On-Cell

Thinner Design
Discrete Sensor Eliminated

Cover Lens
Display + Sensor
Phone Body
Where is the capacitive sensor?
Where is the capacitive sensor?
Where is the capacitive sensor?

In-Cell

Thinner Design
Discrete Sensor Eliminated

Cover Lens
Display + Sensor
Phone Body
Where is the capacitive sensor?

- Receivers
- Color Filter Glass
- Transmitters
- TFT Glass
Where is the capacitive sensor?
Where is the capacitive sensor?

1: top of lens  
2: bottom of lens  
3: discrete sensor (top/middle/bottom)  
4: polarizer  
5: on top of CF  
6: CF glass  
7: TFT glass
Where is the capacitive sensor?

1: top of lens  

- Scratches easily
- Too close to finger
- Where to attach electronics?
Where is the capacitive sensor?

Lens

Polarizer

Color Filter

TFT

2: bottom of lens

- Good for sensing
- Widest sensing area
- Cut-first vs Harden-first?
Where is the capacitive sensor?

- **3: discrete sensor** (top/middle/bottom)
- Industry Standard
- Glass or PET
- Face-up or Face-down
- Many suppliers
- Can use a shield layer
Where is the capacitive sensor?

Lens

Polarizer

Color Filter

TFT

4: polarizer

- Polarizer is already $$
- Highly constrained by LCM
- Sheet or R2R?
Where is the capacitive sensor?

- “On-Cell”
- 2-sided CF processing
- Allows integration with display
- Limited to display size
- Fewer layers

5: on top of CF
Where is the capacitive sensor?

- 2-sided CF processing
- Display noise
- Requires integration with display
- Limited to display size
- Thin & Low Cost

6: CF glass
Where is the capacitive sensor?

- 2-sided CF processing
- Display Synchronized
- Requires integration with display
- Limited to display size
- Thin & Low Cost
- High Performance

6: CF glass
7: TFT glass
Where is the capacitive sensor? (SID Boston 2012)

- With IPS, “Vcom” is on the TFT glass
- Display Synchronized
- Requires integration with display
- Limited to display size
- Thin & Low Cost
- High Performance

7: IPS TFT glass

Diagram:
- Lens
- Polarizer
- Color Filter
- TFT

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Touch + LCD Integration

**On-Cell**
Both touch Tx and Rx are on top of the color filter glass

The “Cell” is between the Color Filter Glass and TFT Glass

**In-Cell**
Tx and/or Rx are located “in the cell” (below the top of the color filter glass)
Ultra-Thin Sensors & Supply Chain Efficiency

Display Integration:
~ 0.7 to 1.0 mm thinner

Discrete Supply Chain Involves Several Suppliers

Supply Chain Simplified with Display Integration
Display Integration Sensor
Definition

On-Cell
Both touch Tx and Rx are on top of the color filter glass

In-Cell
Tx and/or Rx are located “in the cell” (below the top of the color filter glass)

The “Cell” is between the Color Filter Glass and TFT Glass
Create Thinner Stackup Through Display Integration

3.5 mm

Display Integration
~ 0.7 to 1.0 mm thinner

2.5 mm

Today’s Supply Chain is Complicated, Expensive and Time-Consuming

Display Integration with Series 3 and Series 4 is Simplified and Convenient

Reduced Complexity
IPS In-Cell Manufacturing Efficiency Advantage

**For Tx:** Thin Film Transistor (TFT) Layer
(TOP VIEW)

IPS Display VCOM is Segmented by Design

In-Cell with IPS Have “gang” or group Segmented VCOM for Tx

**Process 1 – No Cost**
Change already segmented ITO to “gang” or group to create the necessary In-Cell Tx

**For Rx:** Color Filter Glass (CF) Layer 
(TOP VIEW)

Process 2 – Low-Cost
1-Layer ITO mask after cell assembly and etching on top of CF to create Rx

Rx Location On CF Glass

**In-Cell Efficiency Advantage**

- Rx: 1 additional process
- 1-Layer most likely ITO process
- 1-Layer Low-Temp Rx process key to prevent LCD damage
- Tx: No additional process
- Mask change only to segment VCOM for Transmitters on TFT

“Synaptics in-cell and TDDI offerings are patent pending”
ClearPad 325x In-Cell

- Single Chip for 2D + 0D Buttons
- Synchronization
  - Frame and Row
  - Sleep & Low Power
- 2 Chip Solution (Touch + DDI)
  - Separate Communications and Power
  - Separate Flex and Connectors
- Key Advantages
  - Full synchronization with display Vertical Alignment and IPS Option
  - Flexible Resolution

**Key Advantages**

- Full synchronization with display Vertical Alignment and IPS Option
- Flexible Resolution

**Integrated Sensor**

- Synaptics 325x Touch Controller
- Host Processor and Display Accelerator
- DDI
- Touch Data I2C/SPI
- Synchronization Signals
- Image/Video Data MIPI / RGB
- Vcom & Tx
- Pixel Lines
- Rx

**Synaptics in-cell and TDDI offerings are patent pending**
ClearPad Series 4 Overview

- Single Chip for 2D + Buttons
- Shared Display / Touch Glass
- Single Chip Solution (Touch / DDI)
  - Internal synchronization
  - Internal Transmitter Voltage Control
- Key Synchronization Advantages
  - Full synchronization of Touch and DDI
    - On-Cell Synchronization
    - In-Cell Synchronization (VA or IPS)
    - Discrete Synchronization
    - Sensor-on-Lens Synchronization
- TDDI is capable of user-input and feedback without action from the host processor
  - Can manage power-up of display and the host processor upon touch of display

Series 4 In-Cell Display

- Synaptics Touch / DDI
- Integrated Display
- 10F Multi-touch, 60-120 Hz

Synaptics Series 4 Touch / DDI

- Host Processor and Display Accelerator
- Image/Video Data MIPI / RGB
- Touch Data I2C/SPI

Integrated Sensor

- Buttons
- Vcom & Tx
- Pixel Lines

Synaptics in-cell and TDDI offerings are patent pending
Overlay Capabilities

- The host can configure the overlay properties by programming the display configuration blocks of the flash memory.
  - Currently supported in TDDI Tool (with planned migration to Design Studio™)
  - Interface is open, allowing full customization with customer software over any DCS interface (MIPI, CPU, SPI)

- In addition to the overlay image itself, the following image manipulation operations can be configured:
  - Image Fade-in / Fade-out, including fade rates
  - Animation Sequences (created using multiple images)
  - Image Positional Translation, e.g., linear motion or others?
Series 4 TDDI Enabled Features

- **Wake-up Gesture Capability**
  - TDDI provides fast and simple “Wake-up” by internal processing without communicating to Device-drivers, Application CPU

- **Log-in Screen with Graphics and/or Text**
  - Display sprites and/or graphics such as Clock with overlay memory
  - Overlay memory: no host processor and graphics processor are needed to show log-in screens and status icons/information

- **No-Delay Haptic Driver**
  - Provide a driving signal automatically to haptic amplifier
  - Location-based haptic; Application specific behavior

- **Optimized Multiple Power Mode**
  - Save power consumption by customized power setting
  - Gesture, Log-in, Haptic while host CPU stays in sleep mode

- **Built-in UX**
  - Easy to add new UX features
  - One example is Power On/Off with Gesture
Series 4 Latency Benefit: Faster Response

Older Capacitive Implementation

1 Latency Cycle < 70 ms

Touch Detected and Processed

Display Video Output

Host processed icons contribute to end-user latency

Host Processing

Series 4 TDDI Direct

Series 4 1 Latency Cycle < 20 ms

Touch Detected and Processed

TDDI Direct

Display Video Output

One Chip Solution

With Series 4, touch and video are directly linked to reduce latency 3x

Host Processing

Reduced latency with Touch Sprites
Reduced power consumption
Host processor freed up for Applications

Synaptics in-cell and TDDI offerings are patent pending
World’s first integrated Touch and Display Driver IC in a single IC
- Full in-cell support
- Multi-Finger Touch Support
- Industry-Leading DS4 support
- Supports 3D displays
Further Details on Touch-Display Integration

- Session 37: Projected-Capacitive Touch Panels
  Wednesday (6/6) / 3:30 PM - 4:50 PM / Room 210A

37.1 - An In-cell Capable Capacitive Touch-Screen Controller With 41-dB SNR and Integrated Display Driver IC for 480 x 864 LTPS Displays
(3:30 PM - 3:50 PM)

- Murat Ozbas, Jeff Lillie, Imre Knausz, Chris Ludden, Dave Gillespie, Tom Mackin

- An integrated touch control and display driver IC on a single die is presented. The integrated solution is capable of driving WVGA (480x864) resolution low temperature polysilicon LCDs with multi-touch support for in-cell and on-cell projected capacitive touch sensors. Capacitive touch sensing on a 24 x 24 array with a touch pixel pitch as small as 3 mm on 4.5 inch displays is supported.
Q: Which is the Best Choice?

A: Depends on Your System needs

- Sensor on Lens
- Discrete Sensor
- On-Cell
- In-Cell
- Touch-Display Integration
Systems Engineering
Q: What is the System?
Q: What is the System?
A: To a Systems Engineer, EVERYTHING is part of a System
Information Flow

Eyes → Brain

Brain → Finger

Finger → Touchscreen

Touchscreen → Display

Display → CPU

CPU → Eyes
Information Flow

TouchController → Eyes → Brain

CPU → Display → Touchscreen → Finger
Electrical currents and photons must share the same region without interacting
But…. photons and electrons crash into each other
Transparent Conductors
Electrons and Photons

- **Good Conductors:**
  - Electrons are free to move
  - Metals
  - Opaque
  - Reflective

- **Good Transparent Materials:**
  - Electrons do not respond to passing electric fields
  - Glasses, plastics
  - Uniform index of refraction (no scattering / haze)
  - Insulating
Transparent Conductors?

- Generally not very transparent
- Generally not very conductive

<table>
<thead>
<tr>
<th></th>
<th>Transparency (%)</th>
<th>Resistance (Ω)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metals</td>
<td>&lt;&lt;1% T</td>
<td>&lt;&lt;10⁻¹ Ω/</td>
</tr>
<tr>
<td>ITO</td>
<td>90-95% T</td>
<td>~300 Ω/</td>
</tr>
<tr>
<td>Glass</td>
<td>&gt;&gt;99% T</td>
<td>&gt;&gt; 10⁶ Ω/</td>
</tr>
</tbody>
</table>
Structured materials can combine the best properties of both

- Choose 1% Metal + 99% Glass

<table>
<thead>
<tr>
<th></th>
<th>Metals</th>
<th>ITO</th>
<th>Glass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmittance (%)</td>
<td>$&lt;&lt;1%$ T</td>
<td>$90-95%$ T</td>
<td>$&gt;&gt;99%$ T</td>
</tr>
<tr>
<td>Resistance ($\Omega$/cm)</td>
<td>$&lt;&lt;10^{-3}$</td>
<td>$\sim300$</td>
<td>$&gt;&gt;10^6$</td>
</tr>
</tbody>
</table>

- $\sim1\ \Omega/$ and 99% T

- Make the wires small enough to be “invisible”
Structured Transparent Conductors

- Metal Mesh
- Silver Nanofibers
- Carbon Nanotubes
- Graphene
- And Others…
Structured Transparent Conductors

- Metal Mesh
  - 3M
  - FujiFilm
  - PolyIC
  - Etc…
- Silver Nanofibers
- Carbon NanoTubes
- Graphene

3M™ Unpatterned Transparent Conductor 88xx vs. PET ITO Technical Data Sheet (TDS) Values of Transmission % vs Surface Resistance*

Surface resistance is directly related to EMI Shielding: Lower R = Higher EMI Shielding

*Technical Data sheets value reviewed is for general reference only as the TDS values were derived using different test equipment & modified versions of ASTM D1003 and sample set-up.
Structured Transparent Conductors

- Metal Mesh
  - 3M
  - FujiFilm
  - PolyIC
  - Etc.
- Silver Nanofibers
- Carbon NanoTubes
- Graphene

SID 2008

**Novel Transparent Conductive Film**

*New technology combined with the Shield Rex film for PDP*

**Features**

1. Ultra High Conductivity: Surface resistance 0.3Ω/
2. High Flexibility: Stable conductivity even after repeated bending.
   (4mmφ, bend test 100 times.)
3. High Transparency: Transparency over 80%.
4. Seamless Pattern: Seamless/Continuous fine conductive line pattern.
Structured Transparent Conductors

- Metal Mesh
  - 3M
  - FujiFilm
  - PolyIC
  - Etc.
- Silver Nanofibers
- Carbon NanoTubes
- Graphene
Structured Transparent Conductors

- Metal Mesh
  - 3M
  - FujiFilm
  - PolyIC
  - Etc.
- Silver Nanofibers
- Carbon NanoTubes
- Graphene

**Transparent Conductive Films**

*ITO substitute for flexible applications*

**Characteristics**

<table>
<thead>
<tr>
<th>Property</th>
<th>Typical Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transparency</td>
<td>&gt; 85%</td>
</tr>
<tr>
<td>Sheet resistance</td>
<td>Customer specific</td>
</tr>
<tr>
<td>Min. structure size</td>
<td>10 μm</td>
</tr>
<tr>
<td>Thickness</td>
<td>36 – 100 μm</td>
</tr>
<tr>
<td>Substrate</td>
<td>PET</td>
</tr>
<tr>
<td>Conductive material</td>
<td>Metals (e.g.: Ag)</td>
</tr>
<tr>
<td>Additional wiring</td>
<td>Customer specific</td>
</tr>
<tr>
<td>Form of delivery</td>
<td>Roll</td>
</tr>
</tbody>
</table>

**Transmittance [%]**

**Sheet Resistance [μΩ/sq]**

**Transmission without substrate [%]**

© PolyIC 2011
Structured Transparent Conductors

- Metal Mesh
- Silver Nanofibers
  - Cambrios
  - Carestream
  - BlueNano
  - Others?
- Carbon Nano Tubes
- Graphene

ClearOhm™ is available as ink or coated film

Transmission vs. Sheet Resistance

http://cambrios.com
Structured Transparent Conductors

- Metal Mesh
- Silver Nanofibers
  - Cambrios
  - Carestream
  - BlueNano
  - Others?
- Carbon NanoTubes
- Graphene

μm size gaps between ~100nm wires
Structured Transparent Conductors

- Metal Mesh
- Silver Nanofibers
  - Cambrios
  - Carestream
  - BlueNano
  - Others?
- Carbon NanoTube
- Graphene
Structured Transparent Conductors

- Metal Mesh
- Silver Nanofibers
  - Cambrios
  - Carestream
  - BlueNano

Conductivity
Sheet resistances down to $R_s = 8 \, \Omega/sq$

Transparency
Up to 93% due to nanowires’ small cross section & shadow area

Production volume
Scalable to millions of square meters per year

http://www.bluenanoinc.com/
Structured Transparent Conductors

- Metal Mesh
- Silver Nanofibers
- Carbon NanoTubes
  - Many suppliers
    - Eikos
    - Canatu
    - SWeNT
    - Unidym
    - Mitsui
    - Cheil
    - LG Chem
    - Top Nanosys
- Robust
- Flexible
- Non-reflective
- Somewhat absorbing (gray)

Image courtesy of wikimedia.org
Structured Transparent Conductors

- Metal Mesh
- Silver Nanofibers
- Carbon NanoTubes
  - Extremely Durable
  - Many Patterning Methods
    - Inkjet, shadow mask, silk screen, gravure, etc…
- Wide range of applications
- But still too gray for most touchpanel use

http://www.swentnano.com/tech/docs/sid_nano.pdf
http://en.wikipedia.org/wiki/Transparent_conducting_film
Structured Transparent Conductors

- Metal Mesh
- Silver Nanofibers
- Carbon NanoTubes
- Graphene
Organic Transparent Conductors

- Metal Mesh
- Silver Nanofibers
- Carbon Nano Tubes
- Graphene
- PEDOT:PSS
  - Flexible polymer
  - Blue color
  - Less stable than inorganic alternatives
  - AGFA Orgacon™
  - Heraeus Clevios™ (was Bayer Baytron™)
  - Kodak - new PEDOT is almost colorless
    - New etchants for invisible patterns
## Organic Transparent Conductors

- Metal Mesh
- Silver Nanofibers
- Carbon NanoTubes
- Graphene
- PEDOT:PSS
  - Stability ?
  - Color ?
  - AGFA Orgacon™
  - Heraeus Clevios™ (was Bayer Baytron™)
- Kodak →
  - new almost colorless
  - New etchants make invisible patterns

### New Improved Performance

<table>
<thead>
<tr>
<th>KODAK HCF-350 Film</th>
<th>New Offering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Resistivity</td>
<td>350 ohms per sq</td>
</tr>
<tr>
<td>% VLT</td>
<td>85%</td>
</tr>
<tr>
<td>Haze</td>
<td>Less Than 3%</td>
</tr>
<tr>
<td>Color</td>
<td>L* 94.43, a* -0.3, b* -0.6</td>
</tr>
</tbody>
</table>

Brian Johnston

FlexTech2011
Transparent Conductors
Current State of the Art

- Capacitive Touch Sensing continues Rapid Growth
  - Volumes Increase / Costs Pushing Down
- Requires “Transparent Conductors”
  - …which often aren’t so transparent, and not very conductive
- ITO may be expensive, but…
  - Fits the existing supply chain
  - Offers invisible patterns when used with good index matching
- Structured micro- or nano-materials offer a better combination of optical transparency + electrical conductance
  - Metal Mesh – 3M, PolyIC, etc.
  - Silver Nano-Fibers – Cambrios ClearOhm is the leader
More Systems

- Supply Chain
- Manufacturing Processes
- Cell Phone
  - Radio
  - Computer
  - Display
  - Touch
  - Power Management
  - Etc…
More Systems

- Supply Chain
- Manufacturing Processes
- Cell Phone
  - Radio
  - Computer
  - Display
  - Touch
  - Power Management
  - Etc…
Manufacturing Process Flow

Design → Order materials → Receive materials → Anneal ITO → Mask Making

Pattern ITO → Etch ITO → Strip → Print Metal → Punch 1

Laminate → Punch 2 → Inspect → FPC Attach → Test

Ship
Manufacturing Process Flow

Design → Order materials → Receive materials → Anneal ITO → Mask Making

Pattern ITO → Etch ITO → Strip → Print Metal → Punch 1

Laminate → Punch 2 → Inspect → FPC Attach → Test

Ship

Design Change!
Manufacturing Process Flow

- Design
- Order materials
- Receive materials
- Anneal ITO
- Mask Making
- Pattern ITO
- Etch ITO
- Strip
- Punch 1
- Laminate
- Punch 2
- Inspect
- FPC Attach
- Inspect
- Test
- Ship

Design Change!

- Metal Mesh Patterned Roll
  - 3-8 weeks?

Time-to-Market favors processes with later customization. Long lead times can be a killer in consumer electronics.
Summary

- Capacitive Sensing
  - Light Touch
  - Complex Interfaces
  - Gestures
  - Durable
  - Smooth Integration

- Touch Sensing Systems
  - ASIC
  - Sensor
  - Firmware / Software
  - Display
  - User Interface
  - Supply Chain
  - User

- Transparent Conductors:
  - ITO – available now
  - Metal Mesh – lowest resistance
  - PEDOT, Graphene, CNT…
  - Metal NanoFibers – flexible, low cost, could replace ITO

- Where is the Sensor?
  - Sensor on Lens
  - Discrete Sensor
  - Display Integration

- Best Design:
  - The one that best solves your System needs
Thank You!

Bob Mackey
Principal Scientist
Synaptics
bmackey@synaptics.com
Bob Mackey, Principal Scientist, Synaptics

Since 1996, Bob Mackey has been developing new technology in the flat panel display and touch sensing arenas. He joined Synaptics in 2002, developing a number of new touch sensing techniques, including the ClearPad transparent capacitive sensing platform, which is used in mobile phones, remote controls, and music/video players. Mackey holds more than thirty patents in the display and touch sensing fields. He did his graduate research in Materials Science at UCSD and NRL, and has a Bachelor of Science degree in chemistry from Caltech. Mackey is a Hertz Fellowship recipient.

Other interests include distilling brandy, large-scale pyrotechnic performance art, and building and flying various types of aircraft.