Opportunities for OLED Materials

NanoMarkets, LC

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OBJECTIVES AND SCOPE OF THIS REPORT

The main objective of this report is to provide a comprehensive overview of the OLED materials market, thus assessing the future potential of the industry. At the same time the report also seeks to provide detailed eight-year forecasts for the OLED materials business by segregating the market under individual materials sets with separate revenue and volume estimations.

In compiling our forecasts, we examine the trends in product development and marketing strategies adopted by leading OLED material suppliers along with the two major consumers, i.e. the OLED display and lighting segments. Both large and small material firms have been taken into consideration in developing our forecasts..

We also take into account announcements by current and prospective players in the OLED materials space regarding pricing, product types, and possible material supply agreements. Major announcements from primary consumers of OLED materials, including Samsung and LG, have also been factored into the forecasting. Different OLED materials that are covered by this report include:

- Emissive layer (EML) materials
- Electron transport layer (ETL) materials
- Hole transport layers (HTL/EBL/HBL) materials
- Hole injection layer (HIL) materials
- Electrode materials
- Encapsulation materials
- Substrate materials

METHODOLOGY AND INFORMATION SOURCES

This report is the latest from NanoMarkets that looks closely at the trends in the OLED materials industry.

The basic forecasting approach is to identify and quantify the potential demand of each of the core and auxiliary OLED materials over the next eight years and then to access the approximate market penetration of those materials. This has been done by keeping in mind the production and commercialization strategies adopted by key OLED material consumers from the display and the lighting space.

As part of the analysis, we assess the competitive landscape in order to determine the likely level of competition from other material manufacturers and novel technologies. In addition, we also access how technical developments around core and auxiliary OLED materials can enable the underlying consumers to commercialize OLED displays and lighting applications that can find the favor of the ultimate end-users, thus providing a scope to expand the addressable market for OLED materials.

To determine where the opportunities lie, we have based this report on both primary and secondary research.

Primary information is gathered largely through NanoMarkets' analysis of relevant applications markets and market trends based on ongoing discussions with key players in the OLED materials segment, including entrepreneurs, business development and marketing managers, and technologists.

Secondary research is drawn from the technical literature, relevant company websites, trade journals and press articles, and various collateral items from trade shows and conferences. This research also includes the complete library of our own reports in this field, which is now quite extensive. Where data has been used from another report, it has been reinvestigated, reanalyzed, and reconsidered in light of current information and updated accordingly.

This report is international in scope. The forecasts here are worldwide forecasts and we have not been geographically selective in the firms that we have covered in this report or interviewed in order to collect information.

PLAN OF THIS REPORT

In Chapter Two of this report, we review the ongoing trends in the performance of OLED materials along with the challenges that need to be overcome through the introduction of new or modified materials. We look at likely shift in demand from key OLED material consumer segments, including small to medium size displays, large displays and lighting applications. Special emphasis has been paid to analyze the impact of a likely shift of focus from large OLED displays to small- to medium-size displays and lighting applications. Technological and production cost hurdles for large OLED displays have been discussed in the report to access the overall impact on the demand for OLED materials in the coming years. In addition, methods to optimize the OLED production process and probable candidates for cost-effective OLED materials are elaborated in this chapter to provide a future roadmap for the materials industry.

Finally, in Chapter Three we review the addressable markets, indicating the potential use of OLED materials for display and lighting applications. We focus on those firms that are actively involved in developing strategies to improve the performance of OLED materials and those that have the potential to commercialize specific OLED materials in a big way. For this purpose, we have considered both OLED material manufacturers and OLED display and lighting panel manufacturers.

At the same time, we provide the core forecasts for OLED materials bifurcating the application of each material under display and lighting segments, wherever applicable. We describe assumptions about pricing, market trends, and other factors that may influence the forecasts.

Chapter One: Introduction

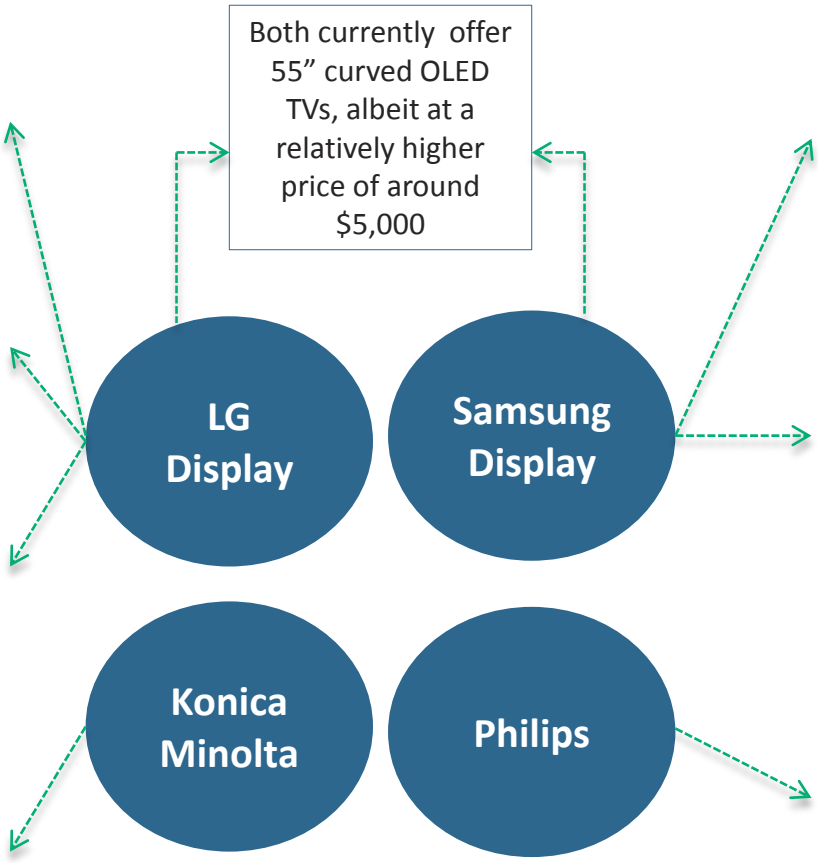
PATHS TO A PROSPERING OLED MATERIALS INDUSTRY

Plans to improve its flexible OLED displays

In a favorable position to successfully produce high-performing large-sized OLED displays given the firm's access to in-house WRGB technology that combines oxide TFT backplane with 4 sub-pixels at the top.

Talks are on with Merck to develop inkjet printing materials. Merck already supplies evaporable OLED materials to LG for the latter's OLED TVs and Merck also intends to supply solution OLED materials.

Konica Minolta's $100 million investment in the world's largest OLED lighting panel mass production facility is another encouraging factor for OLED material providers.



Aims to develop new designs and forms of OLED displays, including horizontally and vertically curved displays.

The agreement between Novaled (acquired by Cheil Industries, a part of Samsung) and Plastic Logic to develop flexible displays for wearable devices is also an innovative move to target a new market.

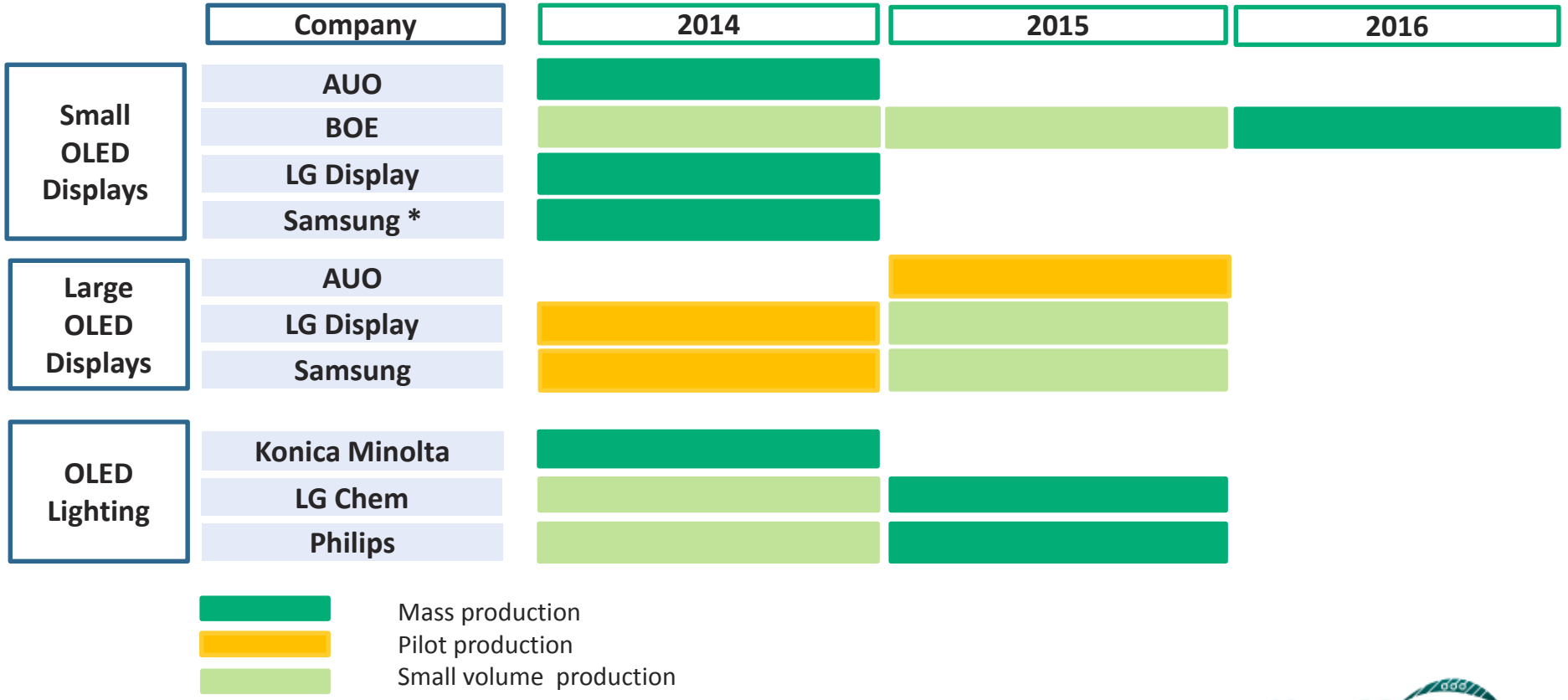
Philips made substantial investment in the OLED lighting space. As a result, OLED lighting panel manufacturing time has reduced to 2 minutes per panel. Prices of OLED lighting panels have also been brought down to $1,250 per sq mtr.

Given these developments, the global market value of the OLED materials industry is likely to rise by 9 to 10 times by 2021 compared to the 2014 level.

OPPORTUNITIES FOR THE OLED LIGHTING INDUSTRY

After small OLED displays, OLED material manufacturers are also considering OLED lighting as a promising end user market along with large OLED displays.

OLED Material Demand Generation Potential of the Key Consumers



** Samsung is rumored to not move ahead with its OLED TV expansion plans in 2014*

MARKET OPPORTUNITIES FOR MATERIALS IN THE OLED DISPLAY SPACE

Sustained Demand from Small OLED Displays

Currently, small sized displays are the most steady revenue generating stream for the OLED Material Industry. The demand for materials from small sized displays is expected to rise on account of Samsung's and LG Display's plan to ramp up their small sized OLED production.

As small sized OLED displays have better market penetration rates compared to large sized OLED displays and OLED lighting products, an increase in the average screen size of small displays is likely to push up the demand for OLED materials in the near future.

Large OLED Displays Yet to Take off in a Big Way

Current Status

Because of the relatively high material usage compared to small OLED displays, large OLED TVs were supposed to be the primary consumer market. However, high processing and material cost along with scalability issues is still considered a hindrance to wider consumer acceptance of OLED TVs.

Although Samsung and LG Display , the early movers in the OLED space, are operating pilot production lines to come up with consumer-ready OLED TVs in 2013, manufacturing related issues with these large OLED displays have prompted the industry, at large, to rethink old strategies and target alternate products such as OLED lighting.

Key Developments

Samsung's recent acquisition of Novaled (via Cheil Industries) can be viewed as a move to gain access to the latter's OLED technology and materials, particularly dopants, in a bid to improve performance of its OLED TVs.

Additionally, the lagging performance parameters of Samsung's OLED TVs present an opportunity for OLED material suppliers to gain access to one of the largest consumers for OLED materials by offering improved material solutions.

MARKET OPPORTUNITIES FOR MATERIALS IN THE OLED DISPLAY SPACE

Abandonment of Large OLED Expansion Plans by Samsung: Probable Implications

Samsung is reported to have plans to abandon its plan to ramp up the existing gen 8 OLED TV manufacturing facility (that would have been in place by 2014 end) as the company has been unable to bring down the manufacturing costs of OLED TVs via its 'True Pixel RGB' technology. Despite having a monthly production capacity of around 10,000 sheets (as of January 2014) from its gen 8 production line, Samsung has been struggling to pull down manufacturing costs.

However, this development seems to be work in favor of LG, which by virtue of its WRGB technology, has been able to bring down the costs of the currently available 55-inch OLED TVs by substantial amount. As a result, LG could find several other Chinese customers (such as TCL , Hisense and Haier) and may also become a key supplier of flexible OLEDs for iWatch – Apple's upcoming smart-watch. Unlike Samsung, which currently doesn't have any variants of OLED TVs on sale, LG plans on introducing at least two more models of OLED TVs – in 65-inch and 77-inch formats – in 2014.
Thus, Samsung's relatively slow pace in making headway in the large OLED TV space can be a boon for LG that plans to increase its monthly production capacity from 8,000 sheets to over 25,000 sheets from its gen 8 line.

At the same time, Samsung's issues with large OLED TVs may also impact UDC to a certain extent as a significant portion of the latter's revenues are dependent on licensing fees received from Samsung for the sale of phosphorescent OLED (PHOLED) emitters. As a result, UDC will be looking to quickly diversify its consumer base in the immediate future.

MARKET OPPORTUNITIES FOR MATERIALS IN THE OLED LIGHTING SPACE

OLED Lighting Being Seen as a Promising Consumer Market

The issues faced by large OLED display manufacturers is a key factor for driving the attention of OLED material manufacturers toward the OLED lighting segment . Despite lagging performance and high costs compared to LEDs, the OLED lighting segment is touted to take off in a reasonable manner within the next five to eight years – thanks to big-budget investment by established companies, including Konica Minolta, LG Chem and Philips.

Promising Developments Undertaken by OLED Material Manufacturers in this Space

UDC	Playing a central role in the OLED materials space, UDC has already shown interest in the OLED lighting space by entering into supply arrangements with players, including Philips, Lumiotec and Kaneka Corporation. While Philips expects to improve the performance of its OLED lighting panels using UDC's emitter materials, Lumiotec intends to have ready access to UDC's proprietary Universal PHOLED phosphorescent and other OLED technologies and materials. Further, by allowing Kaneka to manufacturer and sell UDC's proprietary OLED materials in the Asian markets, UDC has shown interest in catering to Asia that is set to become an OLED lighting panel manufacturing hub.
DuPont	DuPont developed conductive silver nanowire ink for OLED lighting panels that is expected to reduce costs and improve conductivity. This is expected to be commercialized in 2015.
Sumitomo	Despite primarily being a chemical company, Sumitomo has progressed across the value chain by utilizing its polymer OLED (POLED) technology and materials to develop prototype of POLED lighting panels. Mass production is expected soon.

CURRENT PERFORMANCE OF OLED MATERIALS: PHOSPHORESCENT EMITTERS

Phosphorescent Emitter Material	Luminous Efficiency (Cd/A)	Operating Lifetime in hours (LT 95%)	Operating Lifetime in hours (LT 50%)
Deep Red	17	14,000	250,000
Red	30	50,000	900,000
Yellow	81	85,000	1,45,000
Green	85	18,000	400,000
Light Blue	50	700	20,000

All figures are for bottom-emitting structures that have been fabricated with vacuum thermal evaporation technique

Blue Emitters are yet to Reach the Zone of Acceptable Lifetime for Large Display and General Illumination Applications

While red, green and yellow emitters continue to show reasonable improvement in their lifetimes and efficacy, it is the blue emitters that have been a hindrance to commercial adoption in applications such as large displays and lighting solutions that demand long-lasting products.

KEY PLAYERS IN THE OLED MATERIAL SUPPLY CHAIN

Key Companies Active in this Space	Active OLED Materials				
	Hosts/dopants	Injectors/ Transporters	Emitters		
			Red	Green	Blue *
	Cambridge Display Technology - subsidiary of Sumitomo Chemical (Polymer OLEDs)	LG Chemicals	UDC	UDC	UDC
	DuPont (solution based small molecule)	Sumitomo Chemicals		Merck	Merck
	Merck (Both polymers and small molecules)	Merck			BASF
	UDC (phosphorescent small molecules)	Nissan Chemical Industries			Idemitsu Kosan
		Dow Chemical			
		BASF			
		Hodogaya Chemical			

** All the firms are currently researching to develop long-lasting efficient blue emitters*

While material manufacturers are struggling to develop commercial blue emitters, there is a concerted move toward solution process able materials.

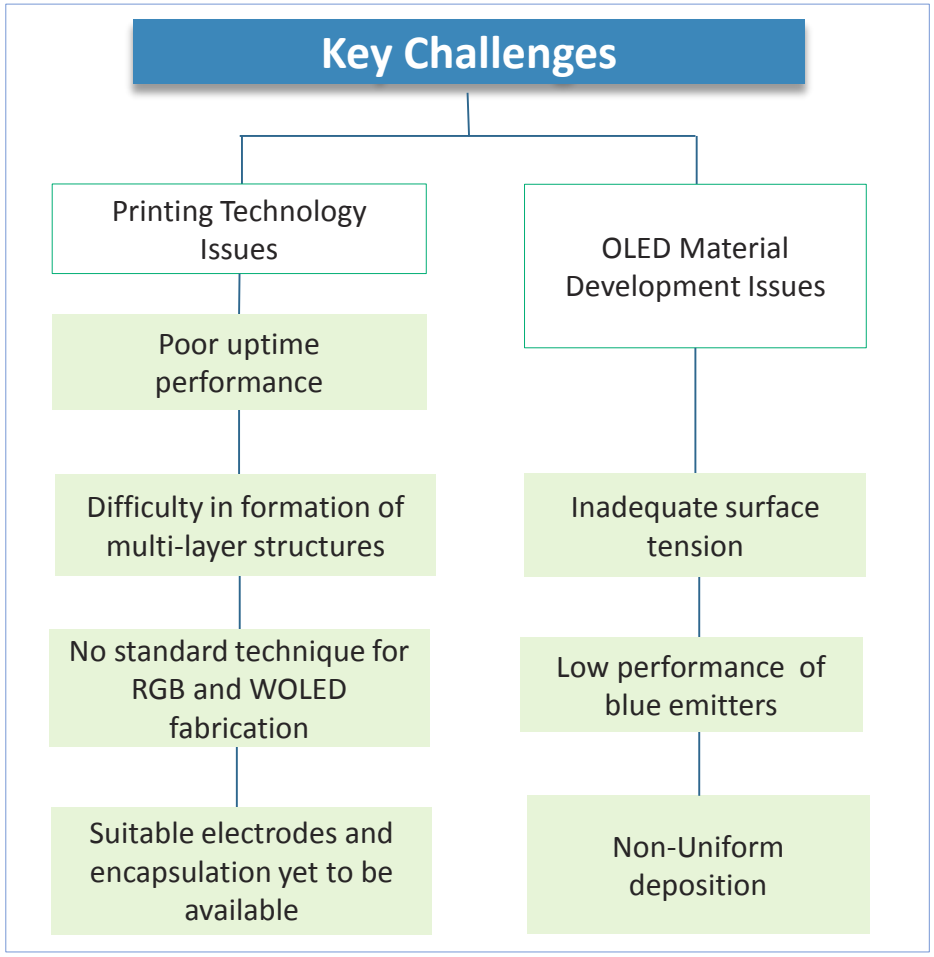
BETTER CONSUMER PROSPECTS MEANS OPTIMISM FOR MATERIAL FIRMS

	2009	2014
AMOLED Display Panels Production Capacity	One AMOLED fabrication line with an estimated total capacity of 26,000 substrate per month	The seven AMOLED fabrication lines, operated by four different manufacturers, can take up the global AMOLED production capacity to around 10 times of what it was 2009.
OLED Lighting Panels Production Capacity	There was hardly any presence of this industry.	It is expected that by 2014 end, there will be at least three big OLED lighting panel dedicated mass production facilities with an annual estimated global production capacity of around 0.5 million panels per month.

With growing OLED panel production capacity, for both display and lighting applications, the OLED material manufacturers can look forward to inking material supply deals with the major players of the industry.

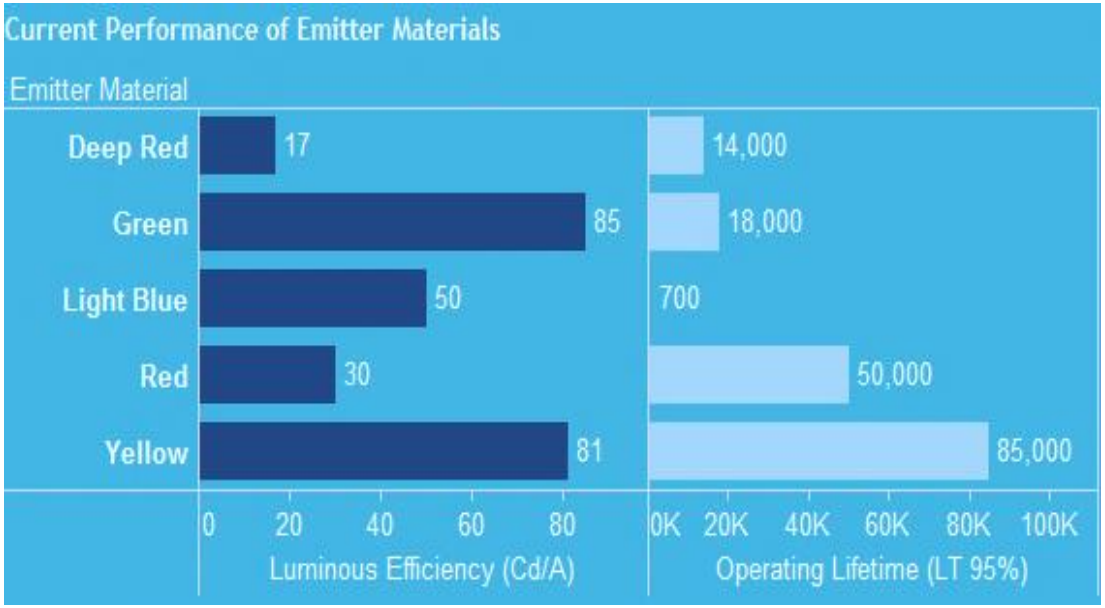
KEY CHALLENGES FOR THE OLED MATERIALS INDUSTRY

Need for Efficient Ink Jet Printing Techniques and Accompanying Materials



KEY CHALLENGES FOR THE OLED MATERIALS INDUSTRY

Lagging Operating Lifetimes of Blue Emitter Materials



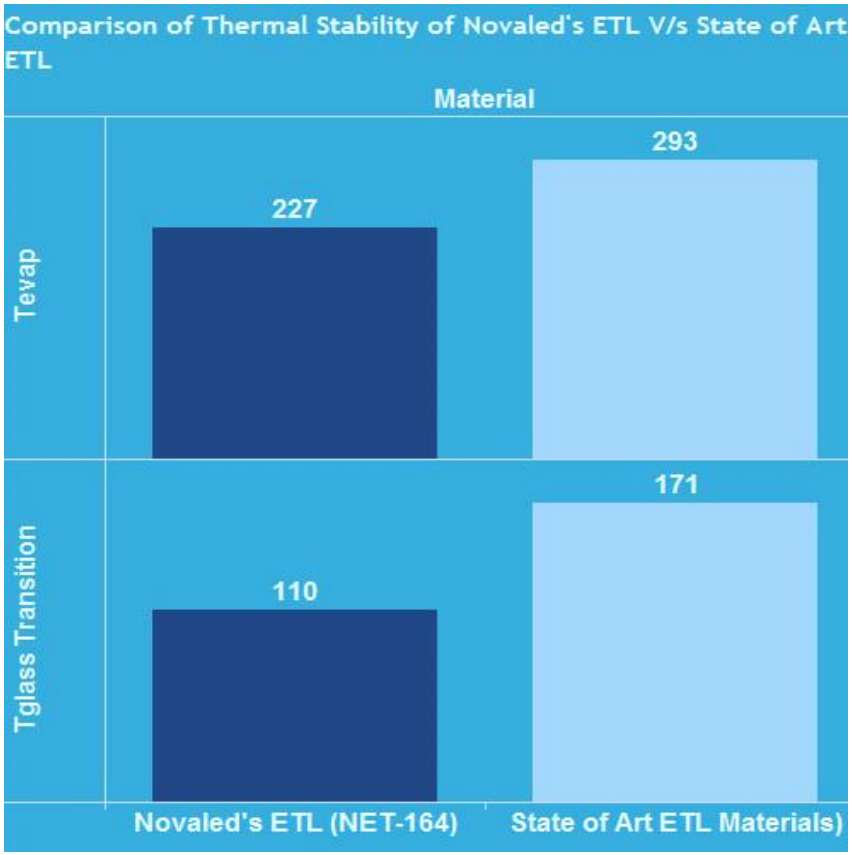
Key Challenge

The currently available red, yellow and green emitters offer long lifetimes under various operating conditions. However, fabricating an all phosphorescent white panel requires blue phosphorescent emitters that currently exhibit operating lifetimes unsuitable for several commercial applications.

Currently, blue phosphorescent materials exhibit a tradeoff between their operating voltage and lifetime. Hence, at present most of the phosphorescent OLED manufacturers use fluorescent blue emitters as a substitute.

KEY CHALLENGES FOR THE OLED MATERIALS INDUSTRY

Low Thermal Stability of OLED Stack



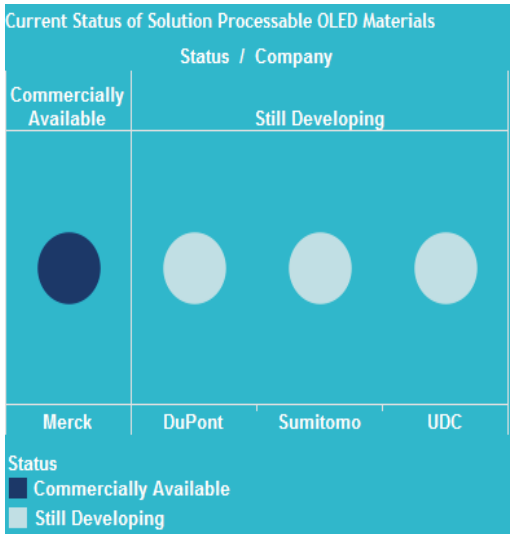
Key Challenge

Improvement in thermal stability is in conflict with other OLED performance parameters such as efficiency, lifetime and especially the glass transition temperatures , the lowering of which can result in the breakdown of the OLED device.

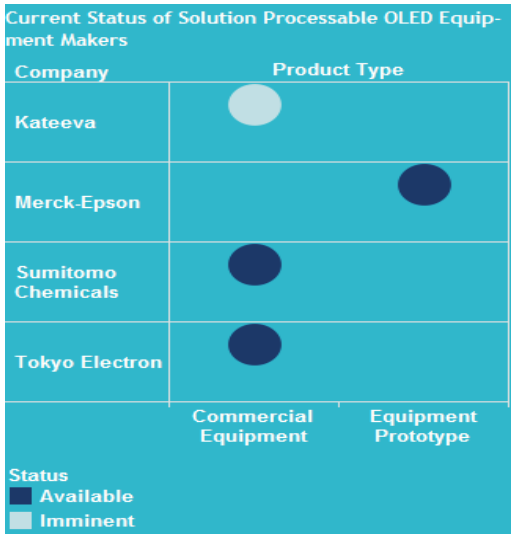
Currently available OLED materials, for instance the electron transport material exhibit lower thermal stability.

Novaled's ETL material, which exhibit greater thermal stability than other state-of-art ETL available, looks promising.

KEY COMPANIES IN THE SOLUTION PROCESSABLE OLED SPACE



Current Status of Solution Processable OLED Material and Equipment Manufacturers



Promising Developments Undertaken by Key OLED Material and Equipment Manufacturers

Kateeva and Tokyo Electron

While Kateeva is in the process of shipping its equipment to an Asian OLED manufacturer, Tokyo Electron has commenced accepting orders for printing OLED panels using its proprietary ink jet printing technology.

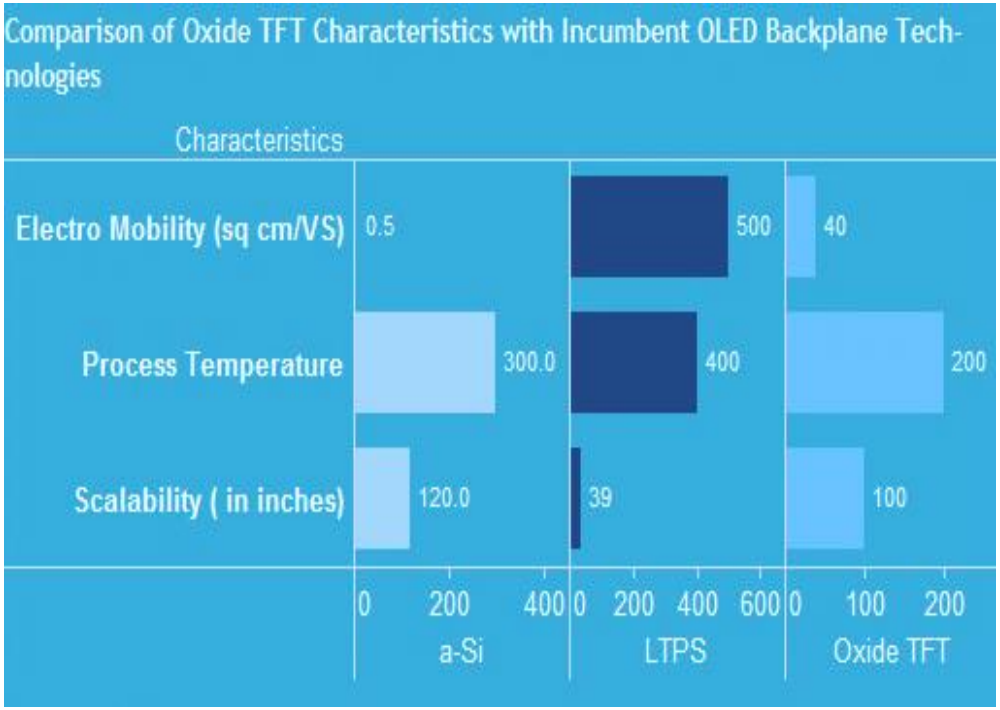
LG Display and Merck

Given LG Display's collaboration with Merck to produce OLED TVs, the latter's printing technology and materials seem to be ready for printing OLEDs.

Samsung and DuPont

Although Samsung is a licensee of DuPont's nozzle printing technology, there is no announcement of commercial production plans.

EMERGING MATERIAL TRENDS: DEVELOPMENTS AROUND OXIDE TFTS



Oxide TFTs

Oxide TFTs can be a feasible option for fabricating large sized AMOLEDs at low costs because of the former's capability to scale up to 100 inch, low deposition temperature process ability, uniformity in deposition and low costs.

Thus far, the LTPS backplanes that have been the mainstay of mobile display technologies do not enable the development of high performance large OLED displays. This has got OLED manufacturers interested in alternate technologies such as oxide TFTs.

However, not Without Issues

However, the critical issues associated with oxide TFTs, such as limited electron mobility, poor stability and unstable threshold voltage, have raised speculations about their market competitiveness. Moreover, manufacturers such as LG Display that use metal oxide TFTs are struggling to reduce prices in order to compete with LTPS TFT AMOLED displays.

EMERGING MATERIAL TRENDS: SILVER NANOWIRE ELECTRODES

While ITO continues to remain as the preferred electrode material, silver nanowires and inks are also being looked at for devising flexible electrodes.

The Potential of Silver Nanowires and Inks

Flexible nature and cost-effective processability of silver are considered to be the driving factors for increasing the addressable market of silver nanostructures in the OLED space, albeit not in the immediate future.

Despite a likelihood of device failure under external pressures because of the weak bonding between silver nanowires and substrates, companies such as Cambrios Technologies Corporation and DuPont are moving ahead with their silver based materials for use in OLEDs.

While silver nanowire ink of Cambrios Technologies Corporation is expected to find use in Novaled's OLED panels, DuPont is targeting OLED lighting panel makers with its silver nanowire ink.

EMERGING MATERIAL TRENDS: NEW HOLE AND TRANSPORT MATERIALS

At present, there is a need to achieve a balance between low driving voltage and long device lifetime. This is mainly because often it has been noticed that while reducing low driving voltage, OLED manufacturers end up offering devices with reduced lifetimes.

Charge balance is the key to ensure the optimization of both these characteristics . In this context, host materials play a critical role.

A hole transport layer (HTL) with more hole injecting transport layers can lead to improved lifetime and efficacy , particularly in solution processed devices. This development also holds the potential to reduce the gap between the performance of VTE processed OLED devices and solution processed devices.

Merck is an active player in this space, wherein under the name of EMD (operated in the US), Merck has been researching a variety of new HTMs that can offer better electron blocking capability. New organic stack configurations have also shown improvement in device lifetime, efficacy and voltage – for both fluorescent and phosphorescent devices.

EMERGING MATERIAL TRENDS: NEW SUBSTRATE MATERIALS

Key challenge for new substrate materials will be to achieve thermal, chemical and mechanical stability comparable to currently used glass substrates.

The Need for New Substrates

High Costs

The high costs of the display grade glass substrates used by OLED manufacturers have prompted the industry to explore low cost alternatives. This type of integrated glass substrate that is being developed by PPG Industries, may hold potential to effect a five-fold cost reduction in the prices of substrates.

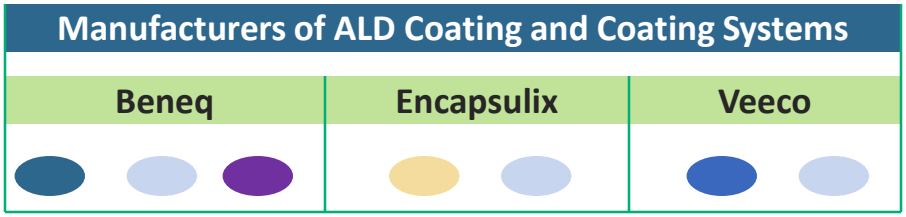
Demand for Flexible Panels

Apart from prices, the need for suitable substrates for flexible OLEDs and cheaper OLED panels have led to the exploration of other substrate alternatives, such as ultra-thin foils, polymer glass and thin glass .

Substrate Material Options

Of all the substrate options, clear plastic substrates have attracted the attention of leading OLED manufacturers, such as Samsung and LG Display and chemical manufacturers DuPont Teijin and BASF.

EMERGING MATERIAL TRENDS: THIN FILM ENCAPSULATION TECHNIQUES



- Commercial Coating
- Supplying to Commercial Manufacturers
- Supplying to Research Institutes
- Commercial Coating System
- Prototype System

Glass Encapsulation

Unsuitable for flexible OLEDs

Rigid, fragile and heavy

Atomic Layer Deposition (ALD)

Enabler of ultra thin displays

Pin-hole free technology

Eliminates side diffusion in large OLEDs

Current Encapsulation Issues

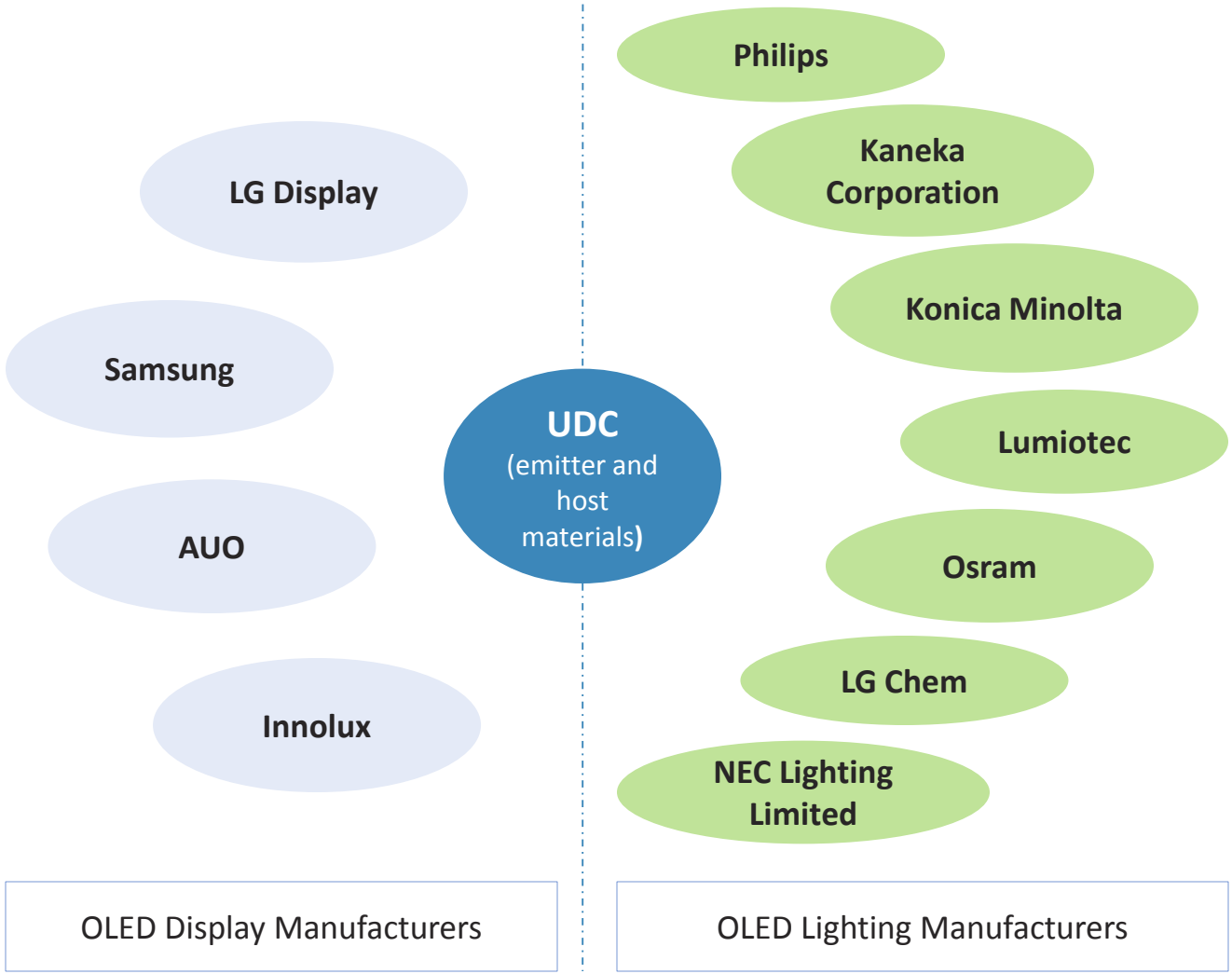
Although Samsung and LG Display are already producing flexible OLEDs, the search for better encapsulation techniques continues.

Current option for encapsulation include flexible glass and polymers that are expensive and unreliable respectively.

Potential Use of ALD

Samsung recently bought Veeco's ALD technology. This coincides with Samsung's plans of replacing its inefficient Vitex encapsulation technology, thus indicating the use of ALD for producing the next generation of flexible OLED panels.

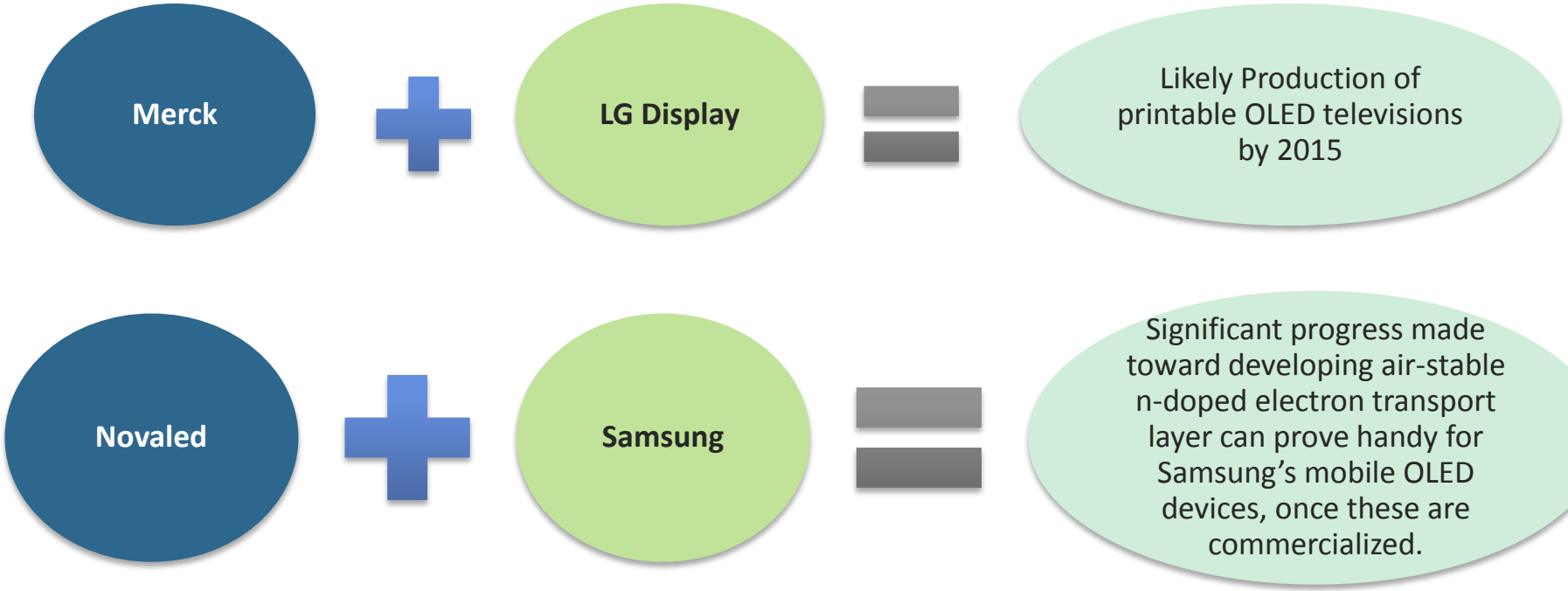
DOMINANT POSITION OF UDC



Through numerous licensing and supply arrangements with major OLED panel manufacturers , UDC is likely to maintain its position as a leading manufacturer and supplier of phosphorescent emitters, especially green emitters.

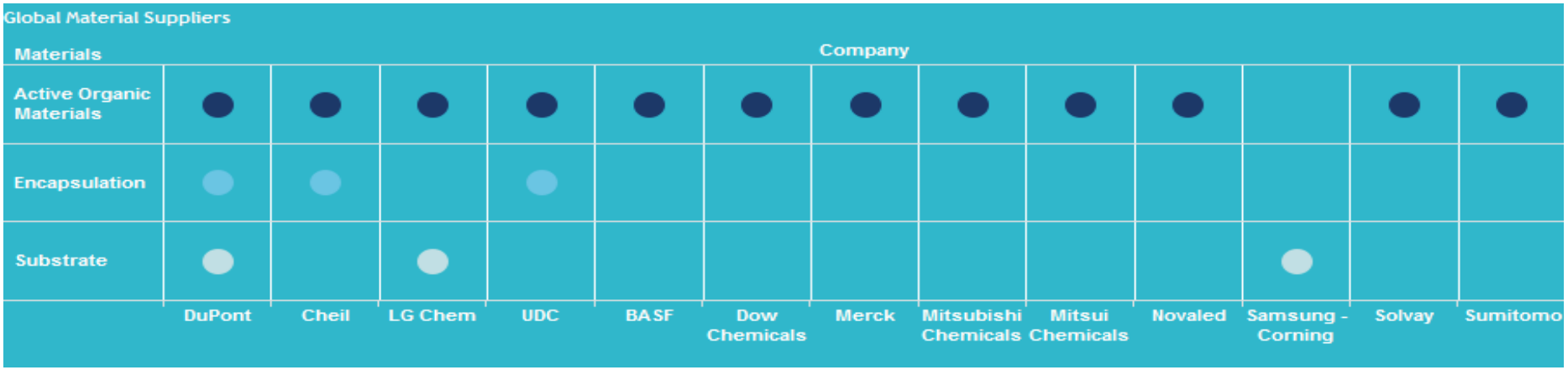
UDC's dominant hold over the OLED materials market is likely to strengthen given that the company is looking to expand its materials portfolio by moving into new domains, including organic vapor jet printing and single-layer barrier encapsulation system.

GROWING SYNERGY BETWEEN MATERIAL SUPPLIERS AND PANEL MAKERS



Bracing themselves to respond to the need of cost effective OLED fabrication materials, companies such as Merck and Novaled are partnering with OLED manufacturers to come up with printable OLED material and truly flexible OLEDs, respectively.

DEVELOPMENT EFFORTS UNDERTAKEN BY KEY MATERIAL COMPANIES



UDC is focused on improving its PHOLEDs as well as outcoupling layer to enhance the light extraction efficiency of OLEDs.

UDC is working on barrier film encapsulation for plastic substrates and alternate stack materials to complement its blue PHOLEDs.

Key Strategies

Merck and UDC continue to remain the chief OLED material providers to major OLED manufacturers, including Samsung and LG.

While DuPont, Merck and Sumitomo are developing solution process able OLED materials, the latter two are looking to transition from being material producers to OLED solution providers.

Novaled's PIN technology delivers greater benefits over the conventional OLED stack. Novaled and Sensient have jointly developed a p-doped ETL with potential for low cost scalability.

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