Growth opportunities in displays

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Context and agenda:

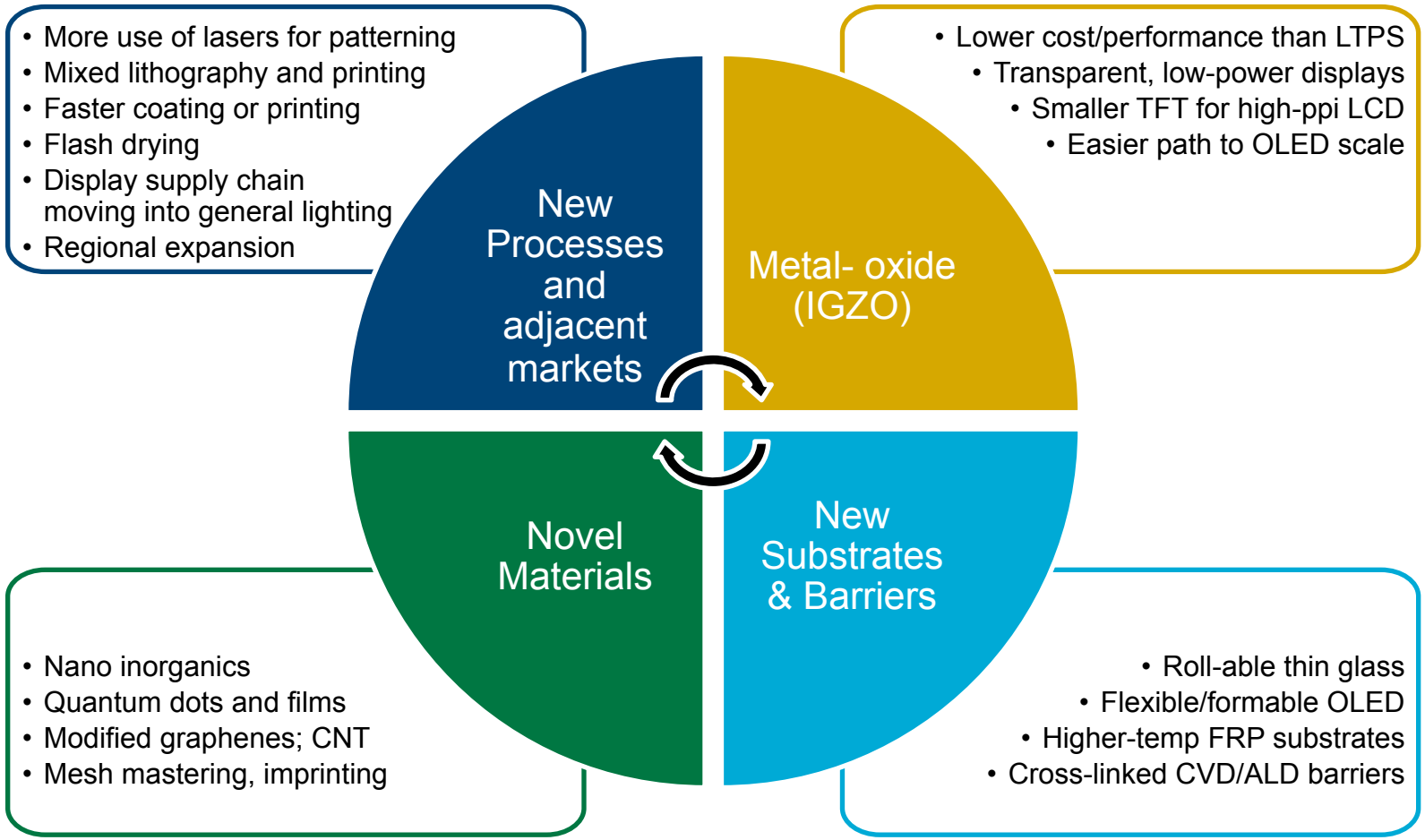
- Players in the flat panel industry in general and the LCD industry in particular are in the endgame.
  - Margins have compressed to all time lows in LCD making and revenues that will soon peak for large panel
  - Of course, in such large industries, there are always micro-opportunities that appear like wild cards.
  - The story of higher growth in device display markets than in large panels is well told by many observers so is not something we discuss here
  - What we would like to do is to outline 7 recent bubbles of growth and value in the display industry and highlight those firms poised to capitalise on these investments. Many of these areas are somewhat new to the table (although some of them are not)

- In this presentation we consider seven opportunities, and profile some of the companies that may be well positioned to take advantage of these trends
  - 1. Metal-oxide semiconductor opportunities
  - 2. OLED and flex OLED opportunities
  - 3. Barriers and encapsulation
  - 4. TCO replacements
  - 5. Regional plays
  - 6. Displays meets lighting
  - 7. Increasing role of lasers in patterning & coating, flash drying

Breaking News

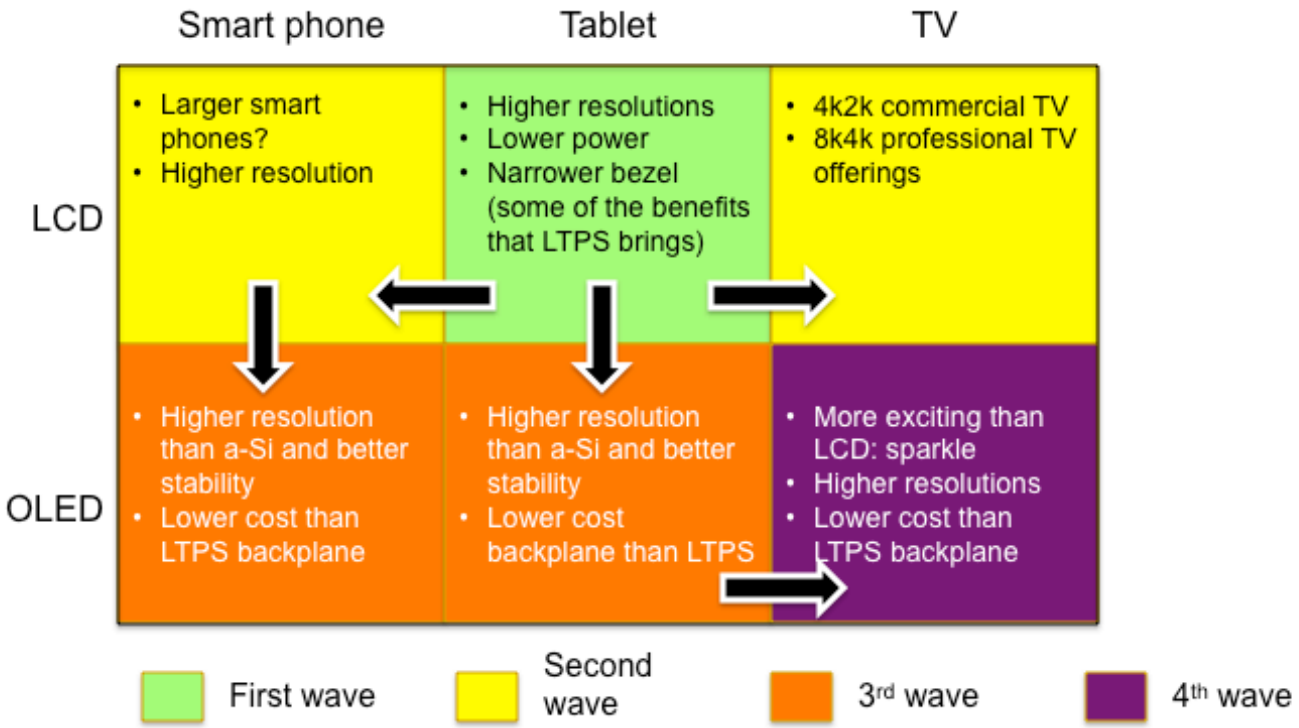
Samsung Electronics will merge Samsung Mobile Display (SMD) and S-LCD into Samsung Display (SDC) on July 1st. Thus, any reference to Samsung concerns SDC as an on-going business.

Overall, we see new ecosystems evolving from novel materials for new processes for new devices on new substrates



IGZO is a potential game changer: top-tier display firms may differentiate themselves and sell premium panels (high-ppi)

Our view on the roadmap for IGZO



- IGZO has emerged as a hot topic in 2012 largely due to the discussion of its potential use for the New iPad
  - IGZO allows for smaller TFT and higher resolutions at less power
  - IGZO offers a low-cost alternative to LTPS technology (11+ masks)
- For now, there are questions about just how much functional integration can be done with these transistors and therefore speculation on simple multiplexing for high resolution “small panels” such as in smartphones
- The other major uncertainty is the degree to which IGZO transistors are stable enough to drive AMOLED. Our view is that this will happen, in large part due to the emphasis in particular put on this by LGD for its OLED TV

Source: HCL

IGZO current status and opportunities:

Current status

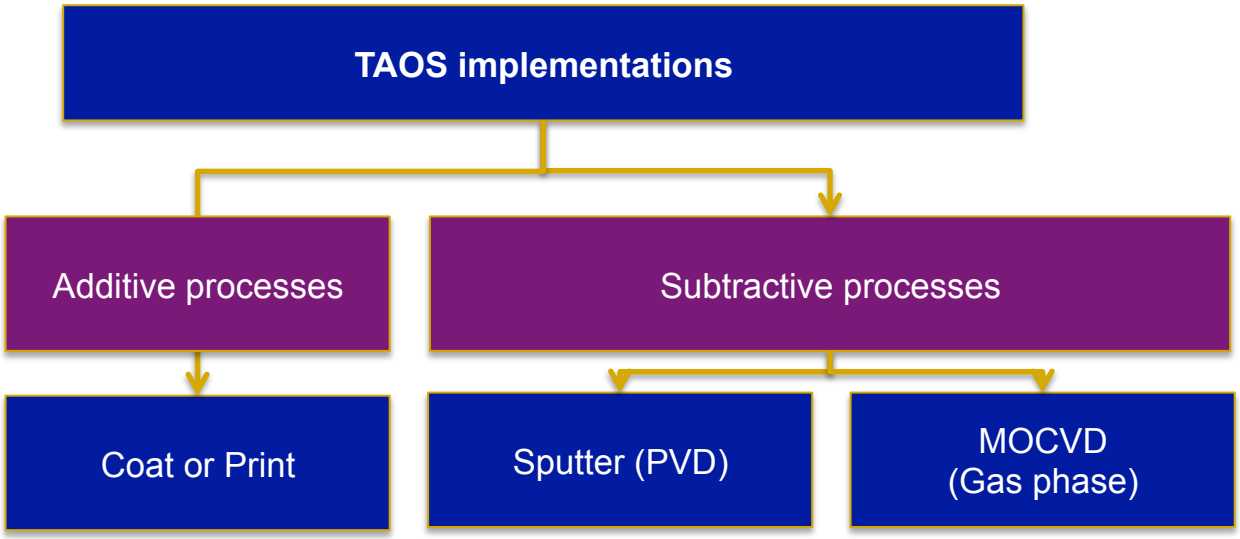
- Sharp has just started shipping product based on IGZO technology.
- For display applications, the primary device and manufacturing challenges have been threshold voltage (V_{th}) shift, leakage due to UV light exposure or the presence of hydrogen, particle control in the PVD process, uniformity over large areas, S/D metal contact resistance, and process repeatability.
- IGZO TFT devices are usually prepared at relatively low temperatures by vacuum processes such as RF magnetron (PVD) sputtering and pulse laser deposition, however, solution-based processes have demonstrated.
- PECVD nitride passivation layers are a source of hydrogen that has been the primary cause of IGZO device instability. Sputtered Al_2O_3 passivation offers the most stable TFT performance, sufficient for AMOLED display, but the deposition rates are slow, so alternatives are being considered
- In time, producers hope to improve IGZO technology enough to use it to control OLED-pixel currents

Opportunities

- Opportunities for processes delivering greater V_{th} stability or device uniformity
- Opportunities for new passivation approaches or hybrid processes
- Opportunities for IGZO targets: toroidal/cylindrical shapes or novel alloy compositions
- There may be an option for MOCVD to deposit the oxide channel
- The fact that IGZO transistors are not light sensitive opens up new opportunities for display technology
  - The most clear cut is the potential for transparent LCD displays since the TFT needs no shield
  - Transparent OLED are also possible
- Finally, the fact that IGZO deposition can happen at room temperature, increases the chances of the display industry exploring lower temperature processing solutions as a complete system at some point in the future

Source: HCL

Transparent Amorphous-oxide Semiconductor* (TAOS) strategies



- More an R&D effort at this point but ink-type processes have been demonstrated
- IMEC, Evonik and various universities are working on this

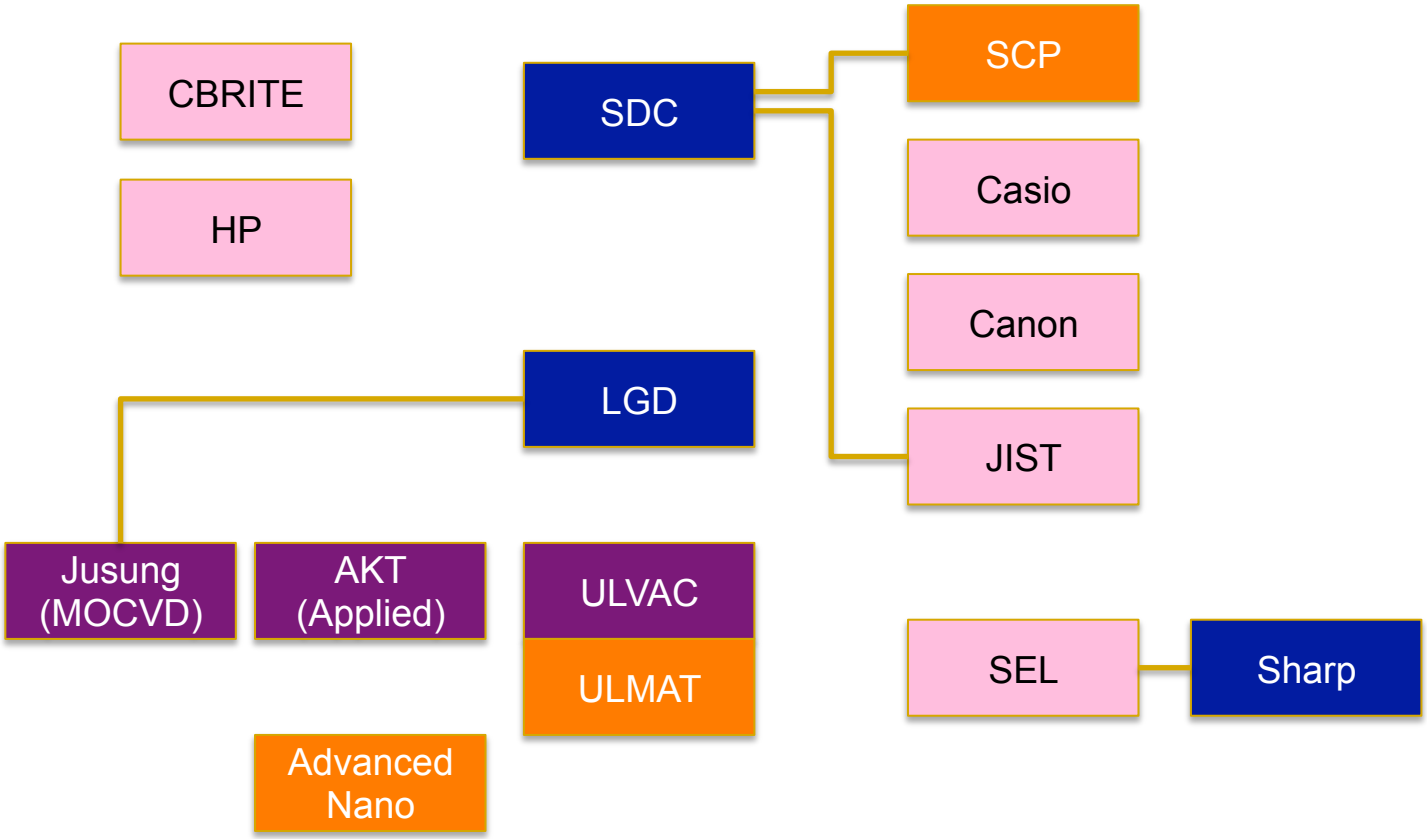
- Sputter based solutions likely to lead to business opportunities for AKT, ULVAC and target suppliers

- Jusung is working on MOCVD for IGZO channel deposition
- We wonder whether MOCVD players like AIXTRON and Veeco will also try this

- For now, the Samsung group seems to be betting on both LTPS and TAOS for AMOLED backplanes.
- LGD seems more committed to IGZO as the basis for high performance LCD and for OLED backplane technology.
  - We hear Jusung has delivered a Gen-6 prototype tool for depositing IGZO with dopant gradients.
  - In other cases, we hear about display makers modifying AKT or ULVAC tools by themselves.
- Other display companies are watching the space closely. The Foxconn/Sharp plan for both LTPS and IGZO in a new fab indicates bets are being hedged.
- Inside display companies, IGZO implementations need to be compared to other high-performance TFT processes such as LTPS or improved a-Si devices.

*Synonyms: compound semiconductors, MO-TFT, IGZO

IGZO market map of key players and participants



- Sharp/Foxconn, LG and Samsung groups are best positioned for IGZO today
- SEL is a key IP player linked with Sharp
- Jusung has a close relationship with LGD
- Samsung has licensed IP from Hosono at JIST
- SCP (Samsung Corning Precision) is an affiliate company of Samsung group and an established target supplier
- ULVAC has own materials offering (ULMAT)

IP Holder | Display Co | Materials Provider | Equipment Company

Source: HCL, Analyst reports

IGZO has already generated new business for several players

	ULVAC (tools, Japan)	AMAT (tools, USA)	Jusung Eng. (tools, Korea)	ULMAT (materials)	ANP (materials)	Umicore (materials)
Profile	The top supplier of PVD tools for FPD and specialist in vacuum systems	A global leader in IC and LCD tools with strong CVD and PVD offerings	Korean public firm with links to LGD; $200m in revenue	A materials business within ULVAC, the leading supplier of PVD for AMLCD	Small Korean firm (KS:121600) that supplies coatings, films, et cetera	A business within the Belgium-based Umicore Group, a €2 billon business
Strategy	Restructuring to reduce break-even and to focus on growth markets	Lead development of tool productivity, especially for IC	Localised, gov't connected supplier with MOCVD plays in LED & LCD	Materials offering by company with strong position for sputter for IGZO	IGZO seems to be an important new offering for a new small company	IGZO business is a growth opportunity for its performance materials business
Product line-up for IGZO	Optimising sputter for IGZO devices plus targets through ULMAT	Optimising sputter for IGZO devices; toroidal targets	MOCVD for control of IGZO deposition at high throughput	IGZO sputter targets aligned with ULVAC equipment offering	Advanced Nano claims it is a leader in targets like Nikko or ULMAT	New IGZO target offerings
Technical and manufacturing capabilities	One of the stronger equipment players especially in the OLED arena	One of the strongest equipment companies	Particular competencies in CVD and MOCVD	An equipment player so strong understanding of the application	Small company with revenues of estimated $30m (2011)	A hard core metals player with businesses in catalysts, energy & recycling
Market position and customer base	Strong channels as one of the main established players	Strong customer portfolio and links to all players	Mid sized Korean equipment player with more scope than smaller captive players	Strong links to the whole display industry and well positioned for OLED also	Positioned as a supplier to Applied materials	Build off the Balzers previous business
Summary	One of the old standing leaders of the industry	The leader in sputter for displays and well positioned for IGZO	Relationship with LGD and potential to grow with international business	The links of ULVAC to the industry are what makes this a force to be reckoned with	Small company but well positioned with Applied materials	A metals player build off the Balzers previous business

Source: HCL, company websites and annual reports, analyst reports

And IGZO opens door for more material suppliers

	SCP (materials)	Materion (materials)	Heraeus (materials)	Nippon Mining (materials)	Mitsui Mining (materials)	Beijing Goodwill (materials)
Profile	A joint venture between Samsung and Corning for glass and other materials	US quoted company with USD $1.5bn in 8 major markets	German privately held business with revenues of Euro 2.5bn	Part of the JX Holdings Group in Japan with $135bn in revenues	Japanese multinational with revenues of $6bn	Chinese target maker with IGZO offering (and others)
Strategy	Specific materials offerings to support Samsung business in Korea and others	Profitable growth based on 8 key markets	Have been in the display targets business for quite a while	JX Holdings is a oil and gas and refining business with a metals business	Engineered materials is one of 5 core pillars including metals businesses	Metals and rare-earths supplier, crystalline materials and substrates
Product line up for IGZO	IGZO targets. Initial business built up based on venture with Sumitomo metal	IGZO target materials	IGZO target offering is extension of current business	Nippon mining is the leading player in ITO sputter targets (50% share)	Mitsui Mining is the number 2 player in ITO sputter targets moving into IGZO space	Rectangular and tube targets including recent IGZO offering
Technical and manufacturing capabilities	SCP mostly known for glass and recently for donor sheets for LITI (OLED)	Metals player only recently in the display industry	Metals player with established business in displays	Oil and gas player with sideline business in targets. Quoted as being a leader in targets	Company is expert on zinc and copper. Targets are part of engineered materials business	Not clear on their technical capabilities
Market position and customer base	Strong position in Korea as a supplier of display glass.	New entrant to the display industry we believe	Have been interested in the displays for a while but not clear what traction	The leading player in ITO sputter targets	The number 2 player in sputter targets with capacity also in Taiwan	Not clear what commercial traction they have made
Summary	Joint venture company with strong Samsung links	Metals player new to the display industry	Established player for TFT targets so IGZO is an additional product	The leading player in ITO sputter targets	The number 2 ITO sputter player and therefore a company to watch	One of 2 Chinese players with offerings in this space

Source: HCL, company websites and annual reports, analyst reports, DisplaySearch 2009

Summary: IGZO may bring a direct solution to a market need. It may also enable new value propositions

- IGZO solves a direct market need in that it provides a (to be proven) scalable platform for higher mobility transistors that could be the basis for AMOLED backplane by providing similar functionality as LTPS but at a lower cost structure (with a more proven path for mask reduction towards a-Si cost parity).
- SEL started as one of the prime holders of IP for the solution that Sharp has developed.
  - Other key IP holders include HP, JIST, Canon and Casio.
  - CBRITE, a Californian start-up also has IP and knowhow which it is actively trying to market to display players.
- IGZO may spin-off new applications.
  - Lack of sensitivity to light: Allows for transparent display applications
  - Lower leakage currents: Allows for lower power devices
  - Room temperature processing: Allows display makers one more piece of the display process at lower temperatures on the route to new processing paths
- The mainstream approach so far seems to be sputter based on new target materials but Jusung's MOCVD approach is certainly important, as are potential metal-oxide inks or coatings
  - Thus far Sharp has done much of its IGZO work without the involvement of ULVAC or Applied Materials in an effort to keep the knowhow private.
  - However, we think that these companies will be an important part of the IGZO answer and clearly the 2 top ITO sputter target players (Nippon Mining and Mitsui Mining) would have lots to fight for in a new market also.
- IGZO is just coming to the market in May 2012, so we think the playing field is still open for innovation and new options.

As OLED evolves, new opportunities will arise but some are being captured only in Korea. Upside for laser processing and moves to flex substrates

Static ongoing trends

- Koreans trying to capture value in Korea
- Importance of alternatives to LTPS for large Gen implementation
- Solution-processable and printable materials still seen as a worthwhile goal
- Increasing resolution requirements for device markets

Dynamic trends

- Relationship between LGD and Samsung for OLED (Currently more hostility)
- Increasing emphasis on flexible substrates
- Increasing strength of UDC as licensee
- Movement towards the use of lasers vs FMM

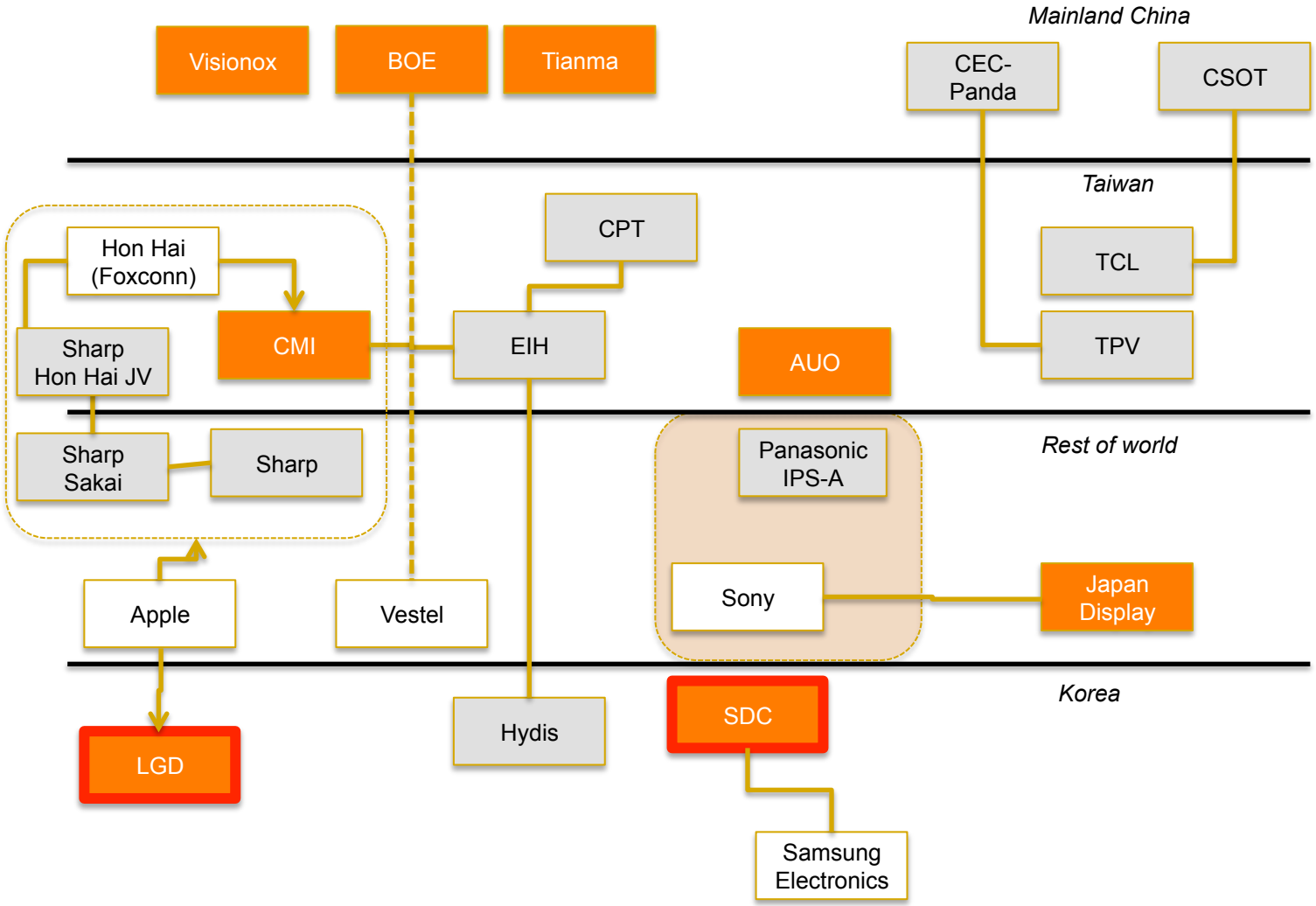
Implications

- **Role of high temperature substrates has increased**
- **Role of laser competency for high resolution (or LITI) has increased**
- **Many of the opportunities for now are in Korea but expect slow traction in Taiwan and China next**

- The OLED migration is finally happening, though we are in general more bearish about its near-term scale than are some analysts.
- The relationship between LGD and Samsung has become more hostile with a legal investigation of alleged theft of OLED IP by LGD. In the past there seemed to be a “basic agreement” that the two firms would not pursue each other. The result of this may be a bifurcation between OLED roadmaps that is more lasting.
- Ongoing trends in resolution for both small and large panels is leading towards a reevaluation of laser methods.
- The new A3 flexible line at former-SMD is a big experiment in the value proposition of flexible/unbreakable products .

Source: HCL

Potential OLED players in the flat panel industry context



- Two Koreans positioning themselves ahead of others
- AUO has so far committed only to small-panel OLED
- We expect CMI to consider a full OLED play later
- Sharp has remained on the side lines of OLED, so far
- Japan Display could be a technology provider to others
- We expect the Chinese to try to OLED entry but discover it challenging. Visionox (moving to AMOLED from passives), BOE and Tianma all have OLED plans.
- Sony and Panasonic OLED deal
- We would not be surprised to see Russia or Brazil interested in getting into the OLED business, although their paths to technology are not clear

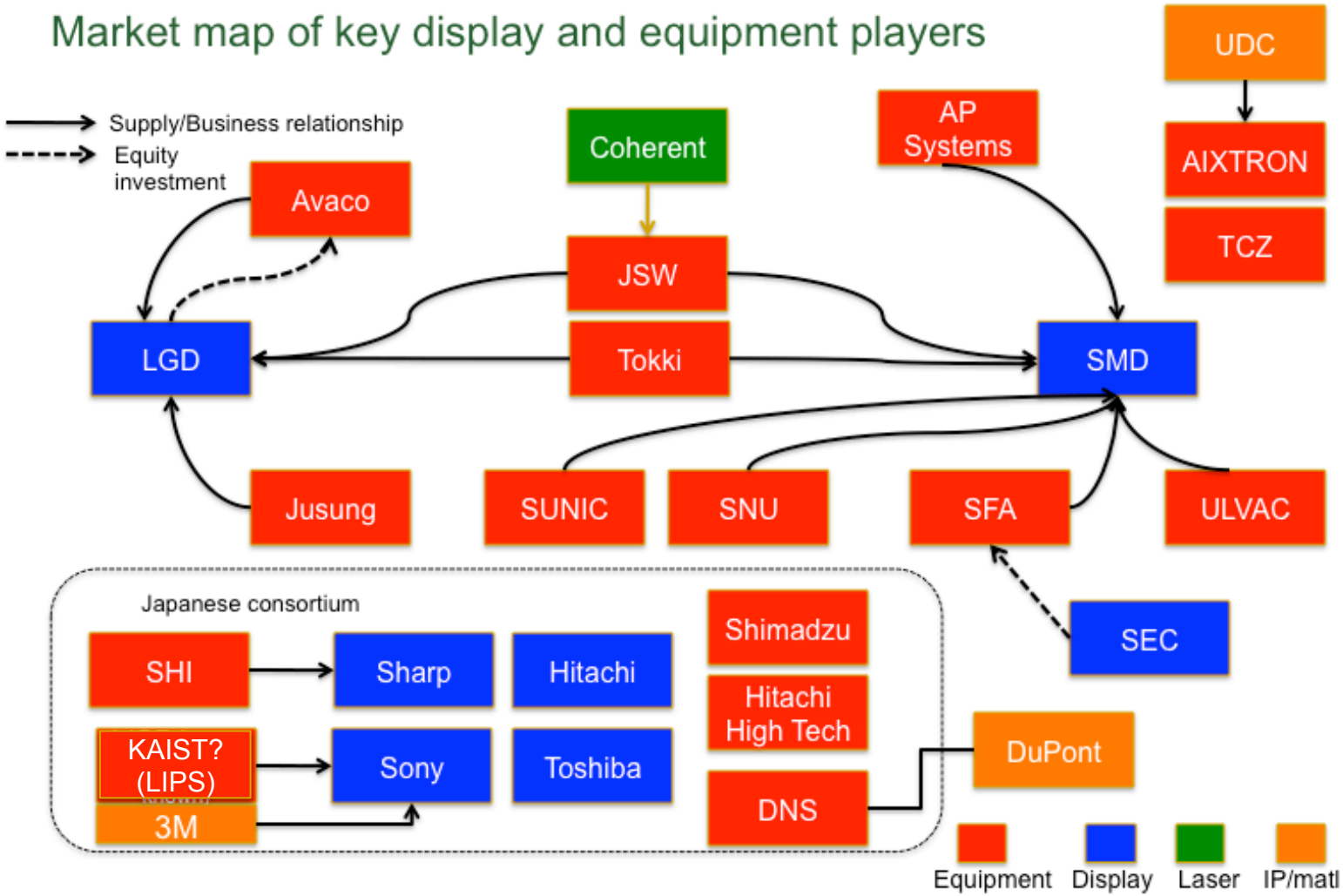
OLED play

LCD/Other

Source: HCL

OLED market map focusing on equipment and materials one layer down

Market map of key display and equipment players



- At an equipment level we see Avaco and Jusung as being particularly well tied in with LGD
- SFA is the Samsung group company supplying much of the OLED equipment into SMD (SMD rolled into SDC on July 1st 2012)
- AP Systems seems to be the beneficiary of moves, we believe, by former-SMD towards greater use of lasers as an alternative to FMM for high resolution displays
- Tokki may still end up picking up a reasonable portion of the new OLED systems business outside of Korea

Source: HCL

Some potential winners in OLED other than Samsung & LG

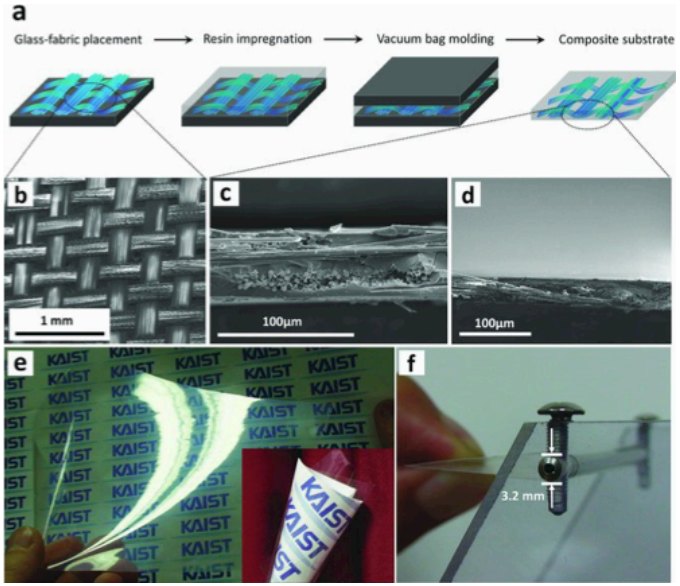
	AP Systems	SFA	Avaco	UDC (Mat'ls and IP)	Tokki (Canon)	Jusung Eng.
Profile	Medium sized laser based equipment maker quoted on the KOSPI	Medium sized Samsung group affiliate picking up substantial orders from affiliates	Small-medium sized equipment company with LGD relationship	American quoted firm on NASDAQ with strong IP portfolio in phosphorescents	Japanese equipment business acquired in the last few years by Canon	Korean public equipment player with links in particular to LGD. $200m in revenue
Strategy	Laser based platform strategy with strong relationship to Samsung group	Display and semiconductor heavy industrial equipment (former Samsung affiliate)	Sputter for LCD and expanding into OLED offerings	Be the most important IP player in phosphorescent OLED	A system solution for OLED deposition and encapsulation	Localised equipment player with LGD connection and MOCVD/LED axis
Product line up for OLED	Laser crystalisation, lift off and LITI plus glass-glass encapsulation	Encapsulation and vertical evapouration equipment	Evapouration and encapsulation	IP and materials sales. UDC is very well networked	A system solution for OLED depostion (FMM) and encapsulation	MOCVD for IGZO plus evapouration and encapsulation capabilities
Technical and manufacturing capabilities	Communications background, with recent high growth profile	Recent revenues in the $900m range, so a serious player	Mid sized business with sputter background	Despite recent Japanese court rulings they have strong IP in phosphorescents	One of the leaders (especially for sales not to Korea) of OLED solutions	Vacuum/PECVD background
Market position and customer base	Close relationship with former-SMD (SDC from July 1st 2012)	Close relationship with Samsung group companies	Relationship with LGD and part owned by them	Well networked with all of the important players in displays and lighting	Well known and strong reputation	Relationship with LGD but focus outside of Korea also
Summary	A key part of the Samsung equipment localisation strategy	Likely beneficiary of much of the Samsung related OLED growth	One of the beneficiaries from LGD	Looking quite well positioned today	May pick up many of the equipment orders outside Korea	A Korean vendor moving to a broader international play

Source: HCL, company websites and annual reports, analyst reports

Overall we still have a mixed view on the OLED opportunity

- We take a neutral outlook on the OLED display market overall, given the challenges it will have to establish itself as a premium display technology, delivering more than LCD can (so inherently OLED will need also to provide for 4k2k resolution and access to 3D as well as scaling rapidly to large panel sizes).
  - Demand elasticity relative to price will be critical. Historical trends suggest low real demand today.
  - Initial pricing for a 55” set has been set at about $9000 so at a high premium over LED-lit LCD sets.
- For now, increasing resolution demands across device markets seems to be leading towards greater exploration of the role of laser-based processes as alternatives to fine-metal masks (FMM, evaporation).
  - DuPont and DNS have secured a test site for their nozzle coat process so this cannot be counted out of the running for future evaporation approaches either.
- UDC, with phosphorescent emitters, is winning the battle between the different materials camps for now.
  - Novaled has an SEC shelf filing (for IPO) and an investment from Samsung group for its PIN materials.
  - Sumitomo/Sumation and Merck remain contenders, also; we expect more attempts to limit UDC claims.
- Second-tier OLED display players (in which we include BOE, CMO, AUO) are just beginning to get their business plans together for large panel OLED. There are rumors of talks between AUO-Sony-Panasonic.
- For now one important indicator is LGD’s view that OLED factory building for now is better achieved through a mixture of conversions of LCD fabs with a little new equipment.
  - This is a more bearish equipment picture than the recent flurry of greenfield facilities

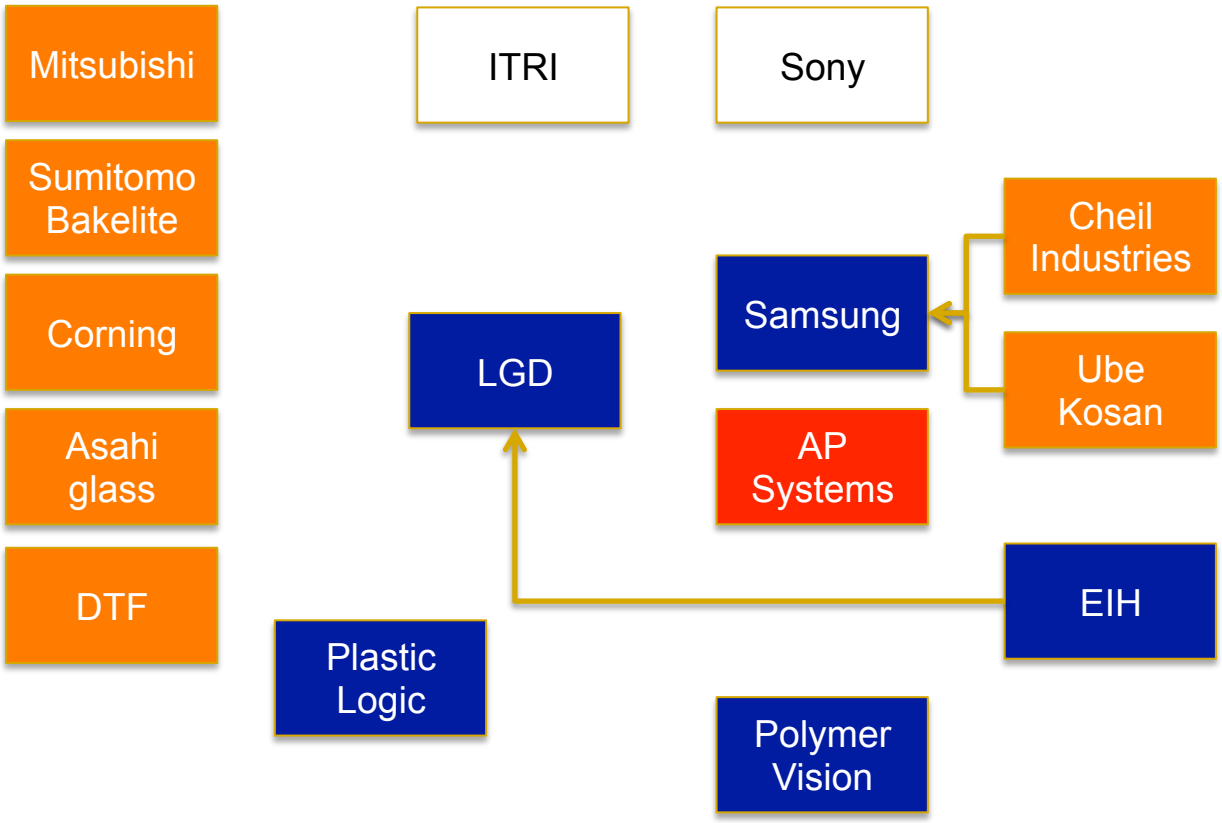
Samsung has started promoting unbreakable or flexible materials for mobile gadgets



- Samsung (former SMD business) announced their “YOUM” brand name for flexible displays.
- It is not currently clear to us whether Samsung is pursuing a single or double pronged approach for flexible materials.
  - A joint venture with Ube Kosan for polyimide substrates
  - An earlier KAIST-developed fiber-reinforced plastic now under control of the Cheil Industries affiliate
- What is clear in both approaches is the role of “high temperature” materials, even if this is in conflict with the haze, colour or cost of the material
- LGD in the meantime is playing catchup and thus far has announced mass production flexible EPD displays, based also on what looks like polyimide (PI)
- Beyond these two players, E Ink Holdings, Plastic Logic, PolymerVision and Sony have flexible device programmes
- What is new is the commitment to a mass production scale facility called “A3” at former-SMD

Source: Daewoo Securities Research, Kaist research paper, Pictures from Samsung

Flexible/unbreakable industry map…
so far, all mid-term efforts use plastic on glass carriers



- Samsung (former SMD) leading the charge into mass production of flexible displays
- LGD is a fast follower with initial mass production emphasis on electrophoretic displays
- Corning has been pressing ahead with work on thin glass for R2R
- PolymerVision clearly one of the long term R&D players in this space with their own proprietary process (if no product, yet)
- Plastic Logic showed a video of its flexible display line in Dresden (at FlexTech) but withdrew from the end-product business
- AP Systems trying to position itself as one of the key equipment players for laser lift off at Samsung (former SMD)

Source: HCL

Selected potential winners in flexible displays other than 2 Koreans

	Ube Kosan	Cheil Industries	Corning	DTF (DuPont Teijin Films)	EIH
Profile	Japanese materials corporate with recent JV with SMD for flex display substrates	The Samsung affiliated Chemical and materials company	The US large corporate and leading supplier of display glass	A joint venture between DuPont and Teijin in Japan	A Taiwan based public display company with long history in flex development
Strategy	$8bn firm with BUs in chemicals, pharma, construction, energy	Repositioning as more of an electronic materials player (less on fashion business)	Create new opportunities for specialist glass at high value	World leader in differentiated PET and PEN films	The leader in the eReader space and lots of work into flexibles but no product yet
Product line up for flexibles	Substrate material used seemingly by SMD in flexible display work	We believe they may produce an FRP substrate	New R2R capable thin glass material.	Heat stabilised PET and PEN materials for flex applications	Announced their work in this space but not yet an actual product
Technical and manufacturing capabilities	One of the leaders in Polyimide for flex circuit applications	Getting a stronger and stronger materials portfolio around plastics/ fibres	The clear leader of the borosilicate glass players	Leaders in PET and PEN material and processing	The leader in eReader display development plus FFS technology
Market position and customer base	JV with SMD for flexible substrate material	Strong focus on the Samsung group for electronic materials business	The strongest player of the borosilicate glass companies	Very well networked in the display and polymer electronics worlds	Market focus on Amazon, (US) and Hanvon (China)
Summary	Important because of the JV with Samsung for flex displays and worth watching	The Samsung group company we believe working on flexible substrates	The dominant glass player trying to come up with a line extension	One of the old standing leaders of the industry	Lots of work on flexibles but no product, yet

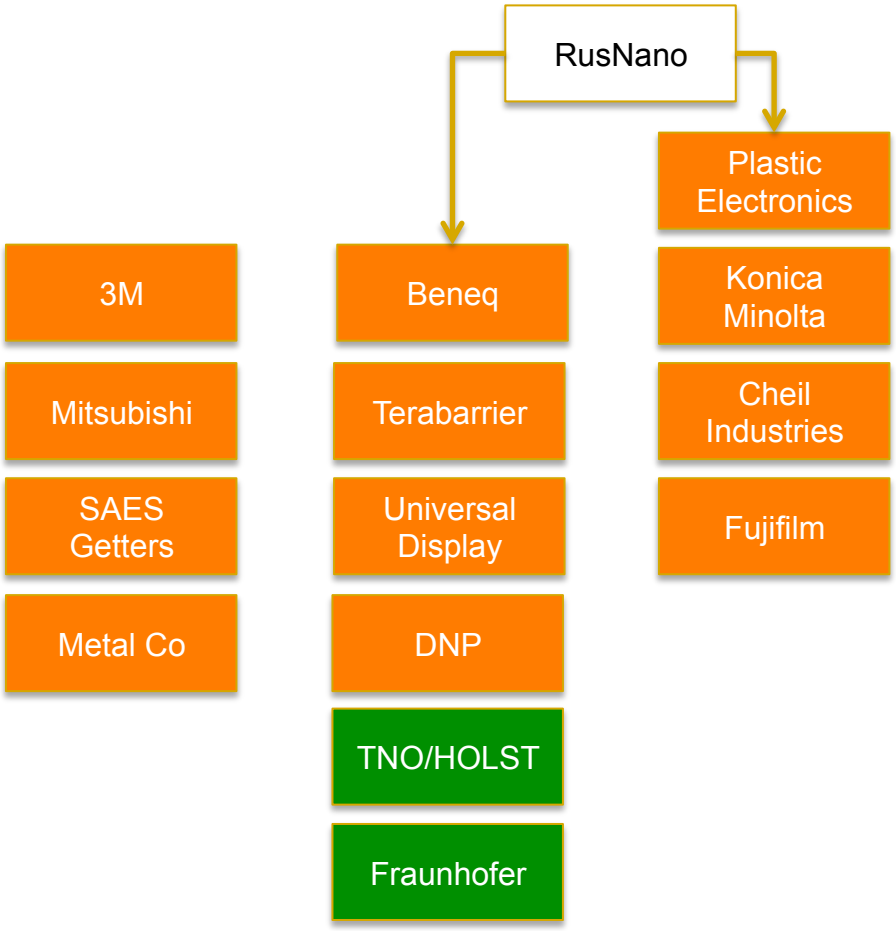
- In the display arena former-SMD (now SDC) is by far the furthest ahead with a mass production roadmap although LGD emphasising flex now
- We had to think long and hard to decide which other display player to add. Sony have distinct competences (but only an R&D programme). We decided EIH worth mentioning

Source: HCL, company websites and annual reports, analyst reports

Flexible or unbreakable summary

- Flexible displays are very early in their mass production days based on a “technology push” from former-SMD (to be part of SDC from July 1st 2012)
  - LGD has been playing fast catch up with an emphasis on EPD displays for now.
  - We expect first products may be one-time bendable (formable) but not flexible in use.
- We look for complete value chains through to the consumer when we evaluate emerging technologies.
  - It is still far from clear that such a chain has been forged here, despite the distribution channels that Samsung Electronics controls through its mobile business.
  - We think automotive markets present an opportunity but we have not seen announcements by car integrators regarding formable OLED. (Though we note co-development of OLED lighting for car interiors by BASF FB and Philips Lighting.)
- For now, Samsung is betting on new, high temperature capable substrates, so that the vast majority of the current batch mode equipment can be used, pretty much as is.
  - This must be disappointing to companies like DTF who have tried to position temperature stabilised PET and PEN as the de facto standard materials for flex displays.
  - Low temperature substrates create all sorts processing and alignment-overlay challenges plus real issues in lamination and edge sealing.
- It is worth noting that the first focus of the flex display industry is to support “unbreakable” and/or conformable products in mass production. Fully flex-in-use products are further away (3 more years even for Samsung) and have new to the world value propositions.

Barriers and encapsulation (and related) market map:



- OLED displays in particular and organic electronics in general can fail from contamination by oxygen or water
- Delays in mass production of OLED displays have led to a proliferation of disappointed technology entrants in the high-barrier film market
- However, a clear winner is not yet evident, not even a dominant material (barrier film) or process approach. Samsung acquired thin-film encapsulation IP from Vitex Systems for its OLED products. The Cheil Industries affiliate is working on films and Samsung Display (after merging with SMD) is working on OLED fabrication
- UDC has a single layer composite barrier material
- 3M is really the only firm that has taken the plunge towards mass production with a $45m investment in capacity for barrier film laminates
- HOLST Centre has several encapsulation-related projects running in The Netherlands and the Fraunhoffer Institute has cross-linked barrier materials in its German labs
- The frontier for now is single layers and ALD is one potential, if slow, technique

Source: HCL

Key barrier film and encapsulation players:

	3M	Cheil Ind. (Samsung)	UDC	HOLST Centre	DNP	Mitsubishi Plastics
Profile	The renewables and displays and graphics groups jointly investing in new barrier line	The Samsung group internal materials company	A NASDAQ listed company in the USA with IP from Motorola and its own R&D	A research lab that does contract R&D with industry in the Netherlands	Japanese multinational with very strong print heritage	Major Japanese multinational player with revenues of $5bn
Strategy	Value added materials player, first to the market with real scale	Moving from fibres/ fashion background into electronics materials	An IP and materials company for OLED (displays and lighting)	Multi-party research programmes in display, PV, lighting and others	Major printing and electronic materials company	Very broad chemicals company with electronic materials business
Product line up for barriers	Web material for barrier film applications	Acquired many of the people from Vitex and working on barriers as part of government deal	UDC has a patent for a single layer hybrid product solution for high barrier	Layered nitride-oxide-stack type approach	SiN on siloxane via CVD approach	X-Barrier provides for medium barrier 10^{-4} WVTR capabilities
Technical and manufacturing capabilities	World class films and materials expertise with manufacturing clout	Building up capabilities in electronic materials and now quite capable	A hard core metals player with businesses in catalysts, energy & recycling	Strong group of partners making quite a name for itself	Print company with deep history in colour filter making	Films and plastics for packaging, building and electronics applications
Market position and customer base	D&G group at 3M is very well networked in the display world	Focus on the Samsung group in the first instance	UDC is well networked among Asian display players	At the moment still Western centric but beginning to get some traction with Asian players	Japanese orientation and strong links to Sharp	Reasonable reach given they have a medium-barrier material
Summary	One of the first players putting down mass production capability	Samsung group company working on barriers as part of WPM programme	OLED materials and IP company that may branch out into barrier solutions	Still at the R&D level for now	Major print and electronic materials company but Japanese centric	Fairly well known, mid-level barrier player

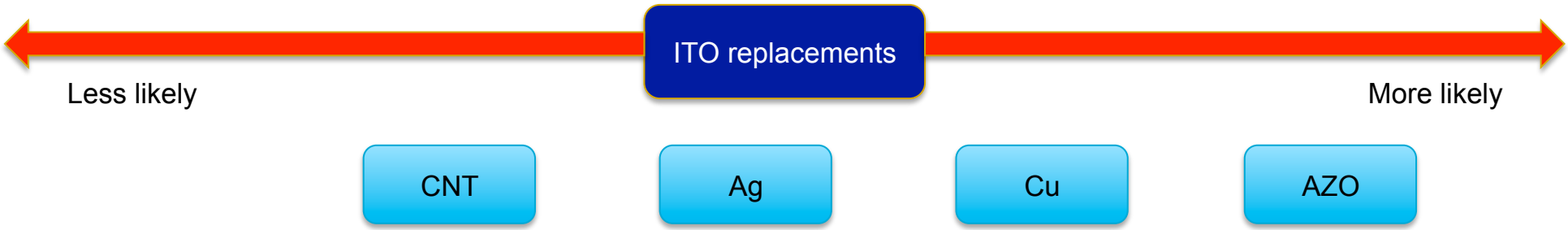
Source: HCL, company websites and annual reports, analyst reports

Barrier film and encapsulation: Summary

- For now, 3M seems to be pretty much the only firm investing into mass production capability for barrier films for 10^{-3} to 10^{-4} WVTR barrier applications but OLED may require 10^{-6} WVTR barriers. There is much room for improvement, and for second sourcing.
- Elsewhere displays and plastic electronics players are either using traditional glass-glass-frit seals, trying metal encapsulation or cobbling together barrier solutions from medium-level barriers
- The holy-grail is a hybrid-single-layer barrier solution but this is not something that has been proven for mass production and many different approaches are being taken. In general, however, the approach has involved modulating CVD chamber conditions so that cross-linked organic and inorganic chains form. Tera-Barrier Films (an investee of Applied Materials) is working on a variation using nano-materials to fill voids in the barrier.
- The barrier market spans other applications such as solar cells, but the “bankability” of long-term reliability is a much greater concern there than it is for displays. Barriers for displays may be less price sensitive than barriers for solar cells, batteries or OELighting (OLED). So, it seems like displays would be the best application for barrier film suppliers. The problem is demand, which has been slow to develop for reasons related to TFT development, pattern deposition and such.
- For now, there is no perfect solution, so this is an on-going opportunity for new entrants. Players in technologies as nascent as ALD are investigating the space (Beneq in Finland is one that has received a cash infusion from RusNano).

Source: HCL

New TCO materials seem of interest but the appetite for technology risk of the LCD industry is muted



- A range of different materials are vying to replace or co-exist with ITO in display fabrication.
- The display industry tends to adopt new material systems more slowly than suppliers anticipate. The current pressure on finding new solutions for OLED patterning for example, comes from understanding that FMM will not enable high-ppi displays. We expect display makers to seek the least disruptive material system.
- In general we take the view that inorganic systems are much more likely to win than organics. We see AZO, solution ITO, or IZO as more likely than more challenging developments like CNT, conjugated polymers or graphenes.
  - Many display companies are relatively weak at material science and they understand inorganic material systems. Moreover, inorganics typically have lower IP requirements and more mature supply chains.
  - Printing has come a long way in the past decade, but Sharp has pulled back from several print-related innovations.
  - “It is much more difficult to fool an electron than a human regarding the actual performance of printed matter.”
- We expect touch screens will present the better opportunity for alternative conductors because specifications are more relaxed and a number of OEM/ODM would like to rearward integrate into touch panel components.

Source: HCL

Some interesting stories in TCO materials

	Kurt J. Lesker	Uni-Pixel	Atmel	Cambrios	C3Nano	Others, e.g. 3M
Profile	Private US firm focused on "All things vacuum"	Small NASDAQ listed corporation in Texas	US public company focused on microcontrollers and recent emphasis on touch	California based start-up with funds from Samsung Ventures (SVIC)	Start up based on hybrid-carbon nanotubes. Spin out from Stanford	A variety of large firms such as 3M have IP related to TCO
Strategy	Materials offering by company with strong position for sputter for IGZO	Current focus on mastering and imprinting for touch panel applications	Microcontrollers, NVM and ASICs for touch plus a novel conductor	Use of silver mesh technology to make functional films for displays and touch	ITO replacement with CNT materials.	Business units may act separately, so there may be little synergy
Product line up for TCO materials	A range of novel TCO materials and sputter targets	Have novel mesh-screen mastering/ imprinting technology	Xsense mesh imprint system based on technology from CIT in the UK	ClearOhm silver mesh as a coating for plastic or glass substrates	Hybrid CNT material claimed to be 1/5 the cost of ITO	Can be broad, such as 3M, or more narrow
Technical and manufacturing capabilities	Mid-sized firm with long history in vacuum systems for semiconductors	Small company but recent mass production deal with Carestream Tollcoating	Mainly an IC company so this competence is separate to that	Small start-up but gaining traction in Huawei's supply chain	Small startup spun out of Stanford	Firms like Solvay, 3M or others may need large demand before investing
Market position and customer base	Not clear how broad their display customer base may be	Not clear how much customer progress they have made. Revenues of $0.2m only	Atmel is well established with touch panel makers today	Have established business with Nissha for touch panels for Huawei	Not clear how much commercial traction they have yet	In general, they use country organizations to lever relations
Summary	Novel approaches with 17 new oxides	Small company with novel new technology for touch applications	Position in touch companies may expand into the display space	The route into touch panels seems a sensible plan. SVIC funding is a positive	Interesting material with decent credentials	Potential for supply when demand grows large enough for them

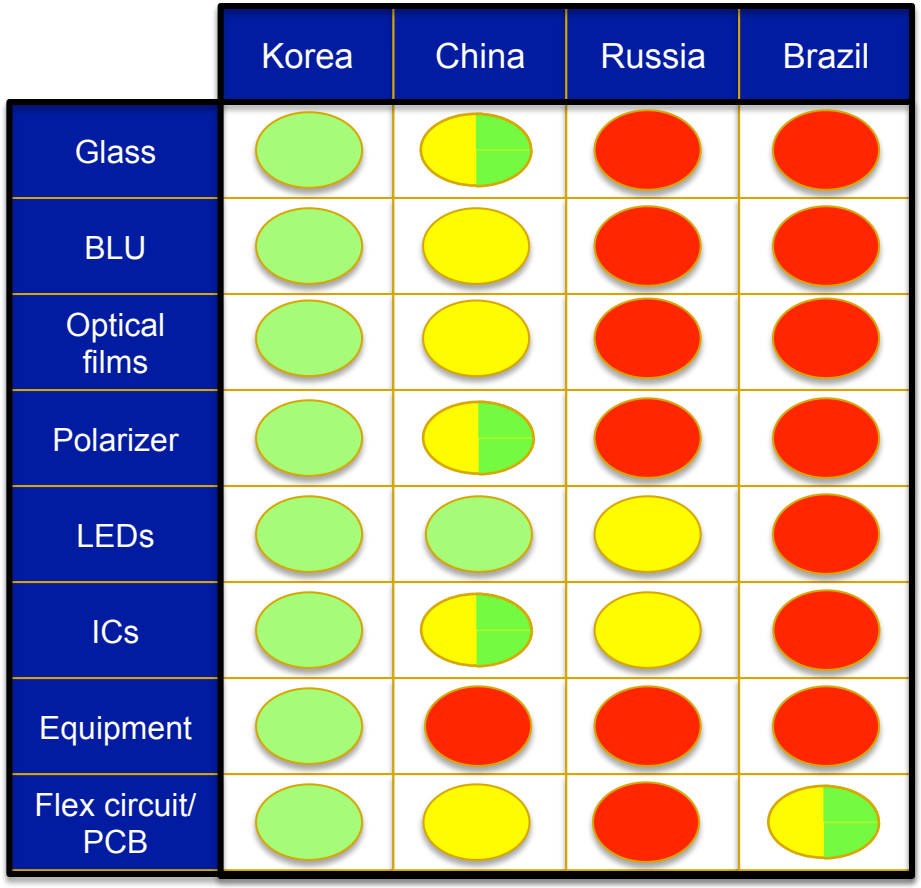
Source: HCL, company websites and annual reports, analyst reports

Summary of new TCO materials and related businesses

- Opportunities for ITO replacements and other conductive material systems are difficult to assess.
  - We understand the interest in ITO alternatives because of price and worries about availability. The fact remains that ITO is a bi-product of Tin mining, so supply will remain independent of price.
  - Display companies are notoriously risk adverse to adopting new material systems unless there is a real imperative to do so. A fiscal quarter of yield loss in a large fab amounts to a fortune.
- However, innovations starting in the touch panel arena may increase general acceptance of novel approaches.
  - Companies like Nissha have been experimenting for a while with ITO replacement materials, for example the nano-silver from Cambrios
  - Uni-Pixel also looking at the touch panel market as a route into displays for its mastering technology.
- In our minds, an interesting conflict may arise between second-tier or third-tier panel makers who have retreated into the touch screen coating market, the first-tier panel makers who want to capture value through in-cell touch systems and ODM who want to capture value through rearward integration of film-based ITO alternatives.
  - We assume smaller panel makers will be unable to recapitalize or retool for alternatives to ITO.
  - We assume ODMs have an advantage in both capital and market position. Brands may see them as means for sourcing displays from several producers while getting consistent touch screen products.

Source: HCL

Geographic proliferation of supply chains is another key trend creating opportunities



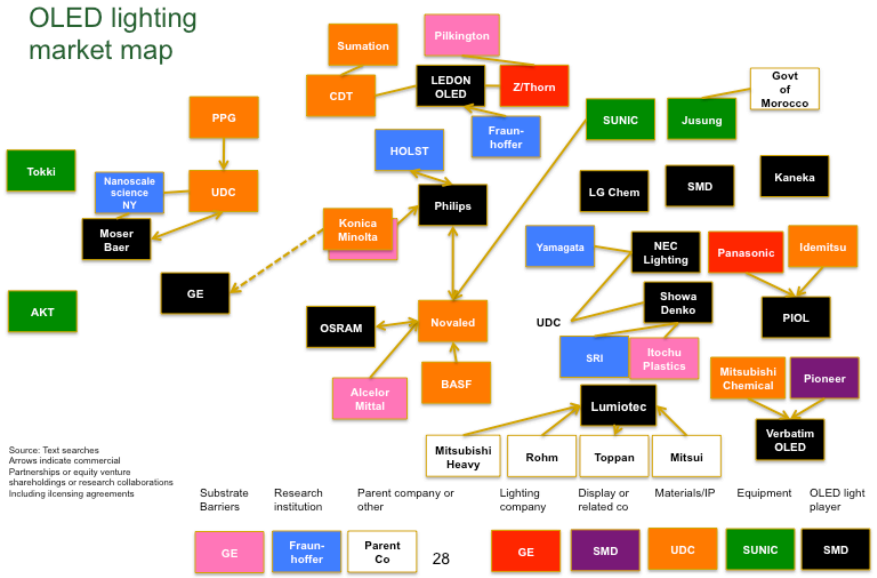
- As regionalisation hits the TFT industry (Brazil, China and potentially Russia) then localisation will be a key strategy to keep cost structures in line with a cost competitive business.
- Tariff structures affect supply chain strategies and create moving incentives for location in-country or importation.
- Corning and Asahi Glass for example have put glass capacity in China and Chinese display makers are establishing domestic supply chains for many other materials.
  - Polariser: Nitto, Sumitomo, LG Chem, Optimax, Daxon
  - BLU: Radiant, Coretronic, Forhouse, K-Bridge
  - Drive IC: New Visions, Tianli
  - However, there is still not the same supply as in Taiwan or Korea and the picture is substantially bleaker in Russia, Brazil or India
- For many types of optical films, local “jobbers” will be needed for cutting large rolls into specific display sizes (and for acting as inventory buffers).

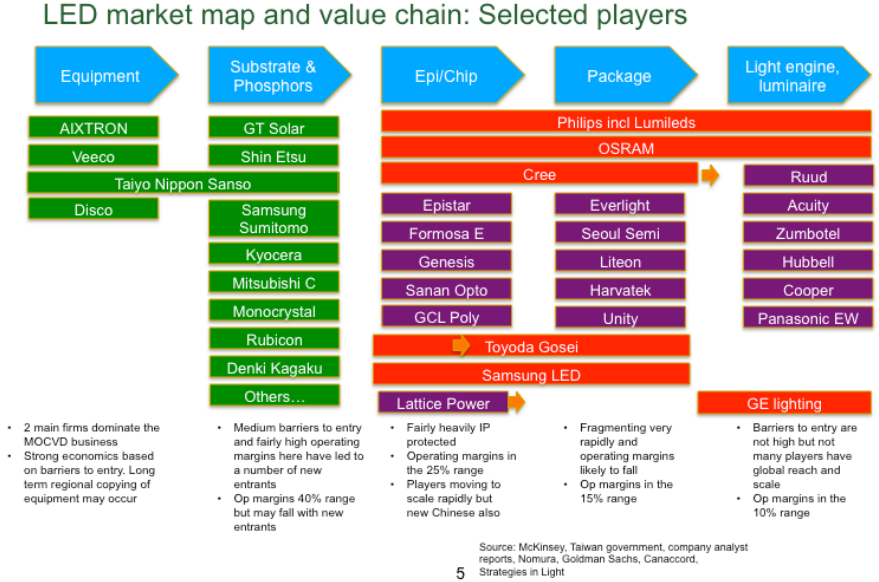
Source: HCL, Tianma presentation

Many of the market opportunities here can be served by imports if local jobbers can cut optical films/polarisers

- Many of the materials required for display making can be imported (Driver ICs, flex circuits) fairly efficiently from abroad
- Substrates and films need to have local infrastructure
  - While transporting of 0.28-0.7t glass substrates geographically does occur, clearly there are logistics and breakage issues
  - All of the optical films and polarisers can be shipped as long roles of material but a jobbers foot print would be needed in new geographies to be able to process these

Displays meets lighting is a new set of market opportunities

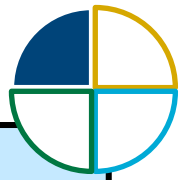




- The display industry competes for resources against the inorganic LED and organic LED industries.
- We think that all of the technology elements are in place for display backlight companies to move into planar LED lighting solutions.
  - BLU companies need new markets for growth.
  - They have learned a lot about heat and optical uniformity that applies to lighting.
  - The dimensions of ceiling light troffers are easy to supply compared to ultra-note PCs.
- We take a more bearish view on OLED lighting simply given the cost-price requirement. However, there is a chance that national policy (especially in Japan, China and Korea and perhaps in Europe) could be bent towards incentives for adoption.
  - The OLED lighting market is a veritable treasure trove of materials related business opportunities.
  - We see synergies with displays in light or colour management, barrier requirements et cetera.

Source: HCL
(See our publication on www.hendyconsulting.com on this space)

Selected winners in “Displays meets lighting”:



	Sharp	Konica Minolta	LG Chem	Samsung LED	Coretronic	Forhouse
Profile	Japanese LCD and PV company with recent interest in LEDs and lighting	Japanese business solutions, healthcare and imaging firm	Major Korean multinational with businesses in 3 fields	This business is being merged into Samsung’s new Components sector	Taiwan listed €2 bn firm and #2 BLU producer	A top-5 BLU maker listed in Taiwan; AUO owns ~25% of this €625m firm
Strategy	A display company also looking at using optics knowhow to move into lighting	Core of the business is in optical imaging	Petrochemicals, batteries for electric cars and electronic materials	Building up epi/chip and package capacity rapidly and entering SSL	Sustain optics technology through projector business and grow elsewhere	Integrating value through joint R&D with AUO
Product line up for solid state lighting	Zenigata product offering of replacement LED solutions	OLED lighting product offering in collaboration with Philips and R&D into emitters	Working on an OLED lighting module business	Planar ceiling SSL plus down lights made with own LED and parts	Makes projector parts and high-end tablet sidelights	Makes PMMA for light-guide sheets that could enable LED troffers
Technical and manufacturing capabilities	Strong electronics and thin film capabilities	Have seemingly demonstrated quite some expertise in thin films and emitters	The LG group (also through LGD) has all the competencies to make a success	LED capacity plus work on glass substrates and packaging for SSL	A leading BLU supplier to Apple and other high-end brands	Evonik Forhouse Optical Polymers JV in PMMA plus Chinese assembly
Market position and customer base	Sharp seems to see-saw in its commitment to B2B business models.	A partnership with Philips Lighting	A new player into OLED lighting but one with all the competencies	Cooperates with Acuity brands in USA (as do other LED markers)	10% market share and key supplier for ultrabooks and tablets (iPad)	May become the #4 backlight supplier; AUO is the main customer
Summary	Interesting story of a display player taking BLU expertise into lighting	Have made impressive progress in development of OLED lighting	A OLED lighting player to watch	Moving very rapidly as we might expect from a Samsung group company	One of the top 2 BLU players and expected to transition to lighting	One of the top BLU players expected to transition to lighting

Source: HCL, company websites and annual reports, analyst reports

…and use of lasers, coating and flash drying are new equipment innovations:

- We have already mentioned the upside for laser companies in displays and related applications.
  - Competition from high-ppi LCD forces OLED makers to consider replacing shadow mask (FMM) processes with laser-induced pattern transfer (LITI or LIPS) processes.
  - Development of organic semiconductors leads to need for contact vias drilled by laser, rather than conventional etching processes.
  - Adoption of transparent, flexible substrates creates opportunities for backside exposure or self-aligned patterning through ablation, which is already applied to solar cell production.
- AP Systems appears to be the current beneficiary of these trends given its relationship with Samsung Display (formerly SMD). We believe Tamarack to be well positioned in plastic electronics because of experience, though larger tool companies may enter the market later.
- We are watching a long list of materials and tools companies in Europe and the USA ranging from corporates such as DuPont (nozzle coating OLED) to start-ups such as Kateeva (thermal jet OLED).
  - There may be opportunities for both patterned and unpatterned coating technologies.
  - Flash drying, such as demonstrated by NovaCentrix, or fast-drying inks with rheologies tailored to specific web speeds are also interesting subjects of innovation.

Key trends and implications for new opportunities

	Winners	Losers
IGZO	Samsung, Sharp, LGD, Advanced Nano, ULVAC, Jusung, AMAT	LTPS equipment players and LTPS fab owners
OLED roll out	AP Systems, SFA, UDC	LTPS supply chain now and FMM supply chain longer term
Flexibles	Samsung Display, Ube Kosan, Cheil, high temperature substrate makers	Low temperature substrate materials for now
Barriers and encapsulation	3M, Mitsubishi Plastic, UDC	Corning
New TCO materials	3M, Atmel, Cambrios	Mitsui Mining, JX Holdings
Regionalisation and new supply chains	Those to establish supply chains in China and Brazil or Russia	Those with overly country centric model (Japanese?)
Displays meets lighting	Samsung, LG Chem, Konica Minolta, Coretronic	GE, OSRAM, Philips
Lasers, coating and flash drying	AP Systems, Tamarack	FMM players

Source: HCL

Summary

- On the whole, see the display industry maturing in a bad way regarding the economics of its participants.
- There are some opportunities for growth and profit remaining, however. These relate to the value of higher-ppi displays or more capable displays using IGZO TFT, unique OLED value propositions, unbreakable or flexible products and regional supply chains in BRIC markets.
- OLED starts from a reasonable point in that SMD has proven it can serve the market profitably, and there certainly are indicators that this is a new game with different fixed-variable cost ratios and a more tightly controlled (Korean) supply chain.
  - The fact that emerging economies want to leap-frog into the technology but without prerequisite competencies makes OLED an interesting option in BRIC countries. Current technology leaders might be forced to pick partners and extract value.
  - Every indication is that material supply will remain important in OLED, as it has in LCD. Corning is still Corning and it has doubled-down with investments in both OLED-specific-"Lotus glass" (in collaboration with Samsung) and through thin flexible glass. Merck still leads in liquid crystals but UDC leads in OLED. Materials players who launch alternative, high-performance materials may end up doing equally as well.
- The industry also faces some important new threats such as pressure to rededicate older fabs, which seems to be occurring at LG Display and Sharp, at least. We shall see what happens with the Samsung mergers.
- "Resources for technology" seems to be a new high level trends also with both Russia and China wanting to trade hegemony in national resources (or lack thereof) for access to high tech (see the Orbos deal for AMOLED in Mongolia).
- Over the past two decades, assemblers (OEM/ODM) have generated more consistent profits than have display makers. We wonder if this will remain true as the industry transitions to new material sets and technologies.