The market for touch screens and ITO replacement

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Content

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- 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 Cd2SnO4, 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 (μohmcm)
Ag	1.6
TiN	20
In2O3:Sn (ITO)	100
Cd2SnO4	130
ZnO:Al (AZO)	150
SnO2:F (FTO)	200
ZnO:F	400

Source: R.G. Gordon

Temperature of processing

Material	
Ag	**Lowest**
ITO	
ZnO	
FTO	
Cd_2SnO_4	**Highest**

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

Source: R.G. Gordon

Etchability

Material	Etchant
SnO2	Zn +HCl or CrCl2
In2O3	HCl + HNO3 or FeCl3
TiN	H2O2 + NH3
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, Cd2SnO4
Highest conductivity	ITO
Best thermal stability	FTO, TiN, Cd2SnO4
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.

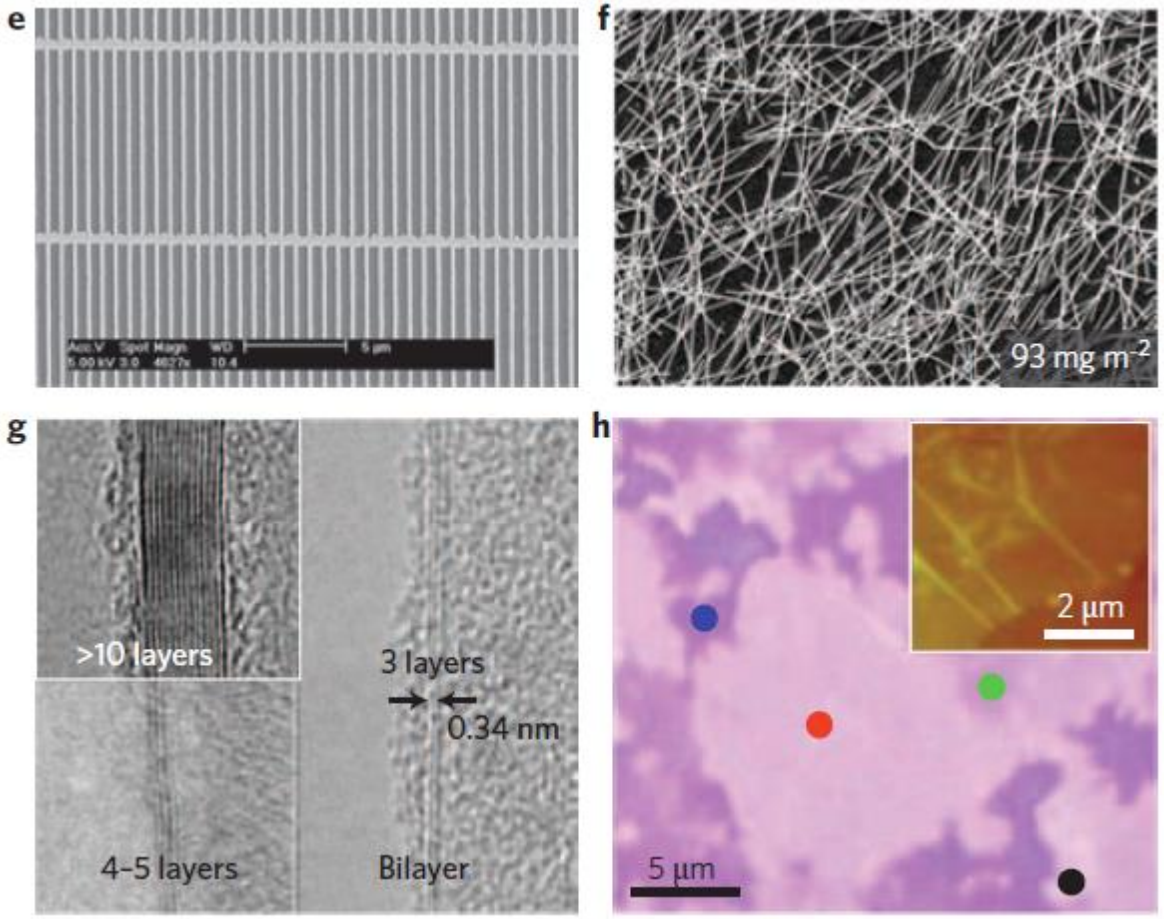
In thin film PV where low temperature substrates are used, ITO or ZnO would be the TC of choice.

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.

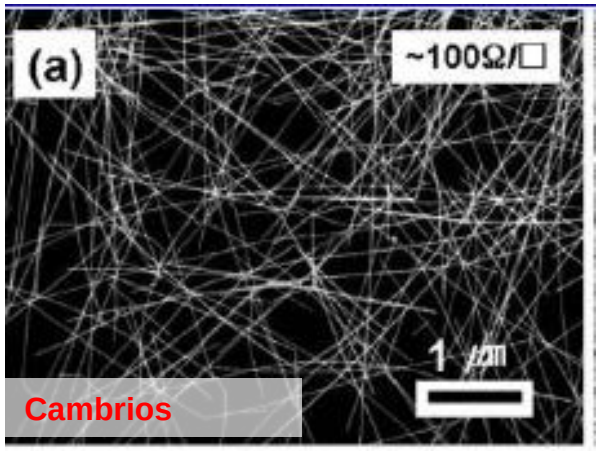
Emerging transparent conductors

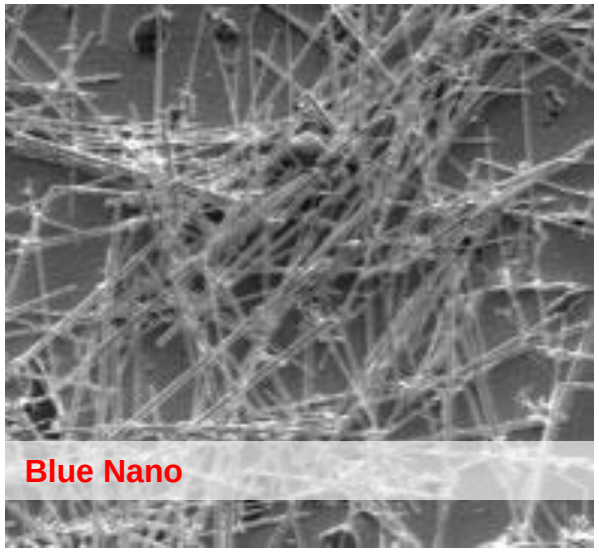
Grids, nanowires, graphene…



Ellmer, Nature Photonics, 2012

Silver Nanowires

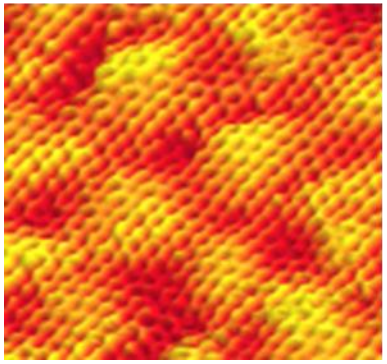




- ✓ Transparent & conductive (touchscreens, displays, solar)
- ✓ High performance on plastic/low-T substrates
- ✓ Flexibility
- ✓ Can be slot die coated

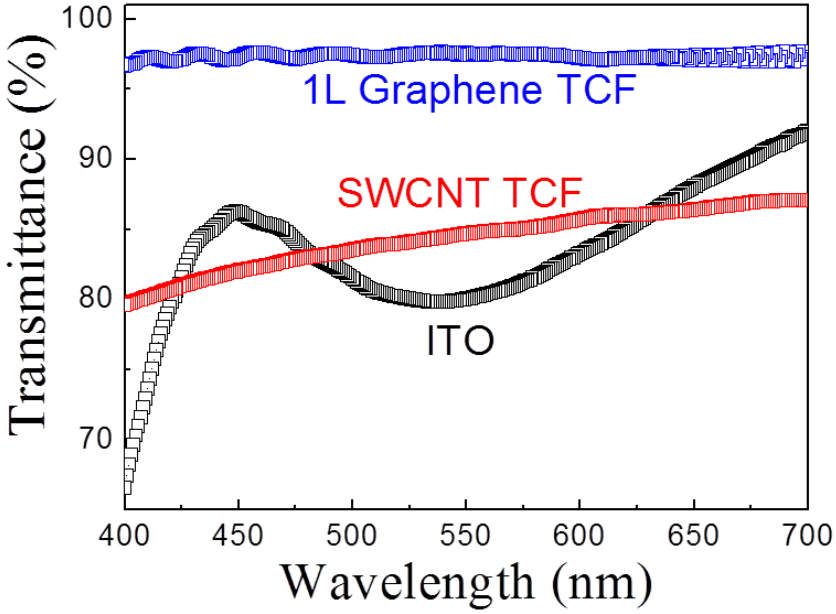
- × High cost (but quickly coming down)
- × No fine features

Graphene



- ✓ Very high performance (in theory)
- ✓ Flexibility

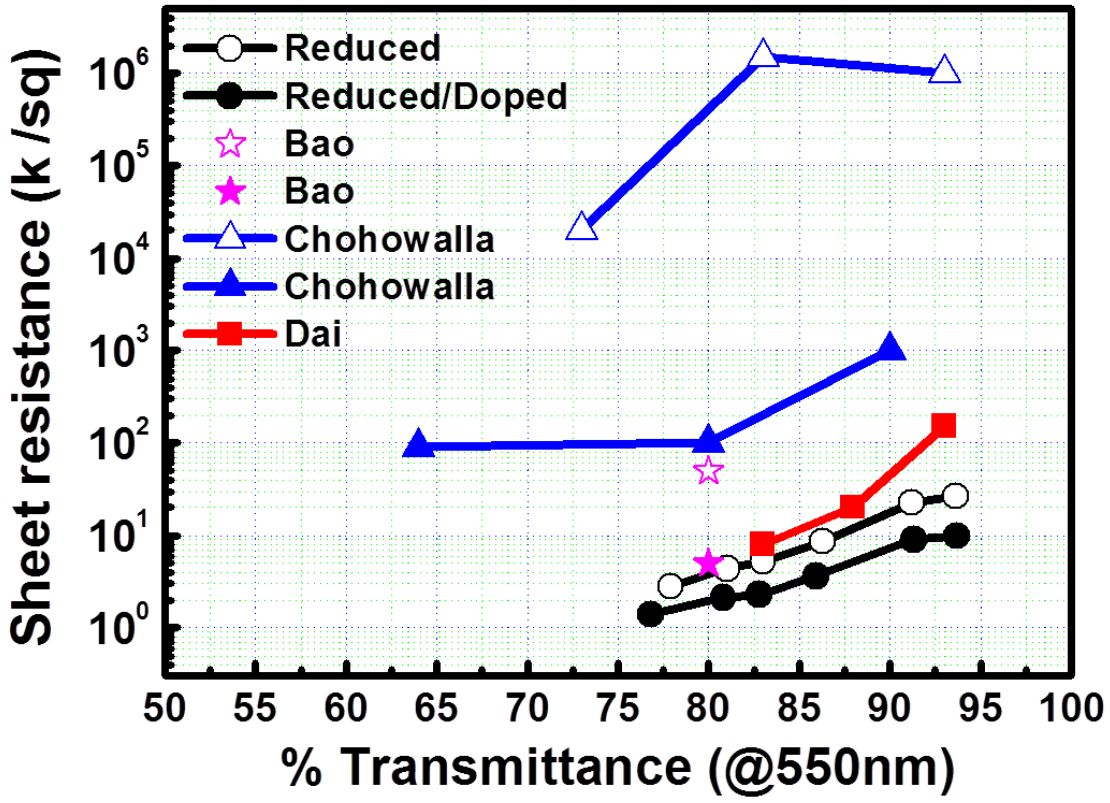
- × There are many different types of graphene
- × Scalable graphene has degraded performance
- × Cost is high
- × No clear way to manufacture cheaply and at scale
- × Difficult to turn into ink (graphene requires special solvents or surfactants)



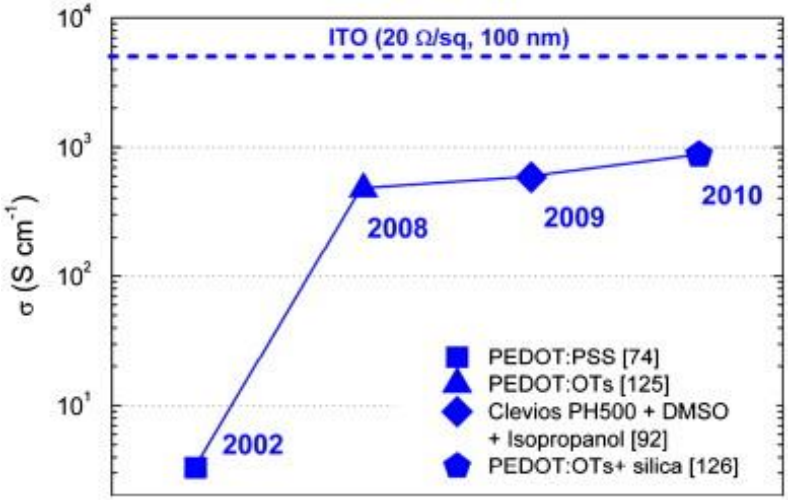
Graphene

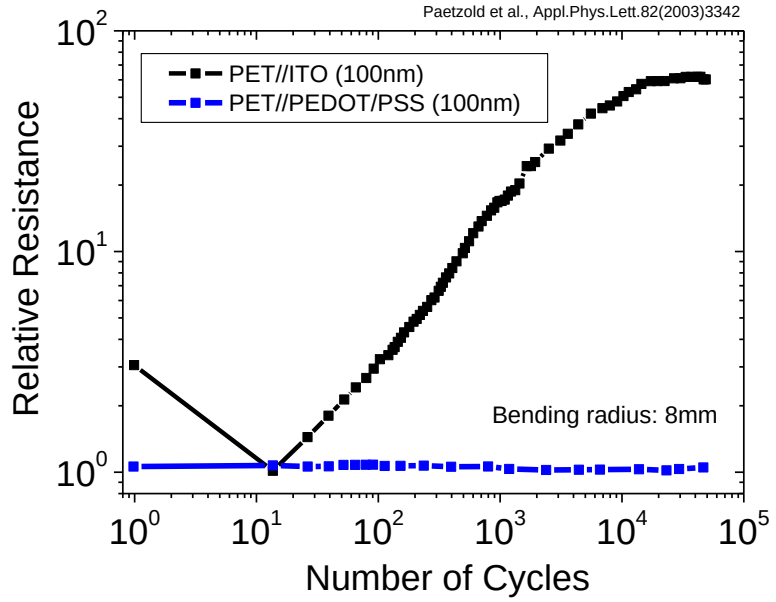
Different types of graphene lead to variable performance

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.

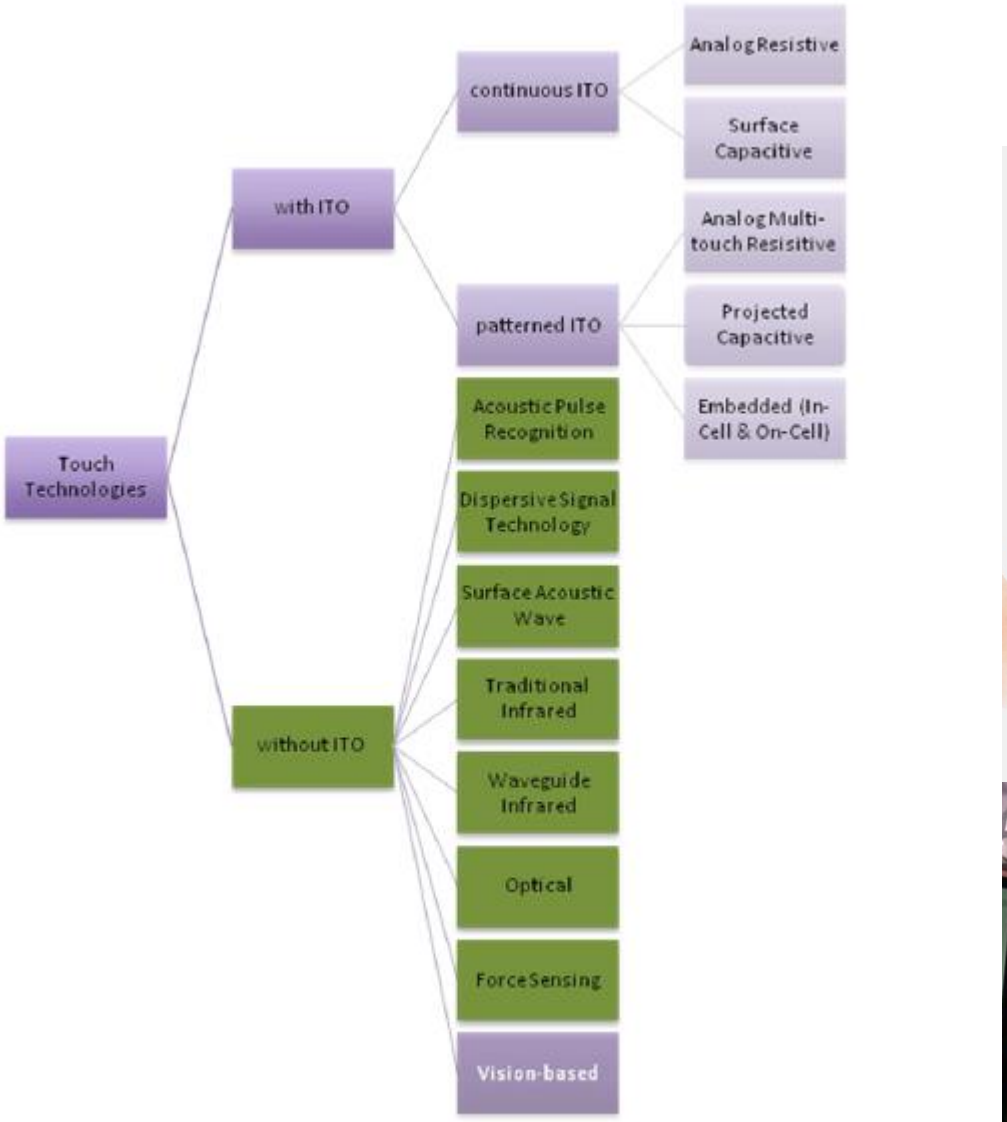
Touchscreen Technologies

Touchscreens

Almost 200 touchscreen ma

Many different types of tech

Intuitive, user friendly



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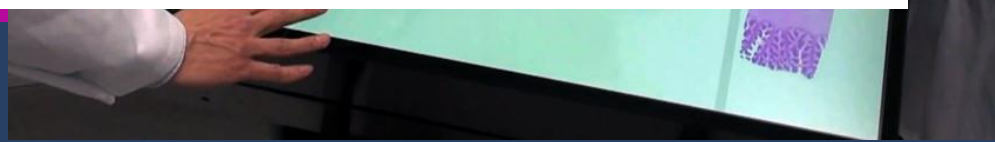
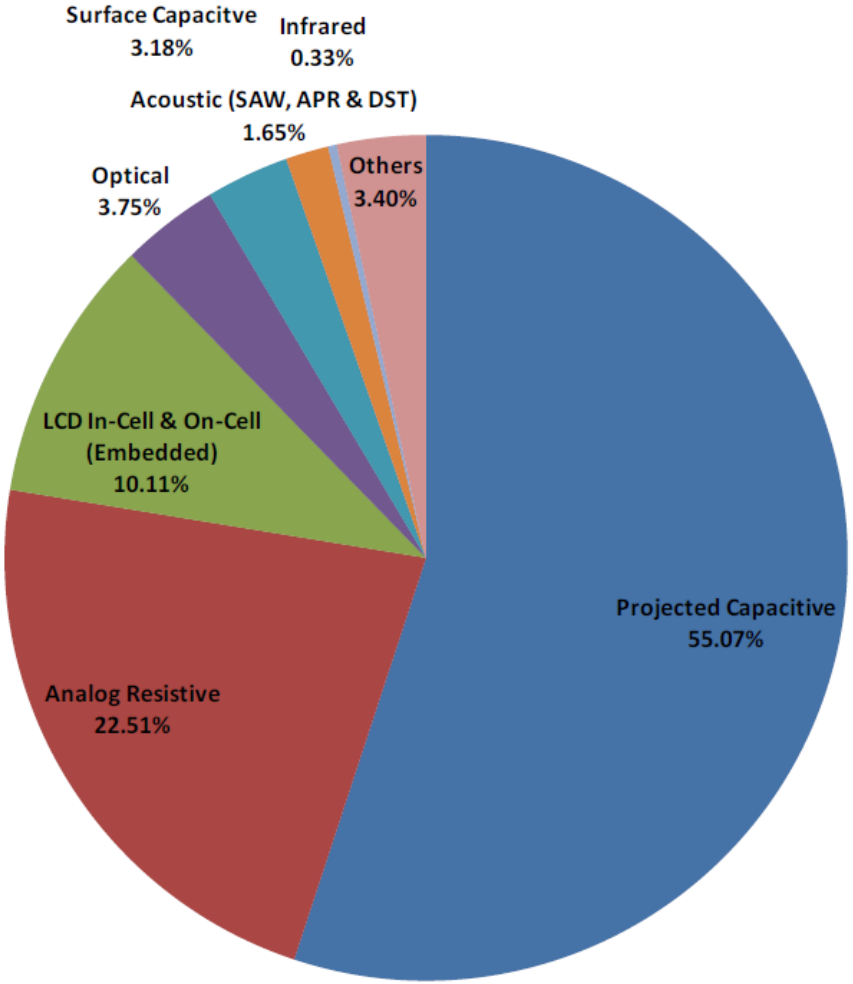


Touchscreens in 2012, by technology



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

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

Small (2..10inches)	**Medium (10..30inches)**	**Large (30..150inches)**
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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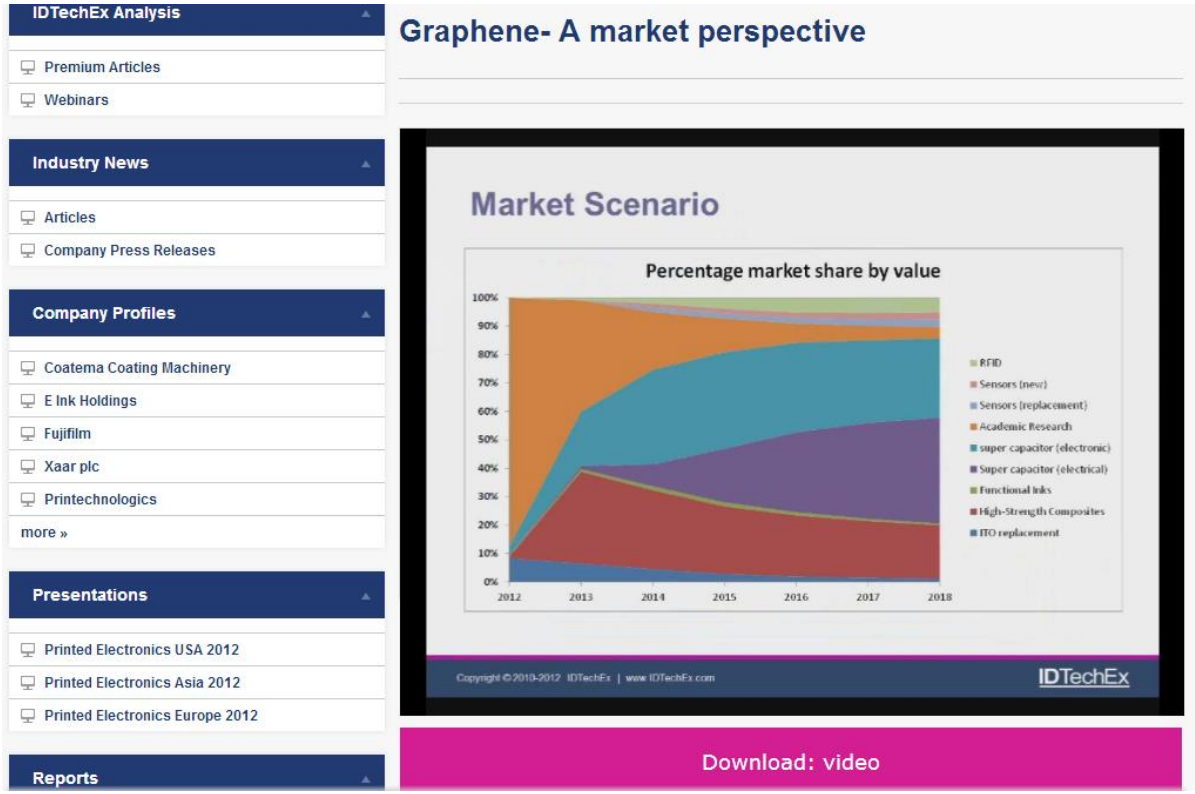

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