Metal Mesh: Enabling Thin, Light and Flexible Devices

2016 IHS Korea Display Conference

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September 8, 2016

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UniPixel Introduction

- A leader in metal mesh Touch Sensors (XTouch) and hardcoat technology (Diamond Guard)
- Acquired key XTouch IP from in 2015 (Atmel's XSense)
- **Gaining momentum with multiple design wins in 2016**
- **Over 1.5 million sensor units shipped to date**
- 70+ employees; 5 PhDs
- 60 issued patents (34 US) + 141 pending patents (71 US)
- Headquarters in Santa Clara, CA; Manufacturing in Colorado Springs, CO; R&D in Houston; Sales offices in Taiwan, Houston, and Santa Clara.
- NASDAQ: UNXL

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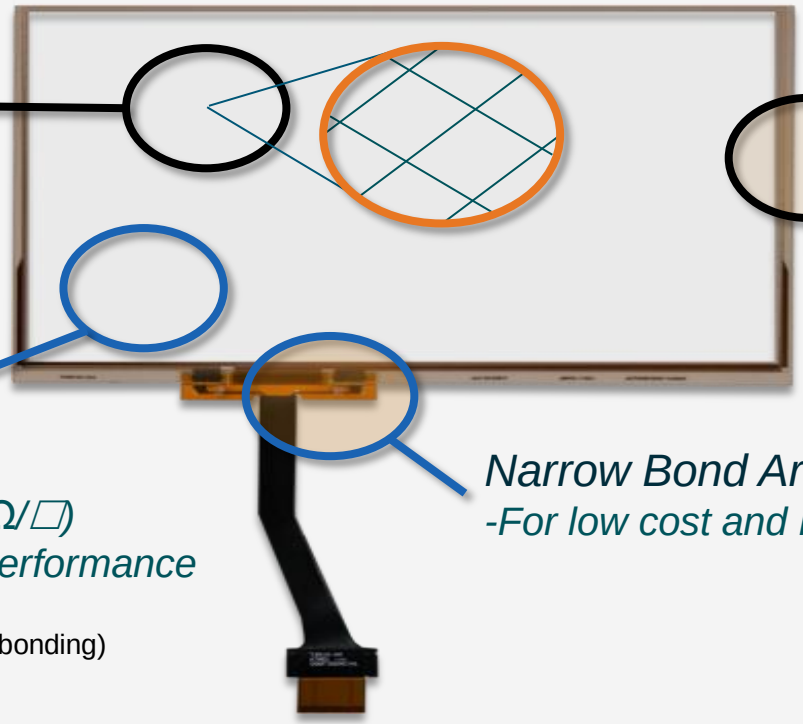
XTouch Introduction

Flexible metal mesh sensor material enables innovative product designs



Copper-based mesh
*~90% light transmission**
-For brighter display

Thin borders
-For reduced weight and size

Advanced Sensor Pattern
-Low Sheet Resistance (<10 Ω/□)
for Finger Touch and Stylus Performance

Narrow Bond Area
-For low cost and high reliability

(* With anti-reflective coating or optical bonding)

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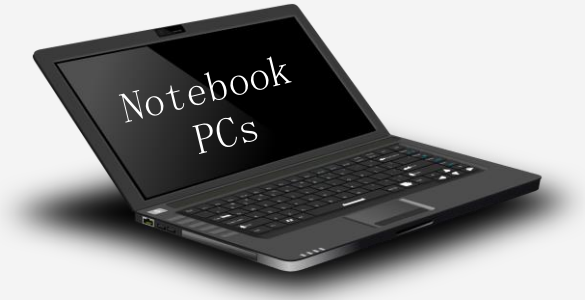
XTouch Design Wins in 2016 Portend Growth of Metal Mesh



Multiple Announced Design Wins Across Multiple Categories

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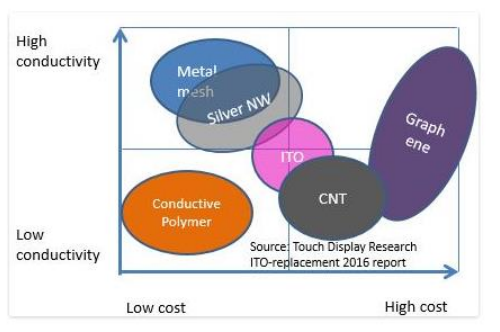
Industry Analysis Predicts Growth of ITO-replacement Technologies



Source: Touch Display Research Inc., ITO-Replacement Report, January 2016

Units (000s)	2016	2017	2018	2019	2020
Metal Mesh	5,802	6,650	7,334	7,919	8,406
Nanowires	959	1,578	1,719	1,794	1,873
Grand Total	6,761	8,228	9,053	9,714	10,279

Source: IHS Q12016 Touch Panel Tracker.

"The ITO-replacement industry has made good progress in the touch panel and other applications in the past two years …"

"We forecast that ITO-replacement will become the major transparent conductor for touch panels after 2021. ITO will be the minor transparent conductor for touch panels."

- Dr. Jennifer Colegrove, CEO and principal analyst of Touch Display Research Inc.

Market Driving Towards Thinner, Lighter & Pen-Input Devices

HP Spectre Pro 13.3”

Dell Latitude 12” 7000

Lenovo LaVie 13.3”

MacBook 12”

Surface Pro 4 12”

Thinner

Lighter

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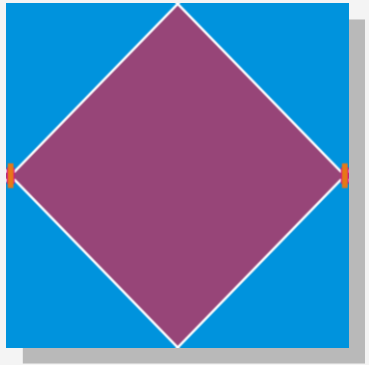
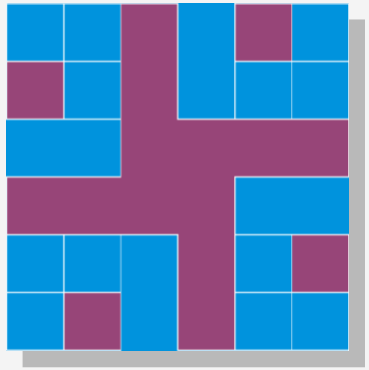
Low Effective Resistance is an enabler of superior touch and stylus performance, thin bezel width, reduced Z-height, and lighter weight.

Effective Resistance: Sheet Resistance

- **Two key factors in Effective Resistance**
  - Bulk material sheet resistance
  - Sensor electrode pattern
- **Typical bulk sheet resistance**
  - ITO GFF: 150Ω/□
  - OGS: 50Ω/□
- **XTouch metal mesh: <10Ω/□**

Effective Resistance: Sensor Electrode Pattern





Diamond: >6□/node or more
Single node (OGS) = ~320 Ω

XTouch: 1-2□/node
Single node= 20 Ω

More □/node = higher total electrode resistance

Lower R = Better Sensor Performance

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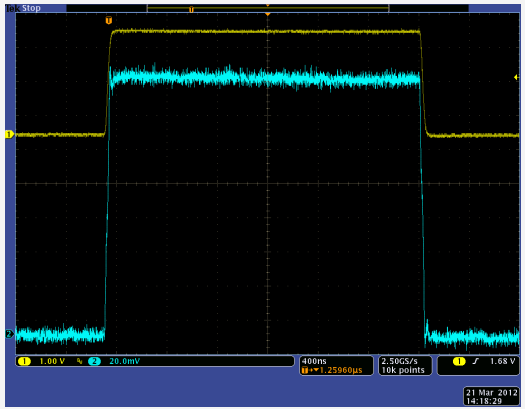
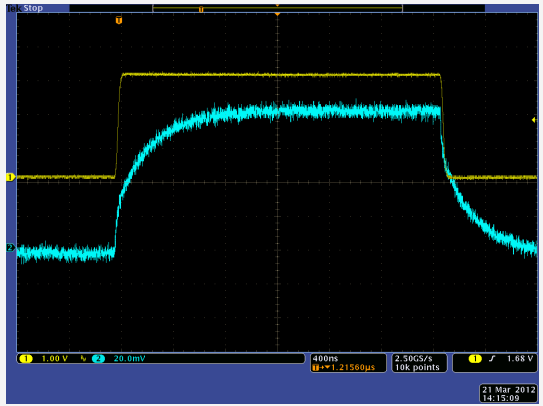
Fastest Touch Performance

Fast XSense charge time offers multiple benefits including improved noise immunity, lower power consumption, and faster responsiveness



4.3" XTouch sensor charge time is <100ns



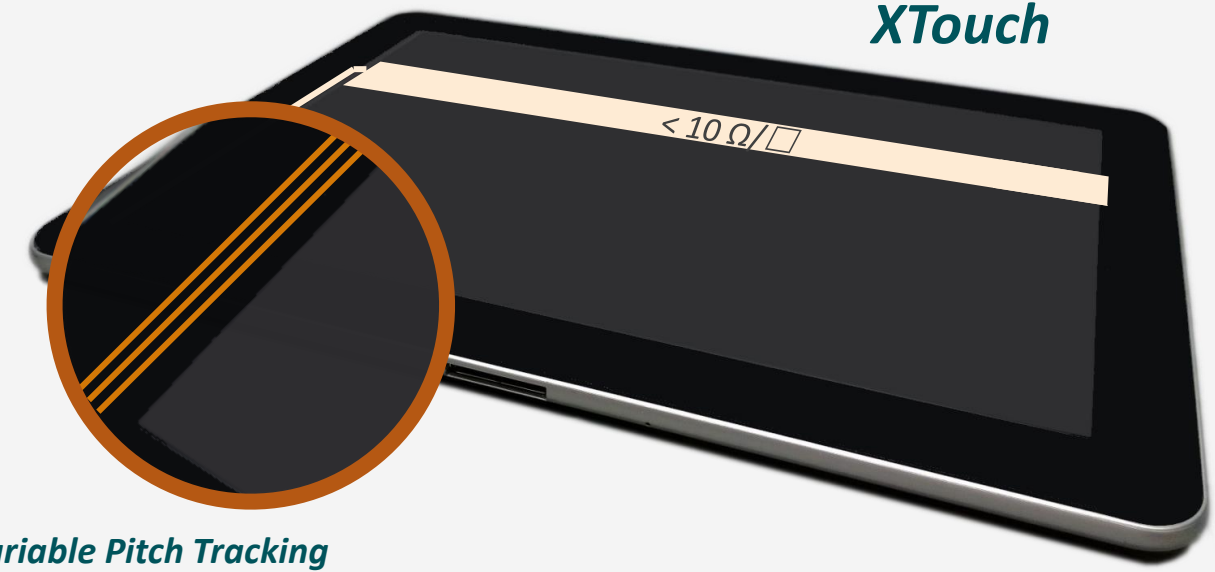
4.3" ITO sensor charge time is 1300ns

Measurements taken using a signal generator

Narrow Borders for Thin Bezel

Low Effective Resistance enables Single Routing

XTouch

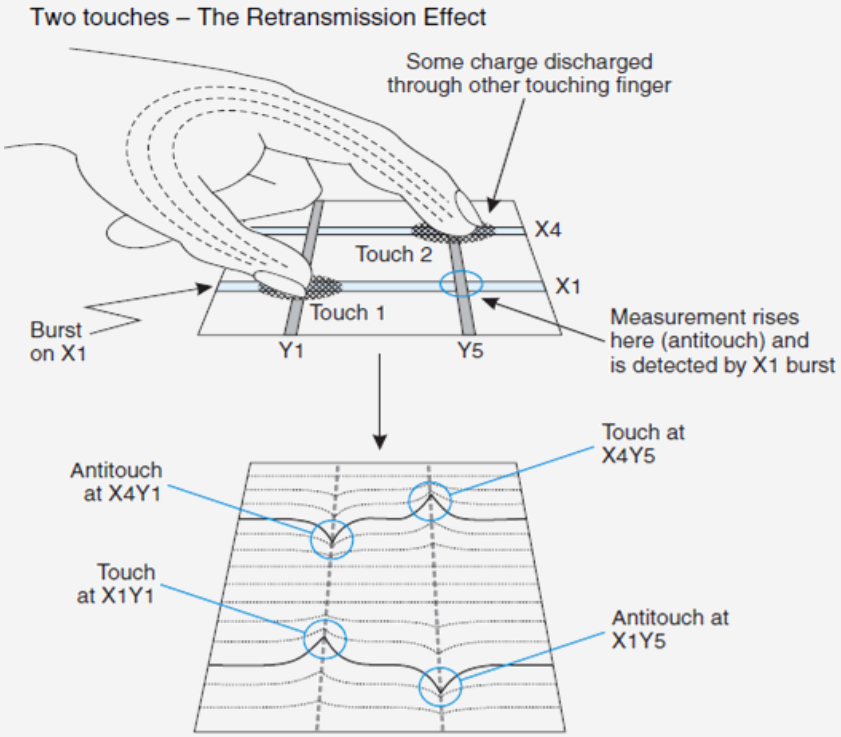


Variable Pitch Tracking

- ***As thin as 20/20µm today with opportunity to go thinner***

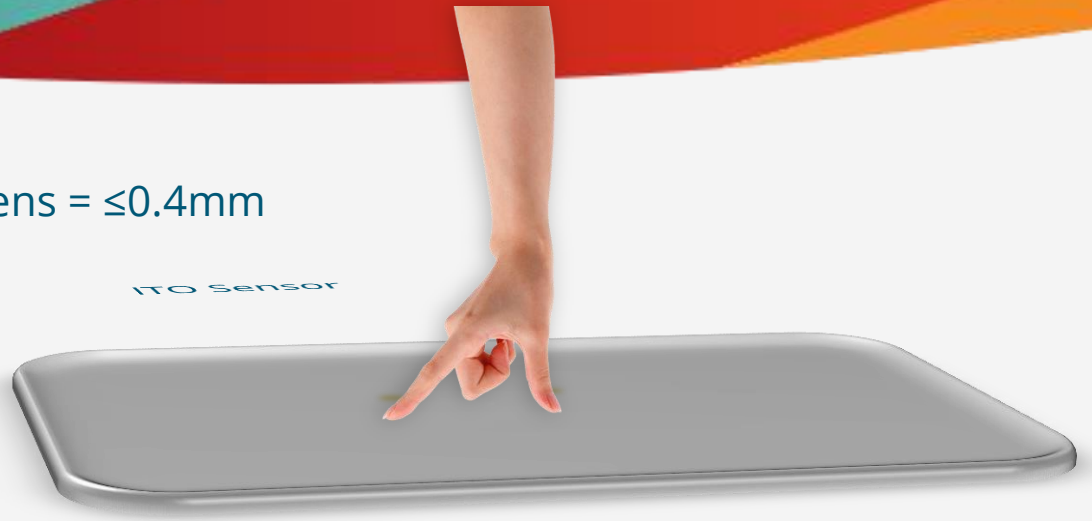
Overcome Re-transmission to Enable Thin Cover Lenses

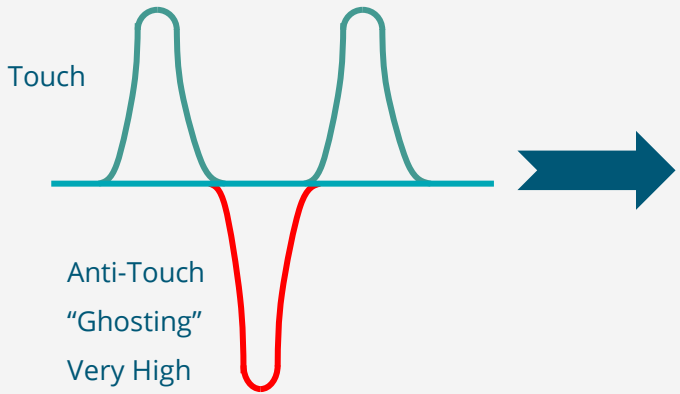
- Retransmission reduces touch sensor signal and causes multi-touch failure with thinner cover lenses
- Moisture performance is related to retransmission



Re-transmission Challenge for Thin Cover Lenses

Cover Lens = ≤0.4mm

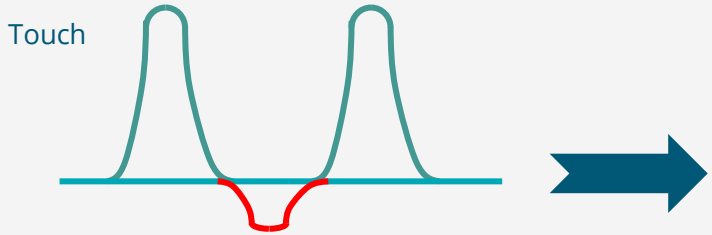




Poor multi-touch

XTouch has low Retransmission

Cover Lens = ≤0.4mm



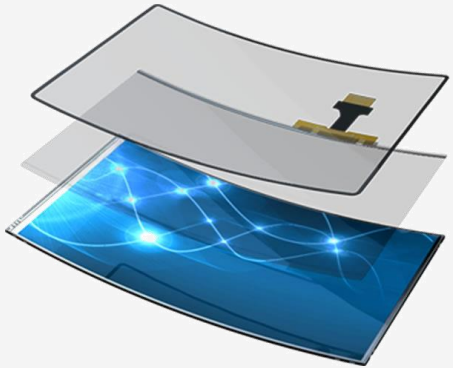
Minimal Anti-Touch
"Ghosting"

Excellent SNR
& Multi-touch

XTouch Flexibility

Metal Mesh Sensors Well Suited for Flexible Displays

- ITO sensors will have difficulty supporting bendable displays.
- Copper-based metal mesh touch sensors, being made of a ductile metal, will be well-suited to support the bendability and thin cover lens requirements of flexible displays.



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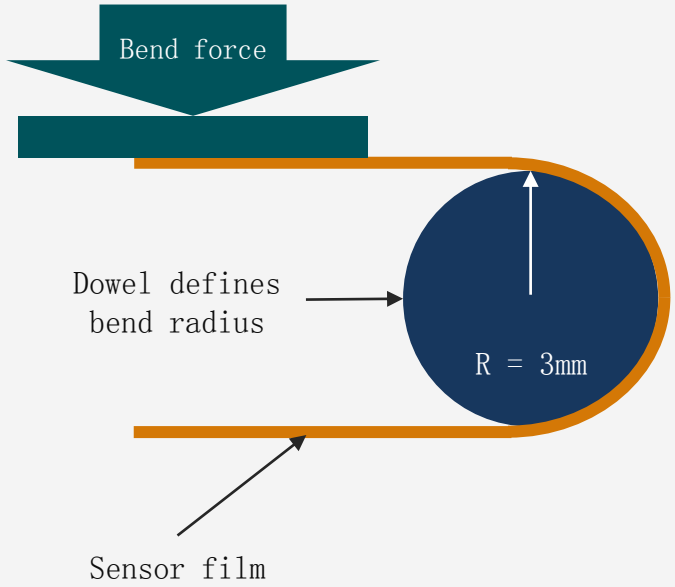
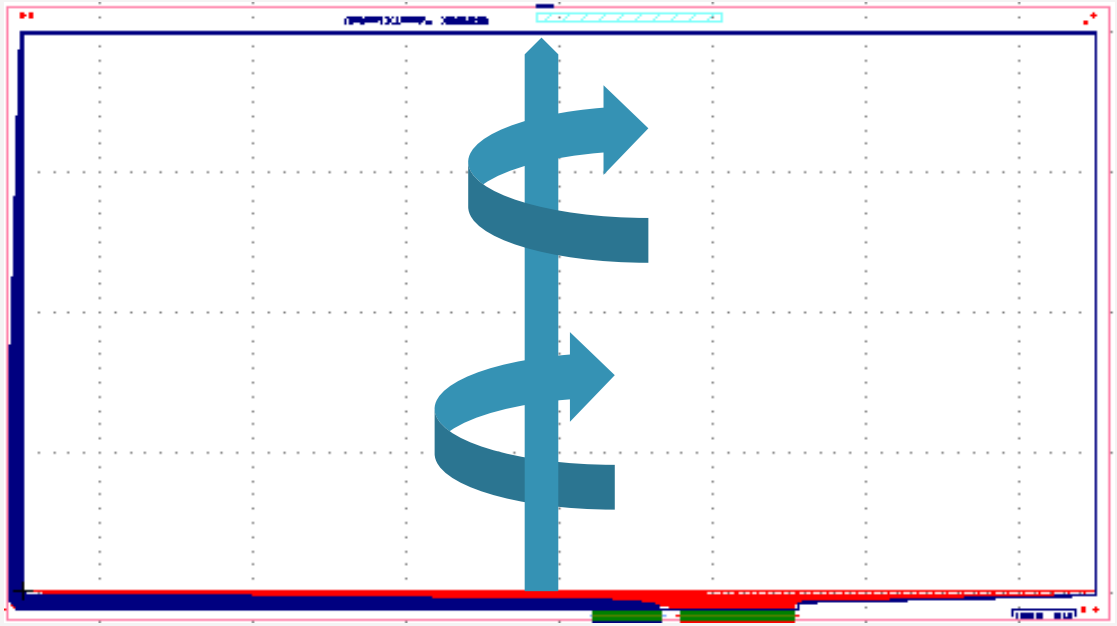
XTouch Bending Test Setup and Conditions

Bend Test Conditions

- 3mm bend radius
- 90,000 cycles
- 120 cycles/min



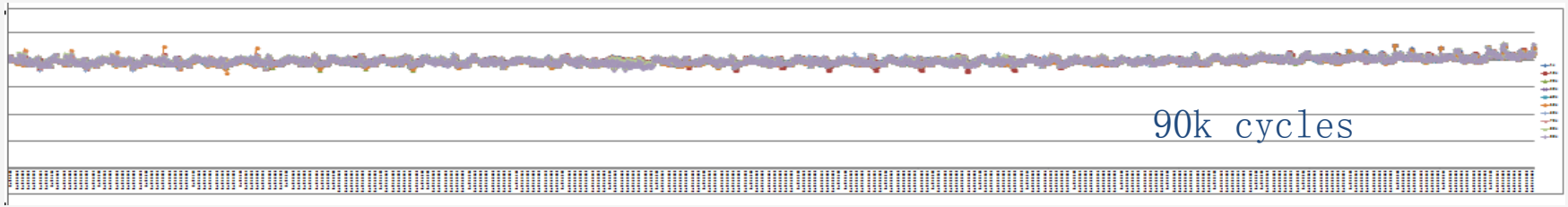
Test Sample and Bending Direction



- Sample: 15.6” XTouch sensor bonded to passive FPC
- Bend testing performed on short axis
- Test Software used to measure Reference Level (related to resistance change)

Bending Test Result

Reference Level Measurement



- Reference Level measured at 90k cycles with no failures.
- Additional testing at increased cycles and smaller bend radius to be performed.

Thin Plastic Cover Lens

Flexible Display Likely to Require Thin Plastic Cover Lens

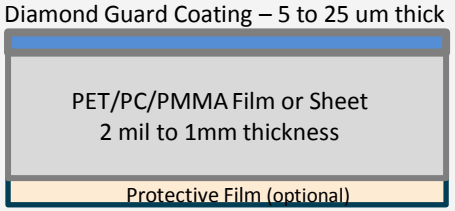
- **Cover Lens for Flexible Display likely to be thin plastic film, perhaps 0.100mm or less.**
- **UniPixel has two technologies to address challenges of thin plastic cover lens material:**
  - Proprietary ***XTouch*** sensor pattern to overcome challenge of *re-transmission*
  - ***Diamond Guard*** hardcoat resin to increase hardness and abrasion resistance of plastic cover lens while maintaining flexibility

Diamond Guard™ Hard Coat

Optically Clear

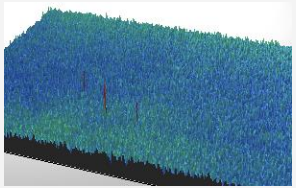
- >90.5% Transmission on PET
- <0.6% Haze on PET

Diamond Guard™ Film/Sheet Layers



Glass like smooth surface – Rq = 13.9 n

Rq = 13.9nm



Hard, scratch & abrasion resistant surface

- **ASTM 6H+ pencil hardness on PET; 9H on PMMA**
- **Taber –** CS-10 wheel – 500 cycles – 500g - Haze – no change
- **Wyzenbeek –** Denim – 1000 cycles – 500g - Haze – no change
- **Bayer** – Luminous Transmission – post Bayer – no change

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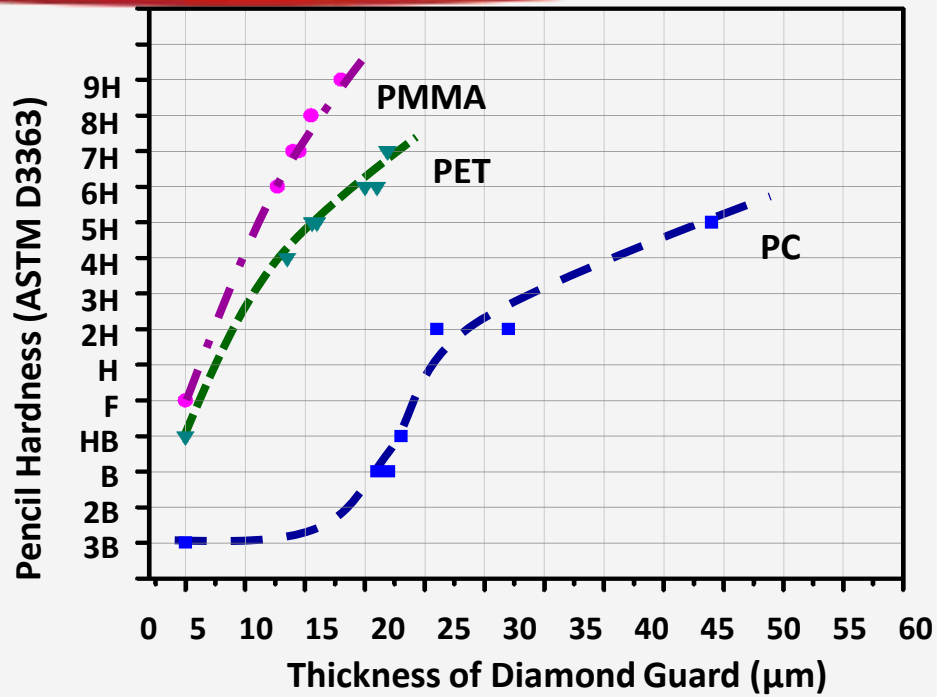
Diamond Guard Key Features

- High Scratch Resistance
- Great Optical Quality – High transmission/Low Haze
- Die cutting compatible
- Flexible and formable
- Very smooth surface
- Stain Resistant
- Chemical resistant
- Easily cleaned surface
- UV resistance

Diamond Guard on Substrates



Actual Diamond Guard pencil hardness measurements on various substrates at varying single layer thicknesses

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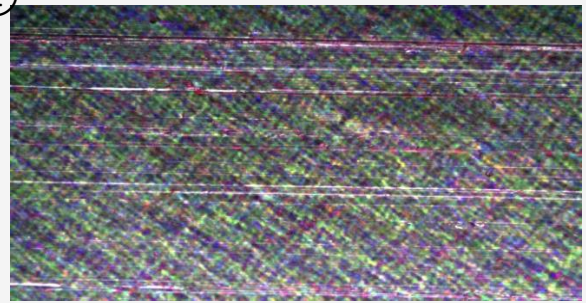
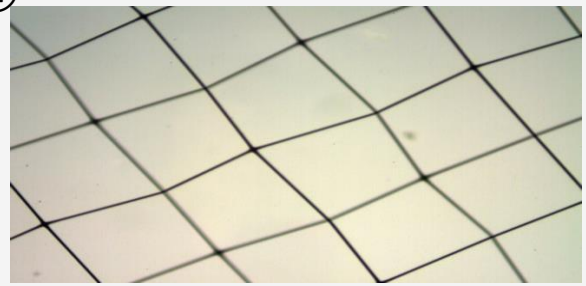
Surface Abrasion Test: Diamond Guard vs. Polarizer

Abradants	Test Condition	Sample	
		Polarizer Films	Sensor (DG-coated)
Steel-Wool	250 g	Obvious Scratch after 10 cycles (Pic 1)	No Scratch after 200 cycles (Pic 2)
Denim	250 g&500 cycles	Obvious Scratch	No Scratch
	500 g&500 cycles	Obvious Scratch	No Scratch
	750 g&500 cycles	Obvious Scratch	No Scratch
	1000 g&500 cycles	Obvious Scratch	No Scratch
Paper Towel	250 g&500 cycles	Obvious Scratch	No Scratch
	500 g&500 cycles	Obvious Scratch	No Scratch
	750 g&500 cycles	Obvious Scratch	No Scratch
	1000 g&500 cycles	Obvious Scratch	No Scratch

① Polarizer



② DG coated XTouch



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Diamond Guard coated PET Cover Lens: Pencil Hardness

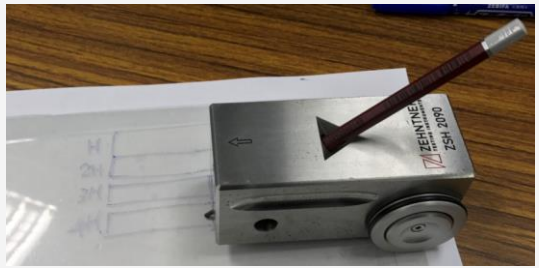
Stack-up

PET Cover Lens

OCA1

XTouch Sensor

OCA2



Stack Configuration				Pencil Hardness Result (750g)					
Cover Lens		OCA1	OCA2	H	2H	3H	4H	5H	6H
Stack 1	195µm	50µm	50µm	Pass	Pass	Pass	Pass	-	-
Stack 2		50µm	175µm	Pass	Pass	Pass	Pass	-	-
Stack 3	250µm	50µm	50µm	Pass	Pass	Pass	Pass	Pass	Pass
Stack 4		50µm	175µm	Pass	Pass	Pass	Pass	Pass	Pass

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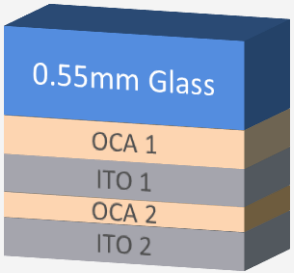
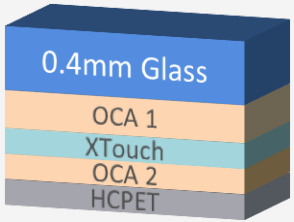
Enabling Thinner, Lighter Touch Panels

GFF



850-1000µm

XTouch
Thin Glass



625µm

XTouch
Glass Cover Lens
Diamond Guard
Bottom Hardcoat

550µm

XTouch
Plastic Cover Lens
Diamond Guard
Bottom Hardcoat

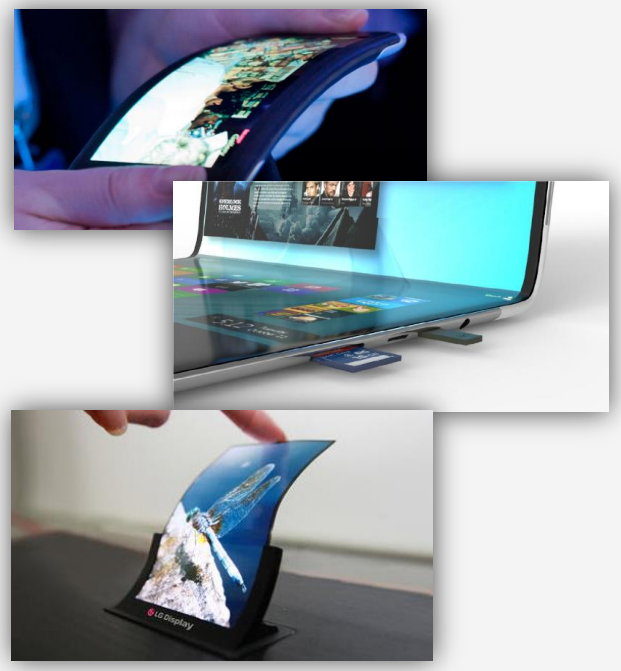
350µm

XTouch
Diamond Guard Top and
Bottom Hardcoat

≤70µm

Conclusion

- Growing market momentum for metal mesh touch sensors.
- XTouch and Diamond Guard help enable thin, light and flexible devices.
- XTouch supports narrow bezel, thin cover lens, and is future-ready for flexible displays.
- Diamond Guard enables improved abrasion resistance for thin cover lenses that will be required for flexible displays.
- The future is curved and flexible, and UniPixel looks forward to contributing to make it happen!



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Thank You!

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