MicroLED: Promise and risks

Hendy Consulting

lan.Hendy@hendyconsulting.com

Introduction

- MicroLED is the new display technology on the block, bringing together the display industry, the LED industry and the semiconductor assembly industry
- MicroLEDs are bright, colourful, with high contrast and the ability to go beyond OLED for certain applications: the applications are those where the particular strengths of the technology combine with the particulars of massive transfer economics of the MicroLED dies
 - The initial applications appear to be SmartWatches and super large TV/signage displays and perhaps automotive
- A number of the more capex-shy display players, and Apple and Samsung have already leaped onto this technology after initial pioneering work by Sony
- However, the industry structure of the resulting industry is far from clear
 - There are several critical uncertainties: whether these displays are driven by a TFT matrix or better driven with embedded discrete ICs or CMOS, and the role of CCL vs discrete RGB
 - The role of vertically integrated players in this is not clear since they may try to keep the technology captive and hold back the promise for others
- We define a set of scenarios for the future of the MicroLED business and look for winners and losers at this early stage



Pros and cons of MicroLED over other technologies





The MicroLED ecosystem, selected players: Most players not well networked yet. 4 big group with broad capability, Samsung, LG, Foxconn, Apple



What is interesting is to look for those conglomerates who may already have most of the pieces in house from LED to transfer method etc to backplane. We should watch LGD/LG Innotek and Samsung and Sharp/Foxconn. Apple will be key also:

	LED	Mass transfer	Display - Oxide	Channels	Segments interest	Summary
Sharp Foxconn Innolux	V	R&D	V	V	TV Phone+ Watch?	We hear rumours of quite some work here by Innolux/Foxconn. Sharp has LED capability also
AUO	-	R&D	No 🖌 Many AUO		AUO interest seems to be at R&D level for now	
Samsung	~	R&D	Not yet but can develop	V	Watches TV/Video displays	SDC and SEC seem to be taking competing approaches right now
LG Group	V	R&D	V	V	TV Smartphone? Video displays	LG Group could be key player in this with access to many of the pieces
CSOT-TCL	-	R&D	Not yet	V	Many but mostly large panel	Some established research on elastomer stamps and micro optics
BOE	-	R&D	Developing	eveloping BO Many a		BOE interest for now is research and development. Does have partnerships for AR/VR
Apple-Luxvue	V	V	No	V	Watch	Apple reportedly in discussion with TSMC and Play Nitride for SmartWatch MicroLED partnering

We need to make clear that we are talking about different value chains (this excludes the video displays value chains):

	Microdisplays (Near-eye & Projection Applications)			Conventional Displays (Direct View Applications)			
Array Backplane	 Jasper Display, others 			 Apple/ Luxvue X-Celeprint <i>existing display producers</i> 			
LED Epi Equipment			Veeco Aixt	ron • Others	on • Others		
LED Source Wafers	 Aledia GLO EpiStar mLED OSRAM Toyoda Gosei Nichia Lextar 			 InfiniLED Samsung Seoul Semi Play Nitride 	 Epistar AOT San'an Opto HC Semitek 		
LED Die Processing		semiconductor fabs in conjunction with LED transfer technology companies					
LED Die Inspection	• QMAT						
LED Transfer & Integration		 Leti Uniquarta Lumiode Play Nitride VueReal 	 mLED Oki Electric ITRI Mikro Mesa 	X-CeleprintApple/ LuxvueMikro Mesa	 Rohinni Foxconn KIMM		
Color Conversion	VerLASE						
Driver Electronics	Macroblock						
Display Modulization	Microdisplay Producers			 Apple Sony Oculus Sharp	 Innolux HKC Opto Huawei		



Recent news in the MicroLED industry:

- The big news in the microLED industry was the 2014 acquisition of Luxvue by Apple
- Recent news:
 - LGD has recently responded to "The Wall" by Samsung by also saying it will have a large MicroLED set out this year
 - Innolux showed an automotive direct view display at around 150ppi based on MicroLED
 - VueReal just completed a \$10.5m Series A fundraising
 - Discussion by LGD that even at 1 Won per sub pixel that a 4K MicroLED display will cost \$23,000
 - Samsung currently sells the Wall at \$300k and plans to sell 60 this year
 - MicroLED info states that Sony believes the cost of its 120" CLEDIS display is \$500k. All of these numbers are in the same sort of very high ball park
 - Rumours that Apple is working with TSMC for LEDs on silicon
 - Rumours of Samsung investing into Play Nitride
 - News that the CEO of Epistar one of the largest Taiwanese players sees revenues from MicroLED as uncertain
 - eMagin also on record as saying MicroLEDs are further out









Let us also look at the forecasts for the MicroLED market by Yole in the Base case and aggressive cases in revenue based on publicly available data

Yole* implied revenue forecast MicroLED at our pricing assumptions \$m



HENDYCONSULIING

DISPLAY, HIGH TECH & MEDICAL IMAGING STRATEGY

Yole aggressive case \$m



Source: *Yole 2017 as published in the public domain, HCL

HCL pre-existing and market views

What is very clear is that these are really early stages since all the bets by the different firms are different:

Company	Target market(s)	Drive approach	Colour generation	Mass transfer approach	Chip type
AUO	Automotive for now	LTPS	CCL	Adhesive	Flip chip
Samsung	Premium TV and signage	LTPS and PCB with interconnect	Discrete RGB	Electromagnetic	Flip chip
Apple	Smartwatch	CMOS	IHS says discrete RGB. We are not sure	Electrostatic	Vertical or flip chip
Google	AR	CMOS	Monochrome blue and green	Monolithic	Vertical flip chip
Sony	Signage	PCB with interconnects	Discrete RGB	Laser lift off	Flip chip
Foxconn/Innolux Sharp	Smartphone and others	Likely LTPS	Discrete RGB?	Sharp have experimented with self-assy	Not known



...and a number of factors will influence the future industry structure

	Requirements for the drive backplane	Implications of mass transfer economics/ repair	Role of verticalisation		Role of non-display participants	How colour is generated?
•	While most industry observers claim that MicroLED can be driven by IGZO and LTPS, there are already players deploying CMOS or the use of distributed ICs The specifics of PWM for MicroLED and the way that the peak current needs to be managed for MicroLED may mean that distributed ICs may be the way to go and not a TFT backplane	 The specific economics of mass transfer are very different to the usual cost factors in the display industry that often mean that display cost scales with area. For MicroLED the cost scales with the number of pixels and their geometric spacing (and on a number of optimisations of repair strategies, transfer strategies, transfer strategies – including intermediate transfer locations) We think the specifics on placing and repairing the right dies in situ will create specific valuable competencies 	Already at this early stage Apple is leading the way towards captive business models (and Google and Facebook among others seeking to do similar things) The LG and Samsung groups may also try differentiated vertical strategies	•	If the world does evolve into a distributed IC driving method then there is a potential role for assembly players and others to get into this business Display companies still might act as channel partners but their role in the business could be substantially reduced LED and semi assembly players could take a greater share of the value	Not yet clear whether players will use blue dies with QD or other colour conversion layer or use discrete R, G, B dies



So we can define a set of scenarios for the future of the MicroLED industry

	Display Centric world	LED and non display players win	Vertically integrated players win	MicroLED fails to emerge
Who leads the business development	Display players dominate this	LED companies with CMOS partnerships and assembly capability	Individual vertically integrated chains	Many players try but few successes
Specific Winners or Iosers	Foxconn Samsung LG Group win on revenue tho' value winners not so clear	Nichia, Epistar Sanan Opto and/or TSMC	Apple, Foxconn glo ITRI?	Most fail given the complexity of the new technology
How the displays are addressed	LTPS or oxide with modifications	Discrete ICs or other CMOS backplanes	Different specific methods in each case	Different specific methods is one of the causes of failure
Summary	A strong potential outcome but value may accrue to materials and equipment	If TFT is not needed then a different structure could result	Whole technology probably delayed if vertical player model results	There is still a chance that this technology fails to achieve promise

- We have four different scenarios for now for how the world might evolve
- The simplest one is that display players end up at the centre of this technology but that still does not necessarily mean that most value will be captured by them
- However, there is a strong chance that a vertically integrated model might result with chains of proprietary technology
- Or that the LED companies work with semiconductor (assembly) houses to form the industry based on distributed ICs

Our base case is a display centric one where companies like Foxconn/Innolux/Sharp, AUO, LG group and Samsung lead

	Display Centric world
Who leads the business development	Display players dominate this
Specific Winners and Iosers	Foxconn Samsung LG Group win revenue wise value: not so clear
How the displays are addressed	LTPS or oxide with modifications
Summary	A strong potential outcome but the value winners may be materials and equipment

- As display strategists, this is the easiest outcome for us to believe
 - However, we are not yet sure that oxide or LTPS will be the drive approach for this technology. If it is not and distributed discrete ICs becomes the norm then perhaps display companies only become channel partners
- In this scenario at least the display companies become the focal points for innovation
 - That of course does not mean that the display firms will seize the lions share of the value created. It still may be that IP holders and process licensees or materials companies do better out of this technology
 - If more complex drive scheme approaches are achievable through LTPS (say instead of oxide) then we wonder whether this will foster a new phase of LTPS value-in-pixel innovations
- Will be interesting to see whether the LED industry can rise to the challenge of microLED dies at such small sizes and even whether competitive forces allow for some technical innovation and profit
- This is a quite likely scenario but we wonder if the value remains where it often is for the display industry: tools and materials



In a second scenario new players help a completely new structure arrive into the display industry

	LED and non display players win
Who leads the business development	LED companies with CMOS partnerships and assembly capability
Specific Winners and Iosers	Nichia, Epistar Sanan Opto and/or companies like TSMC
How the displays are addressed	Discrete ICs or other CMOS backplanes
Summary	If TFT is not needed then a different structure could result

- If TFT are not really the best way of driving this sort of display then this could be revolutionary: we could get a very different sort of industry structure
 - Increases the value on IC content, and on methods for mass transfer and assembly
- X-Celeprint's demo at SID really embodies this sort of world
 - Driven by distributed ICs not TFT: in this world other players could come to the table. Perhaps X-Celeprint could build up a strong business or semiconductor players and assemblers could also play
 - Perhaps in this world view, display companies become a channel to market or lose out completely
- The value here might well end up in the LED/epitaxi or the semiconductor players (either in fabless designs or as the embedded ICs)
 - Some key IP holders may also get some value
- This is an entirely possible outcome but would need for new firms to put together the puzzle of pieces to be able to play



And in a third, only the main vertically integrated players do well

	Vertically integrated players win	 Already Apple seems to be the most far along, although Foxconn/Sharp seem to be trying to move fast and the Samsung and LG groups may catch up Google is trying the same strategy also 		
Who leads the	Individual vertically	 Our view is that technology development is accelerated by some coordination between players 		
development integrated chains		 For now only ITRI's consortium (CIMS) that has quite a number of players seems like it may be influential enough to make a difference 		
Specific	Apple, glo,	though it is not clear how ITRI could monetise its position		
Winners and losers	Foxconn perhaps ITRI?	 The risk is that a number of proprietary positions leads to the technology being delayed substantially 		
How the displays are addressed	Different specific methods in each case	 With different value chains then there is a risk that many different approaches are taken for key elements such as the mass transfer approach and the drive method 		
Summary	Whole technology	 For now, Apple and Luxvue seem to have the largest IP position and headstart on real technology problems 		
	probably delayed	 However, Apple has never owned a display technology in house: i has only managed the efforts of others. Will it succeed? 		



And of course there is a risk that MicroLED fails to emerge in a meaningful fashion:

	MicroLED fails to emerge
Who leads the business development	Many players try but few successes
Specific Winners and losers	Most fail given the complexity of the new technology
How the displays are addressed	Different specific methods is one of the causes of failure
Summary	There is still a chance that this technology fails to achieve promise

- It is still far from being certain that MicroLED will come to fruition
 - A number of key players from PlayNitride to Nichia have said that this market is quite a few years out
 - Cost levels are clearly far too high right now so that even with specific segments being able to support a display price premium, the numbers are too big
- The challenge of entering the display market has always been in meeting a falling cost curve
 - Too many technologies have floundered also for failing to understand how the incumbent technologies respond competitively to the new threat
- In this world then we may see a few sparse winners but overall LCD and OLED remain the important dominant display technologies



So what becomes important for the next phase of growth for this technology?:

- For now we think that the next phase of this technology is the linking up of major groups of companies to try to take some leadership and forward momentum
 - We are concerned that everyone will take their own proprietary approach to the technology and that almost for this reason it is delayed and fails
- At some point some dominant business and technical models will need to result
 - Watching to see whether CCL (colour conversion layers) or discrete RBG and which form of driving dominates will be critical
- The development of appropriate repair/transfer mechanisms to eliminate pixel failures will be very important as the display industry has a very high bar to meet in terms of optical uniformity
- Once some dominant models have begun to arrive then the equipment industry will need to develop manufacturing tools appropriate for real scale manufacturing to bring down cost



....and who might be the winners and losers

Outright winners

- Some of the major IP holders might expect to make ongoing monies
- Differentiated materials
 providers
- One or two of the top supply chains (maybe)

Outright losers

 We expect many of the MicroLED projects and start ups to fail

- Across the different scenarios it is actually very difficult to define outright winners and losers
 - The technology choices are too early even for the scenarios to be clear on which will dominate and the value leaders in each
- If we look at the OLED industry then this was led by two big conglomerates (Samsung and LGD)
 - There is a chance that MicroLED will be the same and that Apple and Foxconn could win: the issue is whether these two firms have the same technology might to make things happen. Neither have really pioneered breakthrough display technology on their own before
- If we had to indicate winners, then all previous display technologies have tended to lead to materials firms taking the lion share of the value: we wonder if anything will be any different here
 - Some of the MicroLED players may make it through but the display industry tends to have a brutally long timeline



Summary

- We are fascinated with this new display technology since it is unlike others in the potential structures that may
 result
 - The specifics of transfer economics mean that the initial markets are not intuitively obvious to display
 professionals without a lot of thought
 - It is currently not a given that TFT approaches will dominate for driving these displays. Without TFT backplanes then the role of display companies is substantially reduced in importance
- The MicroLED industry is still at a nascent stage where clear alliances have not yet been fully formed
 - Many of the major corporates are scouting around at the moment trying to put together the collection of pieces needed to play in this business
- Given that the outcomes are diverse, it is very difficult to say who the winners and losers will be
 - The "Display players win" scenario is the easiest to justify since this is the way of all other display technologies: but perhaps MicroLED will be different industry structure this time around
- For now we think that participants need to focus on the most intractable problems of the industry: these include the driving and interconnect approach, the mass transfer economics/accuracy and the link between redundancy and repair and then on real mass production approaches that can bring cost levels down substantively



Our services

Growth strategy	Performance improvement	Equipment and Capex	Sourcing strategy (Purchasing)
 Market entry strategy Business unit strategy Growth strategies for new technologies 	 Product portfolio management Pricing strategy Cost reduction 	 LCD/OLED factory capex decisions Strategies for equipment makers 	 Sourcing strategies, especially LCD and medical detectors Make/buy decisions
Technology strategy and technology assessment	Partnering and alliances	Professional advisory and business planning	Strategies for materials providers
 Market and commercial strategies for new technology businesses Market tracking services for corporates monitoring technology 	 M&A candidates and assessments Alliance formation support Post merger integration planning 	 Specialist insights for bankers, equity investors and other consultancies Reviews of business plans and models (Strategic audits) 	 Strategy support for materials providers in the FPD, SSL, and PV markets IP and pricing plans

