

# The market for touch screens and ITO replacement

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# Content

- **Introduction**
- **ITO, the incumbent transparent conductor**
- **Emerging options for transparent conductors**
- **Touchscreen technologies**
- **Forecasts/Conclusions**

# Transparent conductors basics

- Metals or metal compounds deposited as thin films
- They always have higher resistivities than the bulk metal (scattering at grain boundaries of multi- crystalline films, scattering when film thickness is comparable to electron mean free path)
- **Trivia:** cheaper TCs, such as FTO or  $\text{Cd}_2\text{SnO}_4$ , extensively used for their optical properties on glass (heat mirrors due to their reflectivity at IR). ITO is no longer used in this application due to the high cost of Indium.

# ITO

**the incumbent technology for  
transparent conductors**

# Conductivity

Approximate minimum resistivities for some transparent conductors

Material	Value ( $\mu\text{ohmcm}$ )
Ag	1.6
TiN	20
In <sub>2</sub> O <sub>3</sub> :Sn (ITO)	100
Cd <sub>2</sub> SnO <sub>4</sub>	130
ZnO:Al (AZO)	150
SnO <sub>2</sub> :F (FTO)	200
ZnO:F	400

Source: R.G. Gordon

# Temperature of processing

Material	
Ag	<b>Lowest</b>
ITO	
ZnO	
FTO	
$\text{Cd}_2\text{SnO}_4$	<b>Highest</b>

Tin oxide TCs more stable than Zinc Oxide based ones at higher temperatures

Source: R.G. Gordon

# Etchability

Material	Etchant
SnO <sub>2</sub>	Zn + HCl or CrCl <sub>2</sub>
In <sub>2</sub> O <sub>3</sub>	HCl + HNO <sub>3</sub> or FeCl <sub>3</sub>
TiN	H <sub>2</sub> O <sub>2</sub> + NH <sub>3</sub>
ZnO	Ammonium chloride or dilute acids

Zinc oxide is the easiest material to etch, tin oxide is the most difficult, and indium oxide is intermediate in etching difficulty.

Source: R.G. Gordon



# The ideal TC material...

Highest transparency

ZnO:F, Cd<sub>2</sub>SnO<sub>4</sub>

Highest conductivity

ITO

Best thermal stability

FTO, TiN, Cd<sub>2</sub>SnO<sub>4</sub>

Best mechanical durability

TiN, FTO

Best chemical durability

FTO

Easiest to etch

ZnO:F, TiN

Lowest deposition temperature

ITO, ZnO:B, Ag

Least toxic

ZnO:F, FTO

Lowest cost

FTO

# Why did ITO win in displays...?

Etchability is a very important consideration in forming patterns in the TC electrode of a flat panel display. The easier etchability of ITO has favoured its use over tin oxide, which is more difficult to etch.

The low deposition temperature of ITO is also a factor for color displays in which the TC is deposited over thermally sensitive organic dyes.

Low resistance is another factor favouring ITO in very finely patterned displays, since the ITO layer can be made very thin, thus the etched topography remains fairly smooth.

Well-entrenched incumbent technology: inertia in moving to other solutions

# Where do other TCs fit?

In thin film PV, FTO is the winner (CdTe, a-Si) due to high thermal stability and low cost.

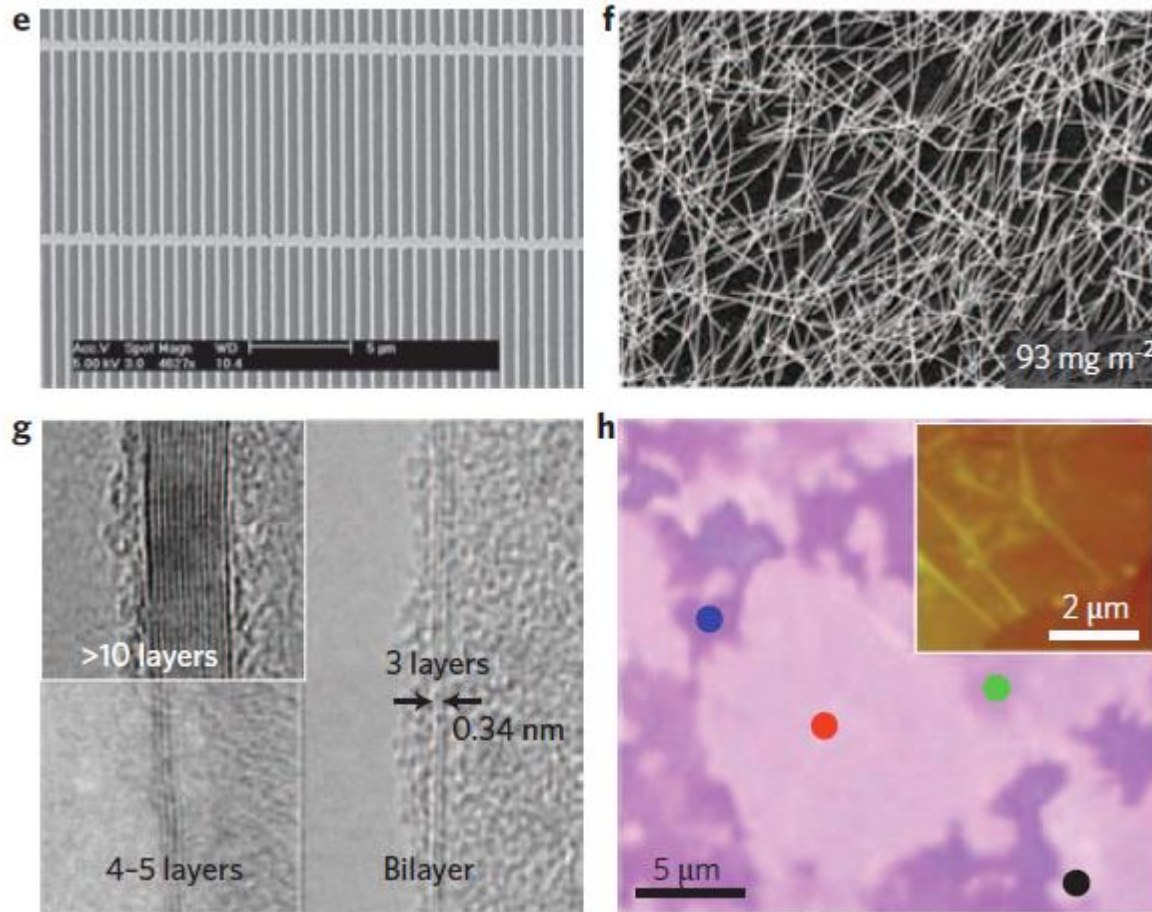
In thin film PV where low temperature substrates are used, ITO or ZnO would be the TC of choice.

EMI shielding: Ag and ITO are the best materials for this purpose.

Electrochromic mirrors/windows: A large market already in automobiles for FTO, a growing market for electronic skin/smart windows in buildings: FTO's chemical inertness low cost and high transparency are key.

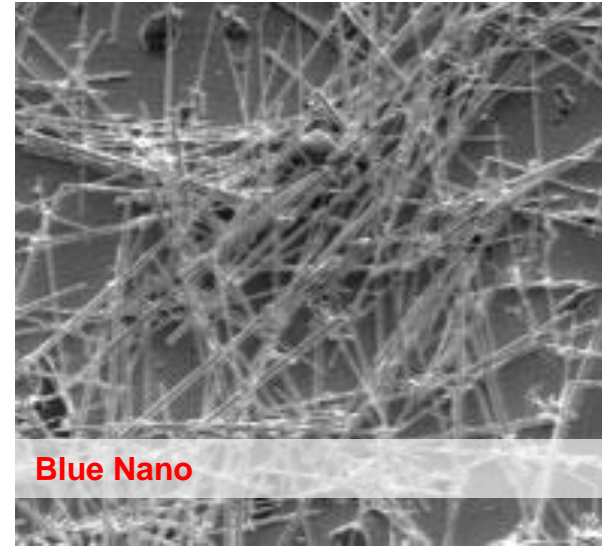
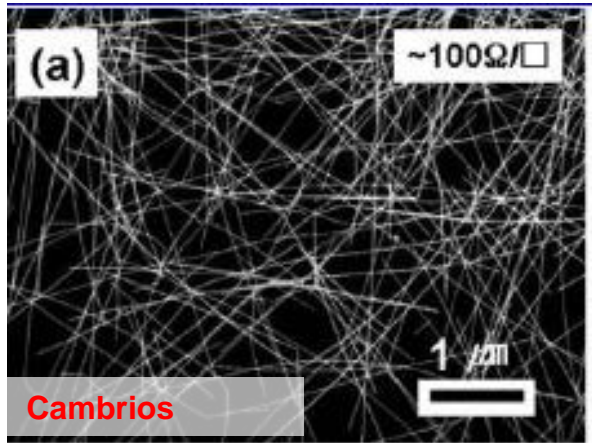
# Emerging transparent conductors

# Grids, nanowires, graphene...



Ellmer, Nature Photonics, 2012

# Silver Nanowires

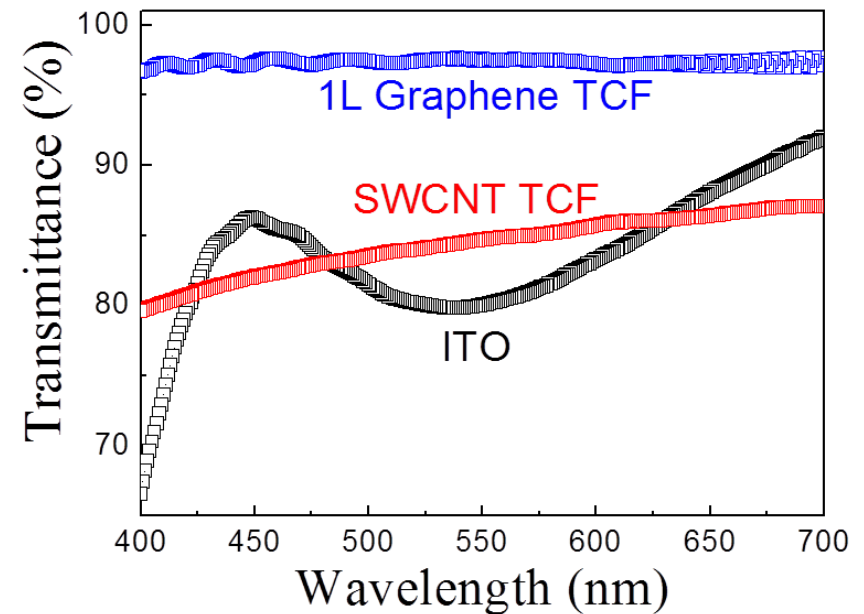
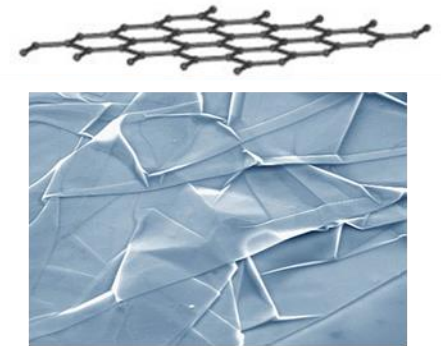
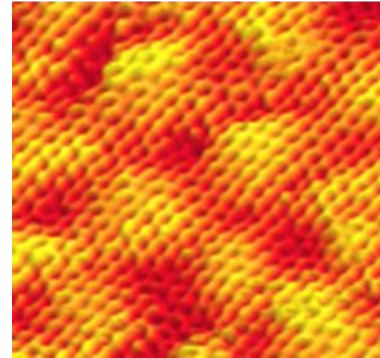


- ✓ Transparent & conductive (touchscreens, displays, solar)
- ✓ High performance on plastic/low-T substrates
- ✓ Flexibility
- ✓ Can be slot die coated
- × High cost (but quickly coming down)
- × No fine features



# Graphene

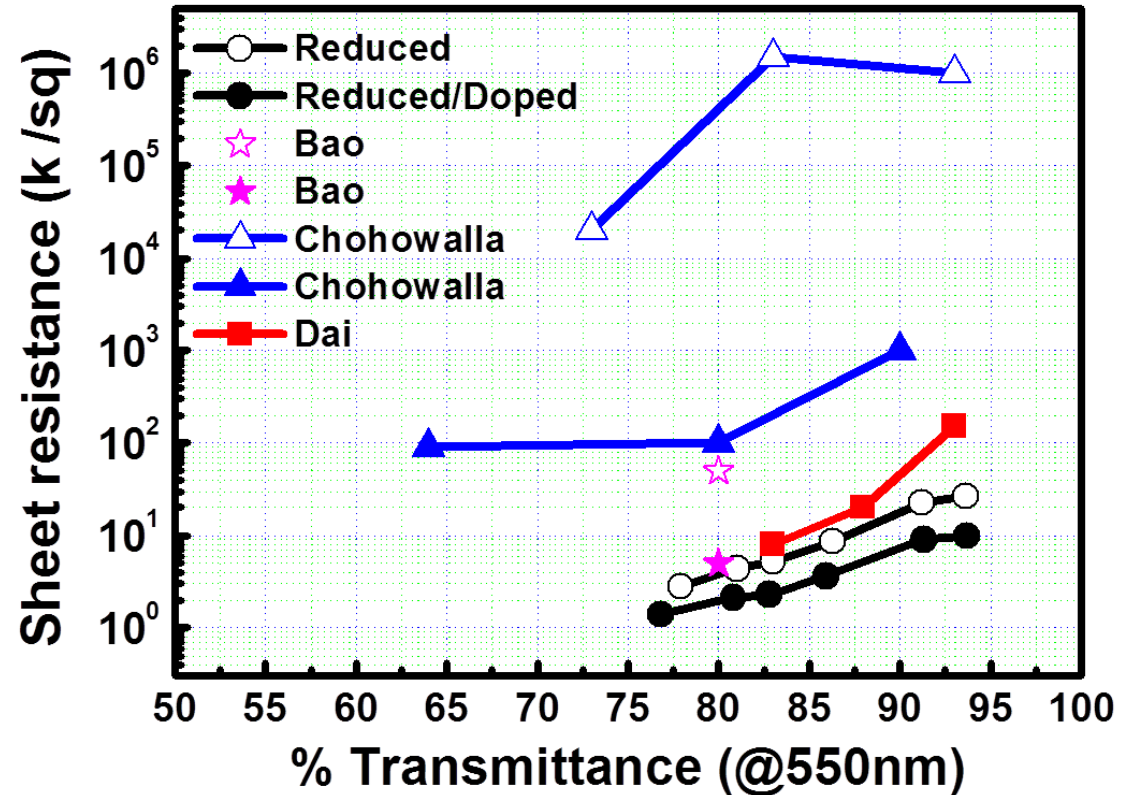
- ✓ Very high performance (in theory)
- ✓ Flexibility
- × There are many different types of graphene
- × Scalable graphene has degraded performance
- × Cost is high
- × No clear way to manufacture cheaply and at scale
- × Difficult to turn into ink (graphene requires special solvents or surfactants)



# Graphene

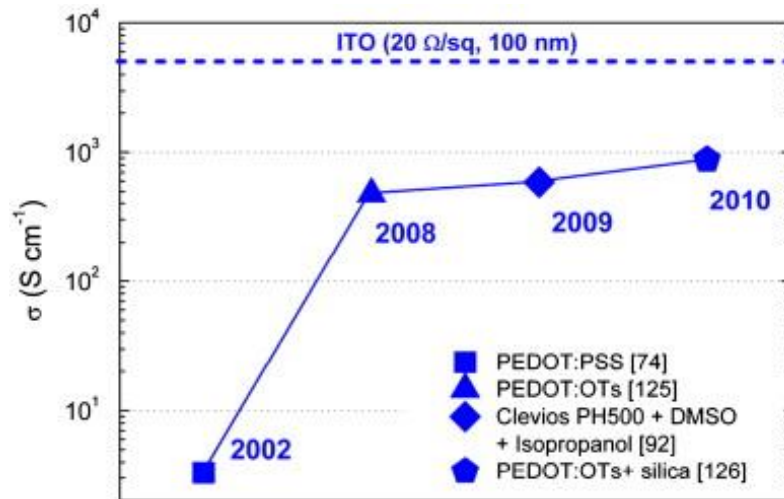
Different types of graphene lead to variable performance

Printable versions available for screen, flexo, gravure. Easy deposition, not the best in performance



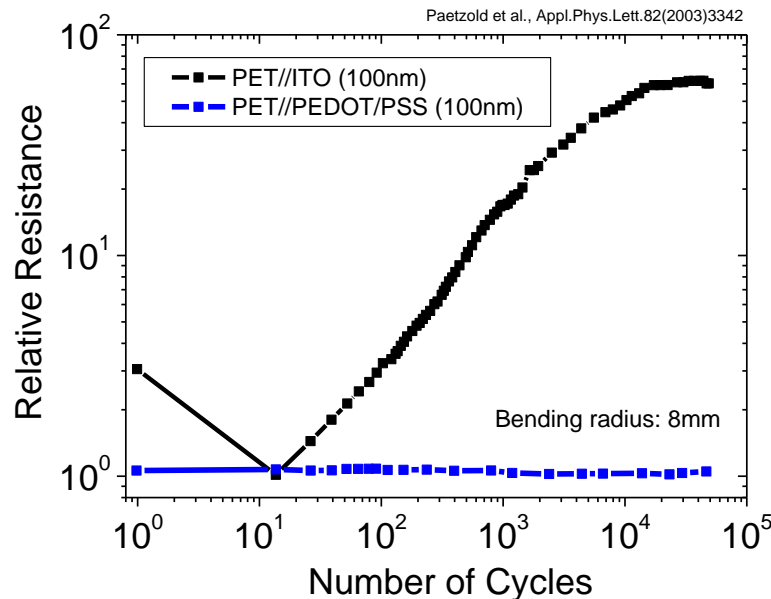


# PEDOT:PSS



PEDOT:PSS is flexible with moderate transmission. The conductivity levels however are still relatively low, despite constant year-on-year improvements.

Currently they are around 1,000 S/cm maximum.



This material **cannot compete** with incumbent ITO technology on optical-conductivity performance alone.

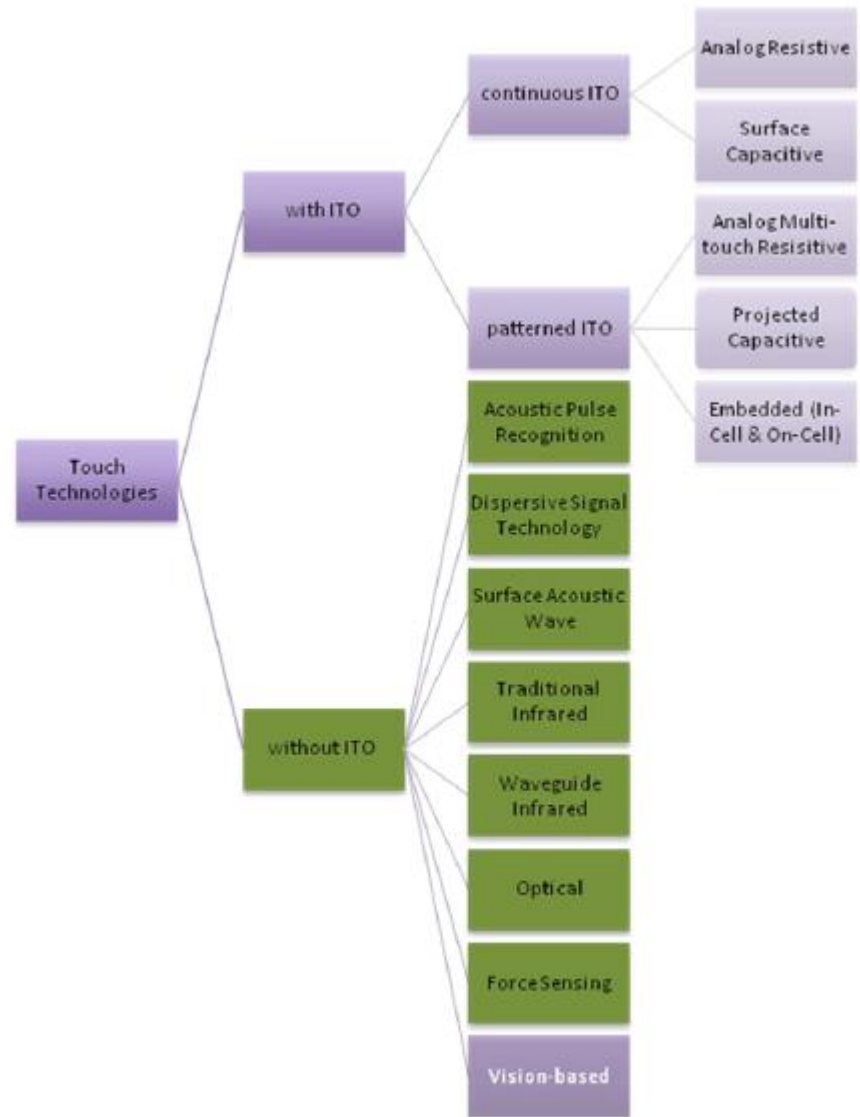
# Touchscreen Technologies

# Touchscreens

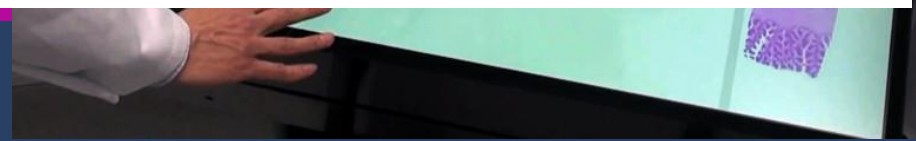
Almost 200 touchscreen ma

Many different types of tech

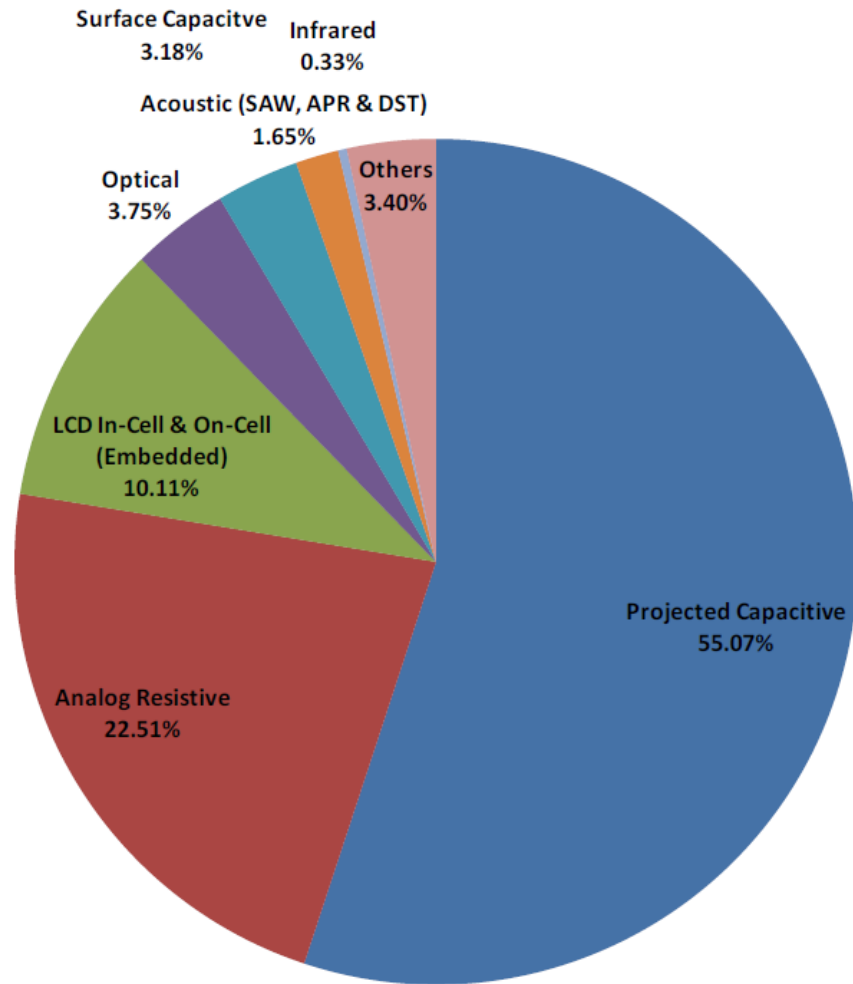
Intuitive, user friendly



Source IDTechEx



# Touchscreens in 2012, by technology



Source IDTechEx

<b>Technology</b>	<b>Measuring</b>	<b>TCE (ITO, ...)</b>	<b>Devices</b>	<b>Suppliers</b>
<b>Projected Capacitive</b>	<b>Change in capacitance</b>	<b>Yes, patterned – X and Y sensor array (or single layer sensor)</b>	<b>Most smartphones Tablet PCs iPod Touch and Nano etc.</b>	<b>Nissah, TI, Touch International etc.</b>
<b>Analog Resistive</b>	<b>Voltage</b>	<b>Yes, continuous – two sensor layers</b>	<b>Some Phones Stylus based PDAs Gaming applications: Nintendo DS and 3DS etc.</b>	<b>Elo Touch Systems, Fujitsu, Gunze, Nissah etc.</b>
<b>Surface Capacitive</b>	<b>Current</b>	<b>Yes, continuous</b>	<b>ATMs, KIOSKs</b>	<b>3M, Elo Touch Systems, Optera, etc.</b>
<b>Surface Acoustic Wave (SAW)</b>	<b>Time delay</b>	<b>No</b>	<b>ATMs, Banking, Kiosks, Industrial Control Rooms,</b>	<b>Displays Solution, Elo Touch Systems</b>
<b>Traditional Infrared (IR) – heat sensitive or optical</b>	<b>Absence of light</b>	<b>No</b>	<b>e-readers, Some smart phones: Samsung U600, Neonode N2</b>	<b>EloTouch Systems, GLB Australia, IRTouch Systems etc.</b>

# Touchscreens are becoming ubiquitous

The biggest application for touch screens in general and projected capacitive (the biggest grower) in particular are mobile phones and tablets with the biggest market opportunity in terms of shipped units lying in the first one.

IDTechEx projects touch penetration in mobile phones to grow from 47% last year to an almost total coverage over 95% by 2023

# Touchscreen technologies by device size

<b>Small (2..10inches)</b>	<b>Medium (10..30inches)</b>	<b>Large (30..150inches)</b>
Projected Capacitive	Surface Capacitive	Optical
Analog Resisitve	Optical	Acoustic (DST)
Embedded	Acoustic (SAW, APR)	Infrared
	Infrared	

# Forecasts



# Other than pro-cap...

- In general, resistive touch will remain present in applications that require precise touch and/or low costs, including medical applications and also game devices.
- The one to watch: Multitouch, supported by a range of technologies, becomes the state of the art for smart phones, tablets, etc.
- Surface capacitive touch is common in sizes ranging from 10 to 30-inch, e.g. ATMs, kiosks and casino gaming. Not expected to grow as other technologies overtake.
- Infrared touch technology is mainly used in medium and large size applications in kiosks, industrial machine control and transportation informatics. Increasingly replaced by resistive and capacitive touch systems.

# Transparent Conductive Films

ITO will remain dominant, followed by FTO, silver (nanowires and nanoparticle grids)

Addressable ITO replacement is \$1.6 billion market (excluding substrate)

Main drivers/trends:

- Low-cost low-end mobile phones will be initial adopters
- Flexible applications in PV, lighting and display will drive low processing temperature ITO alternatives
- Cost/availability considerations will affect current inertia in the field of replacing ITO with alternatives

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**New pilot line for organic electronics**

11 Feb 2013 | Germany  
Organic light emitting diodes (OLEDs) and organic solar cells can now be developed at Fraunhofer Institute for Applied Polymer Research IAP in Potsdam-Golm in a near-industrial scale. The new pilot line was designed and implemented by Fraunhofer IAP ...

**Improved technology could lock in colour for high-res displays**

8 Feb 2013 | United States  
Iridescence, or sheen that shifts color depending on your viewing angle, is pretty in peacock feathers. But it's been a nuisance for engineers trying to mimic the bird's unique color mechanism to make high-resolution, reflective, color display screen...

**New VacuTran™ breaks parts-per-million WVTR measurement barrier**

8 Feb 2013 | Worldwide  
The launch of VG Scienta's new VacuTran is a major game-changing event for the Plastic Electronics industry, enabling WVTR measurement of barrier layers to better than 10<sup>-6</sup> g/m<sup>2</sup>/day and simultaneous O<sub>2</sub> permeation to better than 10<sup>-3</sup> cm<sup>3</sup>/m<sup>2</sup>/day. VG ...

**SmartKem ink evaluation kit for flexible thin film transistors**

Press Release | 8 Feb 2013 | United Kingdom  
SmartKem Limited has announced the launch of a pioneering ink evaluation kit which utilises the company's scientific expertise to significantly streamline the process of producing prototype flexible thin film transistors (TFTs). Forming part of Smart...

**Joint research project FUNgraphen**

7 Feb 2013 | Germany  
The joint research project of four institutes, entitled "FUNgraphen" and funded by the German Federal Minister of Education and Research (BMBWF), will build an innovation center aiming at the development of unconventional carbon nano materia...

**Public funded OLED project So-Light successfully concluded**

6 Feb 2013 | Germany  
Eleven leading German OLED companies and research institutions announced the successful completion of the OLED (Organic Light Emitting Diode) related project: So-Light. This € 14.7 million project was supported by the German Ministry of Educat...

**Transparent conductive films, touch surfaces and haptics at TCF LIVE!**

6 Feb 2013 | Germany  
IDTechEx are pleased to launch TCF LIVE! - a new conference and tradeshow covering the latest technologies and application of transparent conductive films (TCF) - covering raw materials through to the full range of applications. The event, held on Ap...

**Smartphone with LCD and e-paper display**

5 Feb 2013 | Worldwide  
Yota Devices has developed the first dual-screen phone with a full-color liquid crystal display (LCD) on one side and an electronic paper display (EPD) on the other. YotaPhone, which was unveiled last month, features a powerful Android based phone ...

**EU project to take flexible OLEDs from lab to fab**

4 Feb 2013 | Worldwide  
A newly launched, €11.2-million European project aims to help bring flexible OLEDs to market within six years. The Flex-o-Fab project will create a pilot-scale manufacturing chain for flexible OLEDs, and use it to develop reliable fabrication / ...

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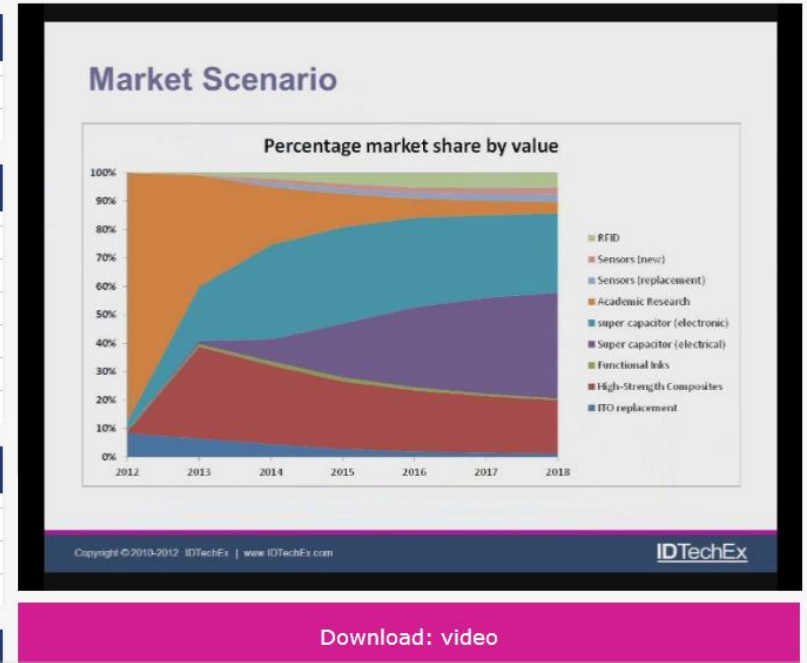
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