研發到量產
OLED過去、現在、未來

2023.12

大綱

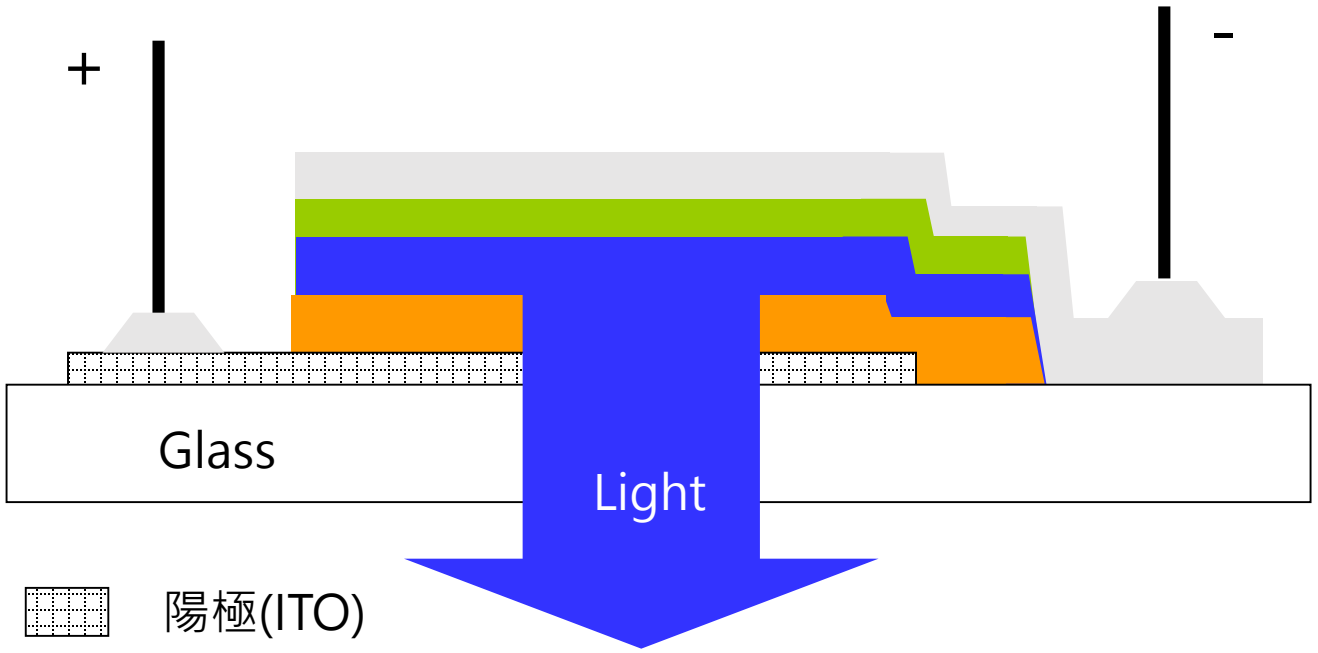
- 過去 : OLED研發到量產
- 過去 : Flexible AMOLED研發到量產
- AMOLED現在

手機、平板、NB、Monitor、電視、AR/VR/MR、Automotive、Transparent

- AMOLED未來

看似簡單...

Organic Light Emitting Diode (OLED)



陽極(ITO)

電洞傳輸層 Hole Transport Layer (HTL)

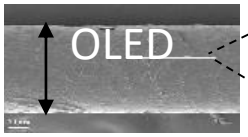
發光層 Emission Layer (EML)

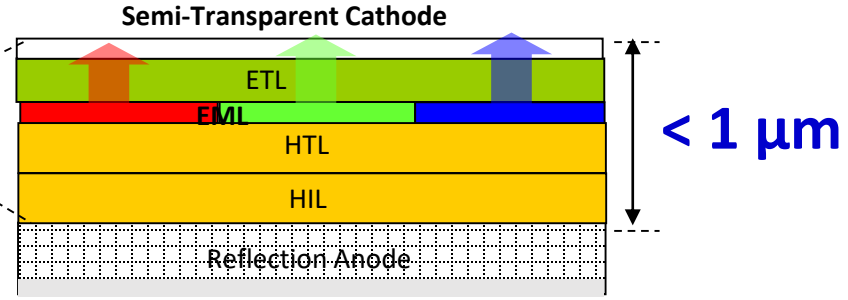
電子傳輸層 Electron Transport Layer (ETL)

陰極 (Al)

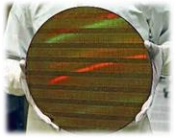
奈米等級...

Hair thickness
50~100μm





12 inch Wafer



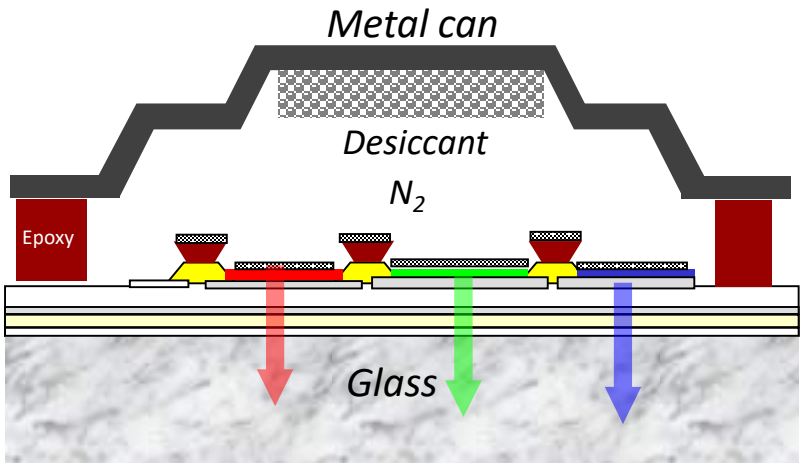
AMOLED Glass

Good particles control ability needed!

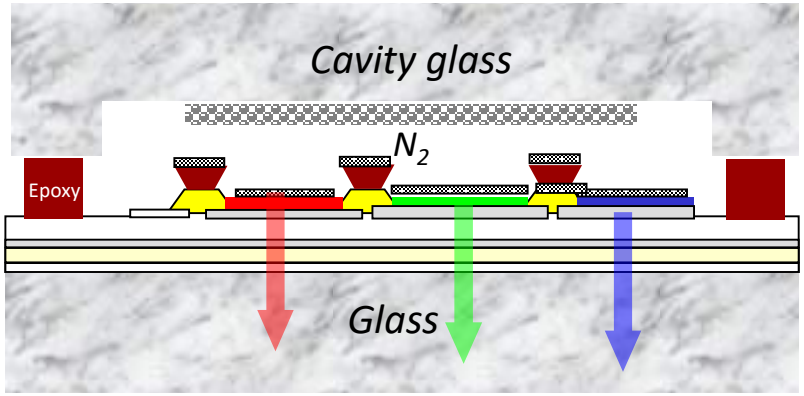
最早商品化 OLED產品

- *Product: Car audio display*

- *Product: Sub-display of phone, MP3*



- ***Metal can*** *encapsulation with desiccant*



- ***Cavity glass*** *encapsulation with desiccant*

AM、PM OLED

OLED

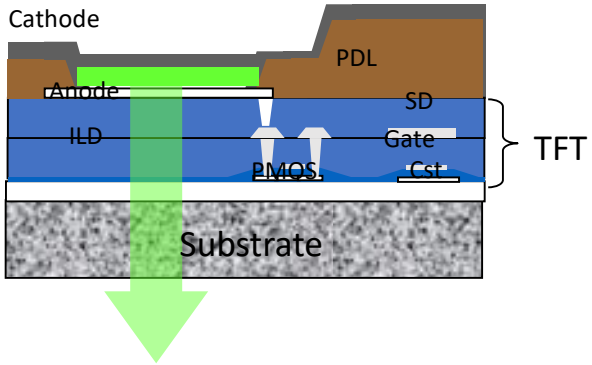
主動矩陣Active Matrix

被動矩陣Passive Matrix

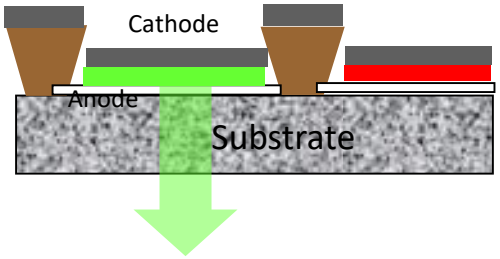
顯示器Display

照明Lighting

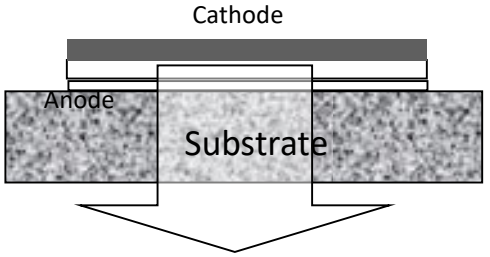
Bottom/Top Emission



- 需要TFT驅動
- 需要畫素
- 高畫質、小中大尺吋顯示面板



- 不需要TFT驅動
- 需要畫素
- 小尺吋顯示面板



- 不需要TFT驅動
- 不一定需要畫素
- 電極阻抗 vs.發光均勻性

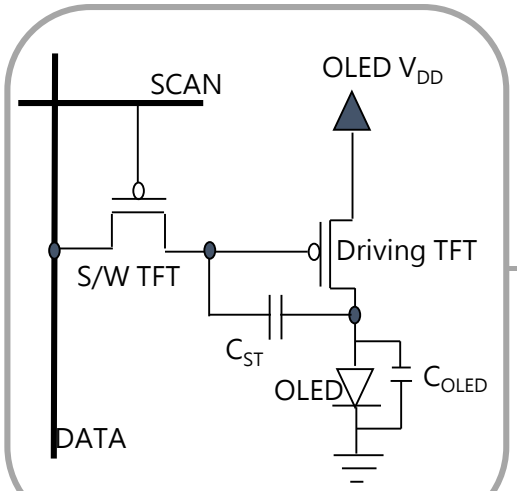
AMOLED量產 第一關 TFT技術選擇

	LTPS	SGS	a-Si	μc- Si	ASPC	SDC	MO
主動層	**多晶矽**	多晶矽	非晶矽	微晶矽	多晶矽	多晶矽	金屬氧化物
結晶化設備	**準分子雷射**	退火爐	不需要	不需要	退火爐	退火爐	不需要
載子遷移率 (cm^2/Vsec)	**50~150**	~50	0.1~0.7	0.1~10	10~30	50~90	5~50
量產化狀況	**已量產**	-	未量產 (V_{th} Shift問題)	-	-	-	-
大面積化	**Gen 6~Gen8**	可大面積化(*1)(2008/SDI 40吋TV)	LCD製程 ,目前可到 Gen 10(Sharp)	大面積化均勻性不易克服	Gen 6已驗證,朝Gen 8(*2)	可大面積化	Gen 8量產，SMD預估可能2015(*3)
主要廠商	**SMD,LG,CMI, AUO**	SMD	SMD,LG,AUO, CMI....	ST	LG	CMI	SMD,LG,SONY,AUO

註：(*1): IMID2009 SMD SGS的第6代底板用裝置現已開發完成，目前第5代底板的量產裝置的使用正在準備之中
(*2): LG:第8代玻璃底板。需要開發能夠進行700℃以上熱處理的SPC處理裝置"
(*3): IMID2009 SMD對於 "第8代大型基板量產的問題" ，演講人預測：可能會在2015年左右

第二關 選擇TFT補償電路

2T-1C

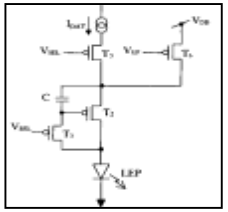


Non uniformity of Luminance

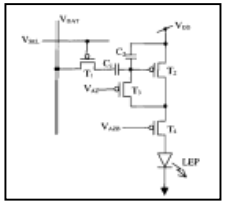
2T-1C + External Compensation

Source: KODAK Global Mura Compensation (GMC) Technology

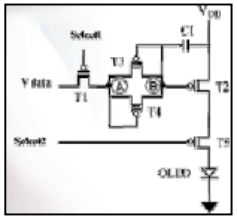
4T-1C



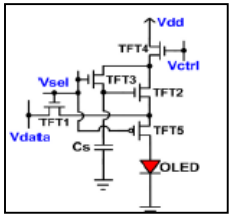
4T-2C



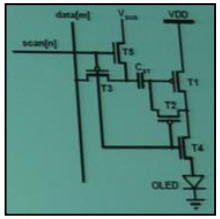
5T-1C



Source: IEEE Electron Device Letters (2004)



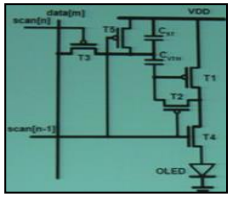
Source: IEEE Journal of display technology (2005)



Source: N. Komiya, *IDW 'Tech. Dig* (2003)

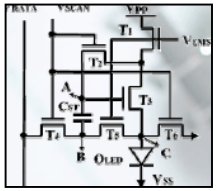
7T-2C

5T-2C



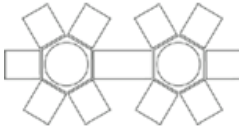
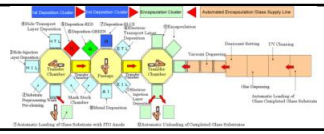
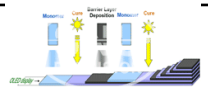
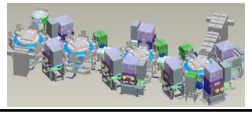
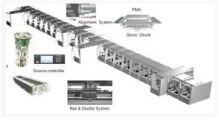
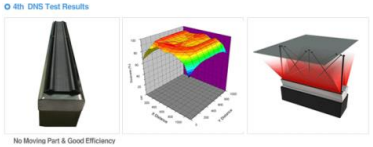
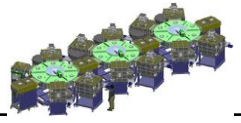
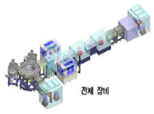
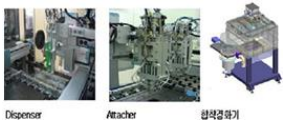
Source: S.M.Choi, *SID Tech. Dig* (2004)

6T-1C

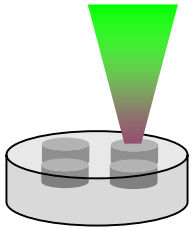
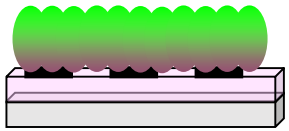
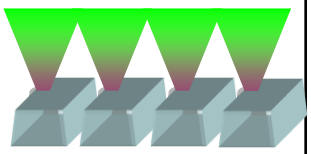
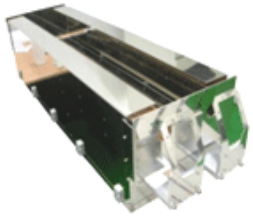
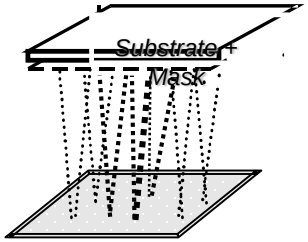


Source: IEEE Electron Device Letters (2005)

第三關 選擇OLED蒸鍍設備

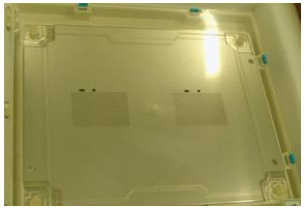
OLED設備商	OLED量產機	說明
ULVAC SOLUTIONS	 	日本,蒸鍍與封裝設備提供
TOKKI	 	日本,蒸鍍與封裝設備提供
Hitz Hitachi Zosen		日本,蒸鍍與封裝設備提供
SNU PRECISION SNU Precision	   	南韓,蒸鍍與封裝設備提供
Sunic system	  	南韓,蒸鍍與封裝設備提供
VAS Your Artistic Solution	 	南韓,蒸鍍設備與蒸發源提供
SFA	  	南韓,蒸鍍與封裝設備提供
JUSUNG ENGINEERING		南韓,蒸鍍與封裝設備提供

第四關　選擇OLED蒸鍍技術

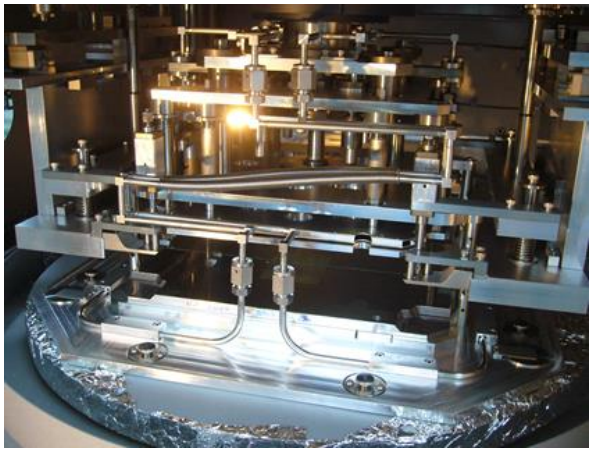
	點蒸發源	線蒸發源			面蒸發源
型態		Linear Source	Parallel shot	Linear Nozzle Source	Area Source
示意圖				(*1) 	
代表廠商	TOKKI ; ULVAC	ULVAC	TOKKI	YAS	ULVAC
基板尺吋	370x470mm	550x650mm ; 620x375mm ; 600X720mm	>Gen 3.5	~Gen8	>Gen 6
TACT time	Cluster :4 分鐘	Cluster : 4 分鐘 Linear : 2 分鐘	NA	NA	Linear : 2 分鐘
材料利用率	1~5%	Cluster : 10%~20% Linear : 50%	NA	40%~50% (*1)	>40%

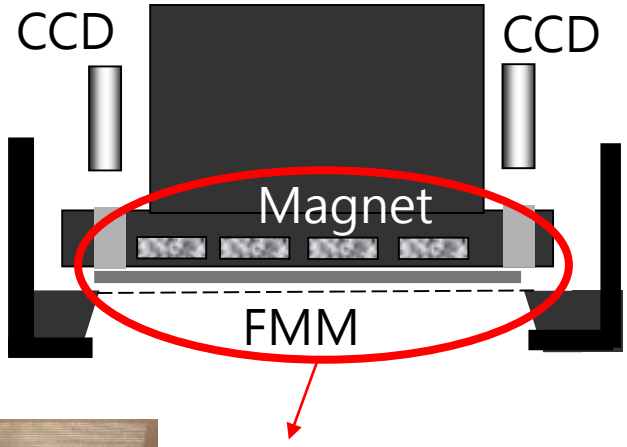
註：(*1) 資料來源 : http://yasoled.koreasme.com/com_04.html

Fine Metal Mask技術掌握在日本、韓國

	DNP 大日本印刷	TOPPAN	HANSONG	SEWOO
FMM圖示	NA			
FMM技術	*Etching *衍用 CRT設備 R2R	*Etching *衍用 CRT設備 R2R	*Laser *Etching	*Laser *Etching
產品與技術服務	*FMM+Frame *FMM Only	*FMM+Frame *FMM Only	*FMM+Frame *FMM Only *Tension Equipment 	*FMM+Frame *FMM Only

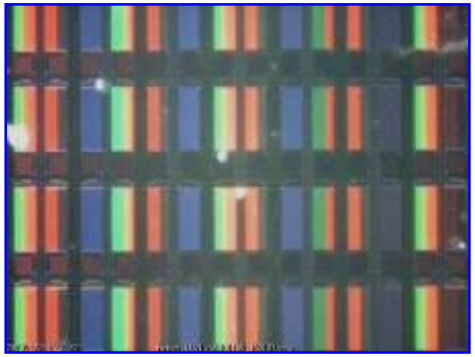
FMM vs. OLED蒸鍍機Issues





•微觀：FMM Hole Open與基板 Sub-pixel R/G/B對準位置偏移

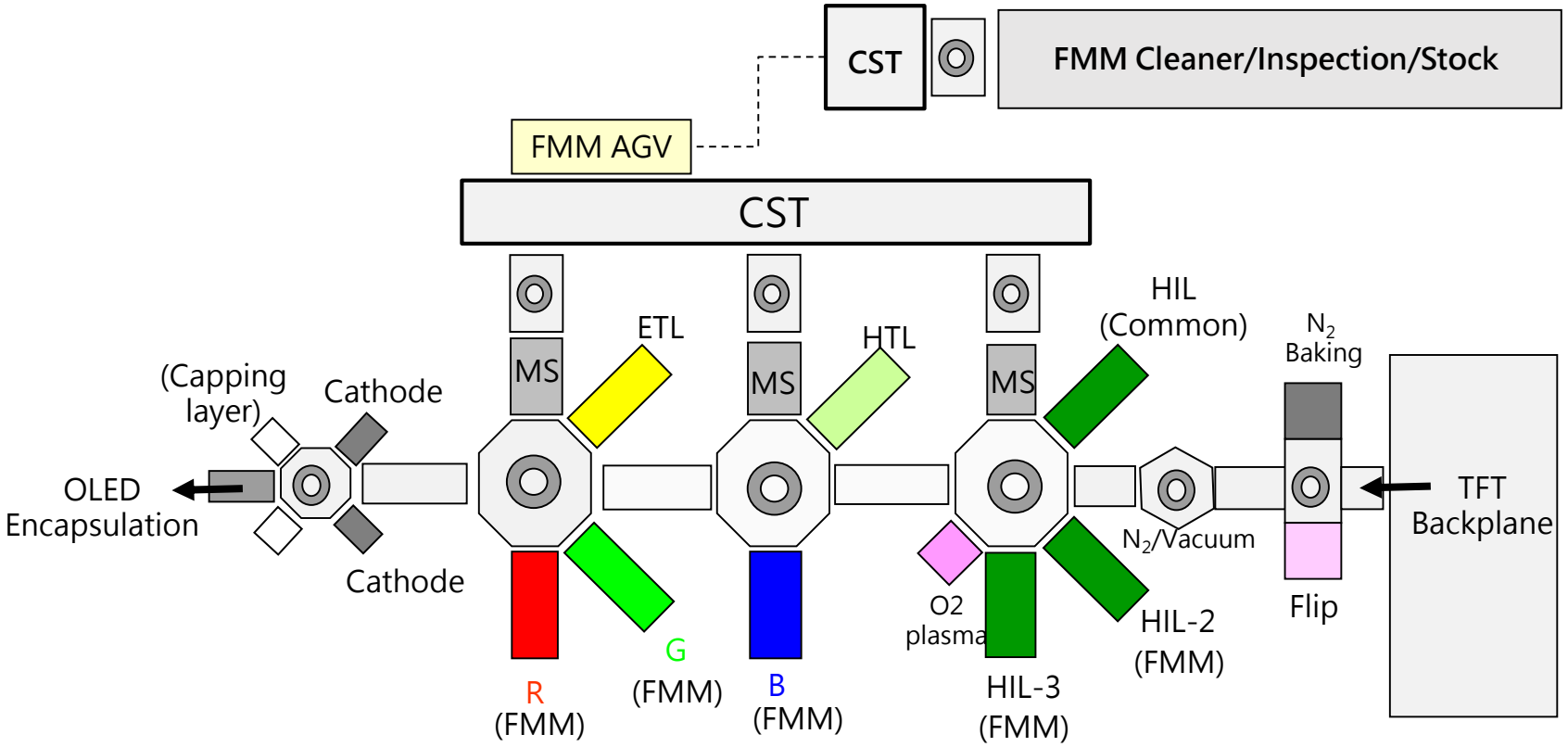
混色

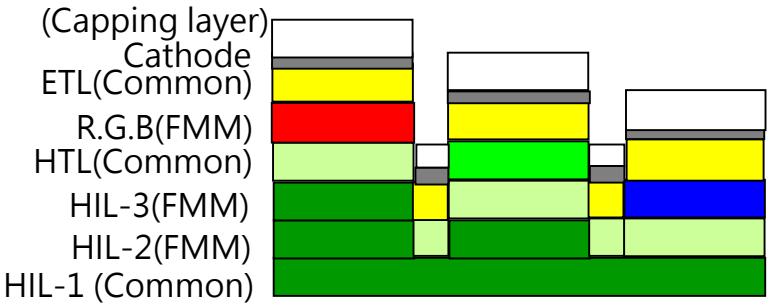


蒸鍍腔體Up stage磁鐵與FMM吸附造成

•巨觀：牛頓環

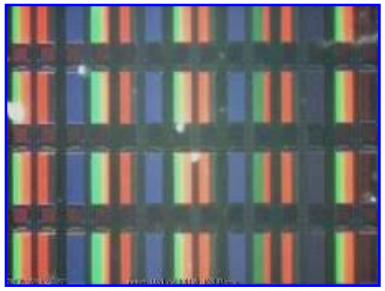
Conventional OLED Evaporation Line

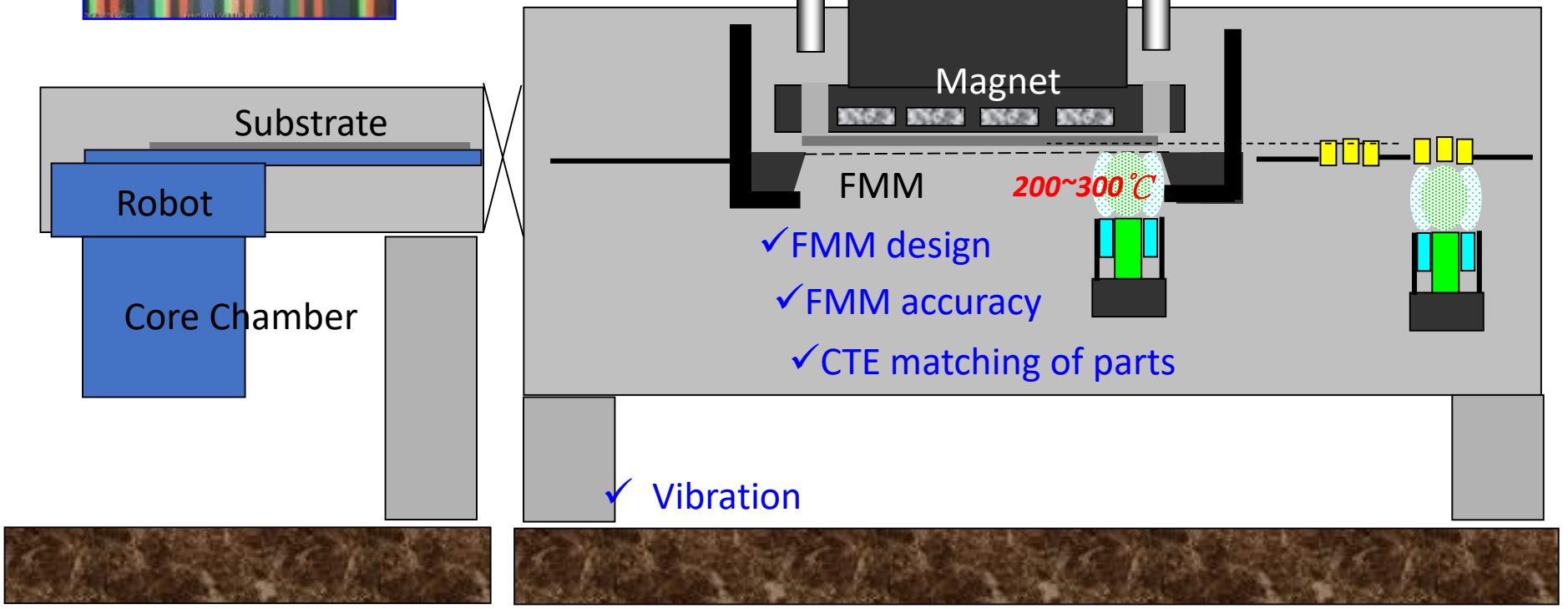




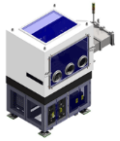
Consideration of High Resolution OLED Evaporation

Color mixing issue





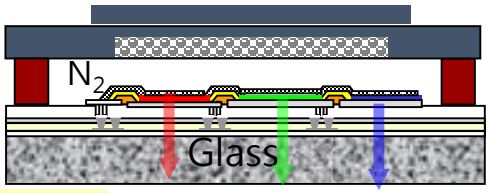
第五關 選擇OLED封裝設備

OLED設備商	OLED量產機	說明
LAN TECHNICAL SERVICE CO., LTD.		日本, 封裝設備提供
HITACHI Inspire the Next	 	日本, 封裝設備提供 ODF/VAS
AP Systems		南韓, 封裝設備提供
ALACO		南韓, 封裝設備提供
Global First & Best Top! TOP ENGINEERING		南韓, 封裝設備提供
LIG 에이디피		南韓, 封裝設備提供

第六關 選擇OLED封裝技術

1997 → 2006

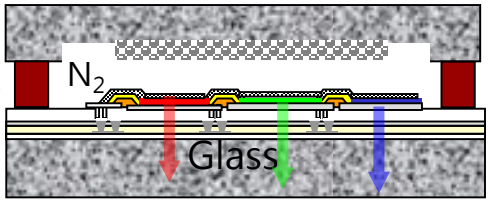
Metal



Tape Getter

BE AMOLED

Cavity Glass

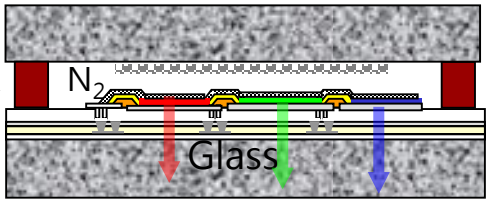


Tape Getter

Liquid Getter

BE AMOLED

Glass



BE AMOLED

Resolution<200ppi

How to do ?

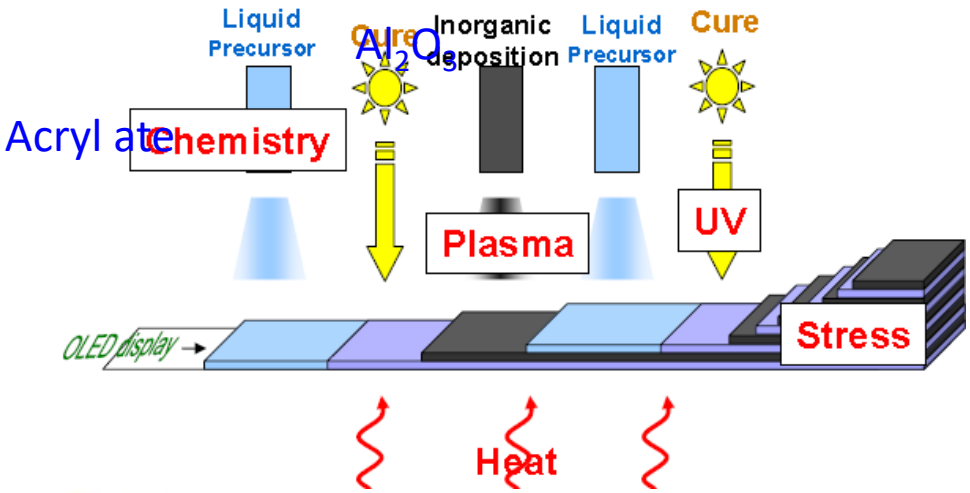
Without Getter

Thin Film Encapsulation ?

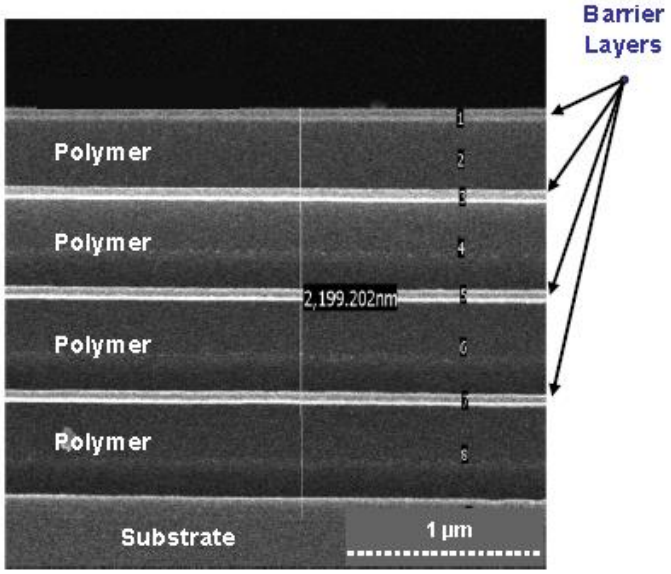
TE AMOLED

High resolution >200ppi

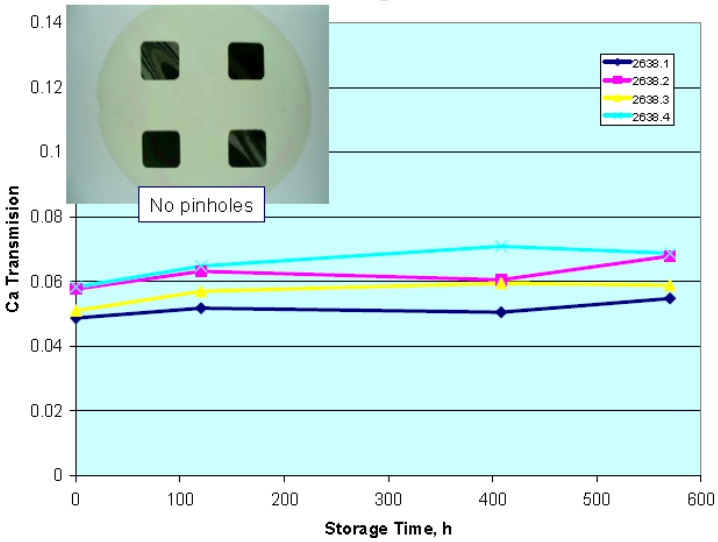
OLED薄膜封裝(TFE)技術



BARIX™ Encapsulation
WVTR~10^{-6} g/m^2.day



Almost no change after 570 h 60C 90% RH!

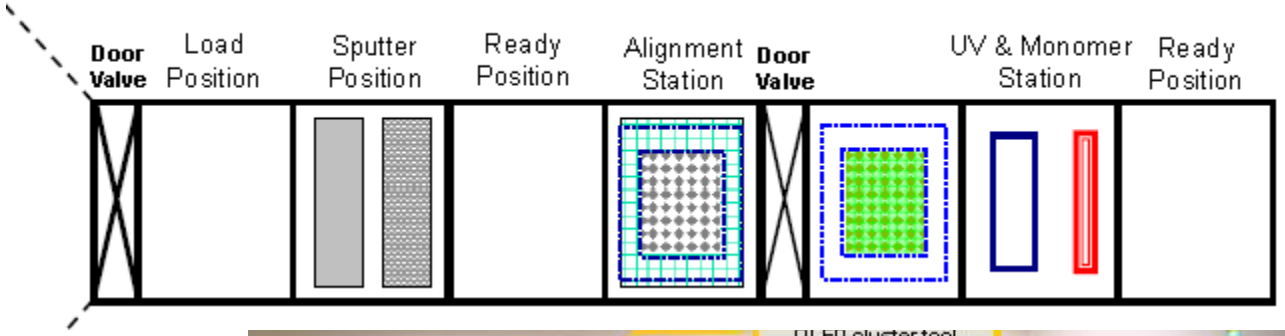


Permeation rate of ~1x10^{-6} for the combination of encapsulant and barrier substrate at 21C

Source: Vitex

Vitex R&D Pilot Line

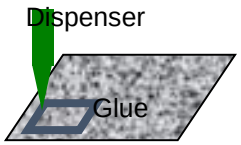
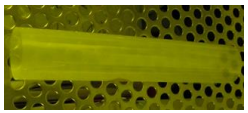
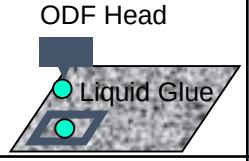
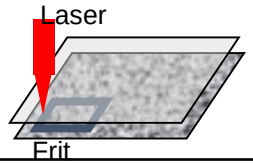
Vitex Encapsulation Tool



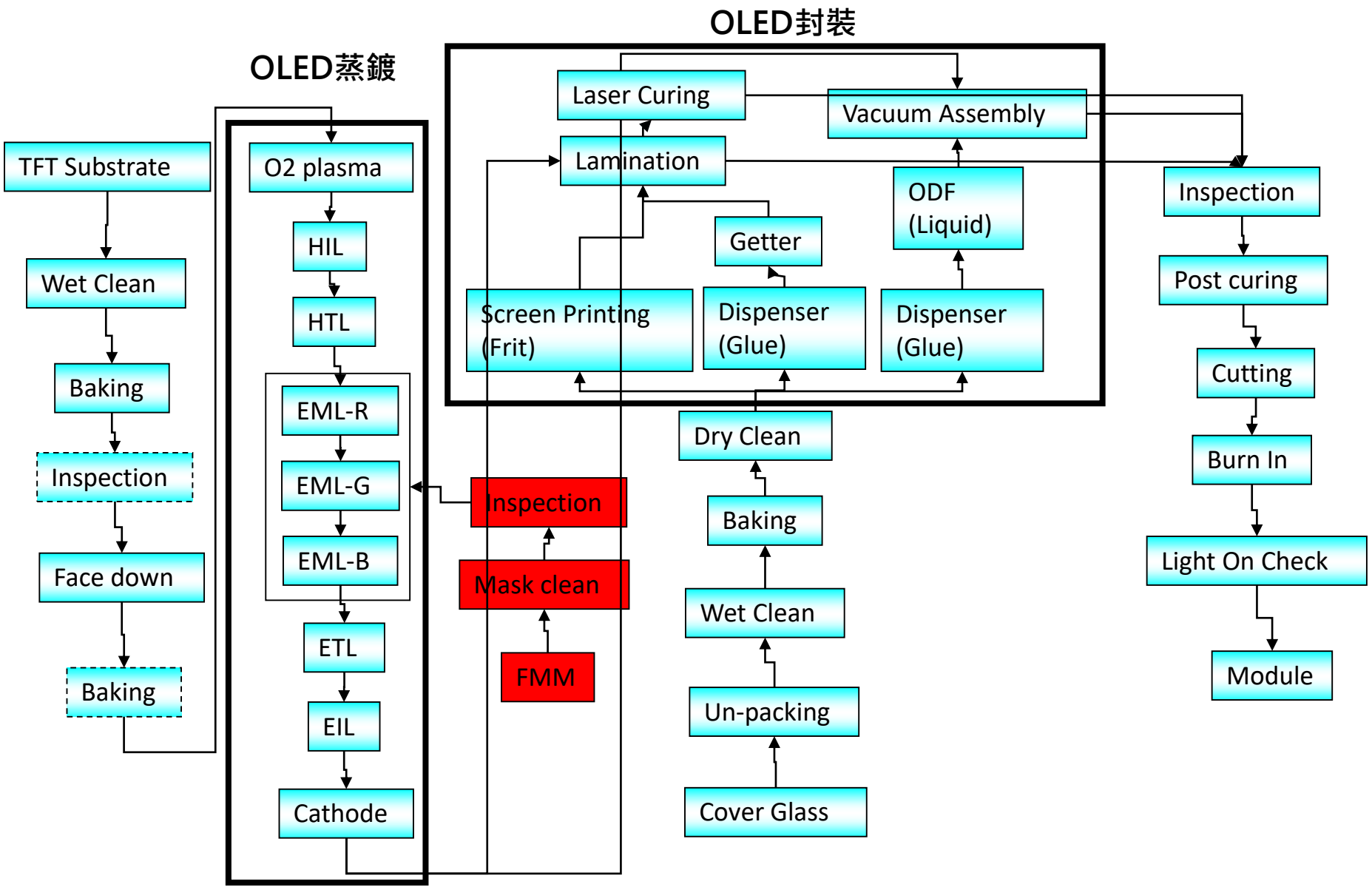
トッキ株式会社

Source: Vitex

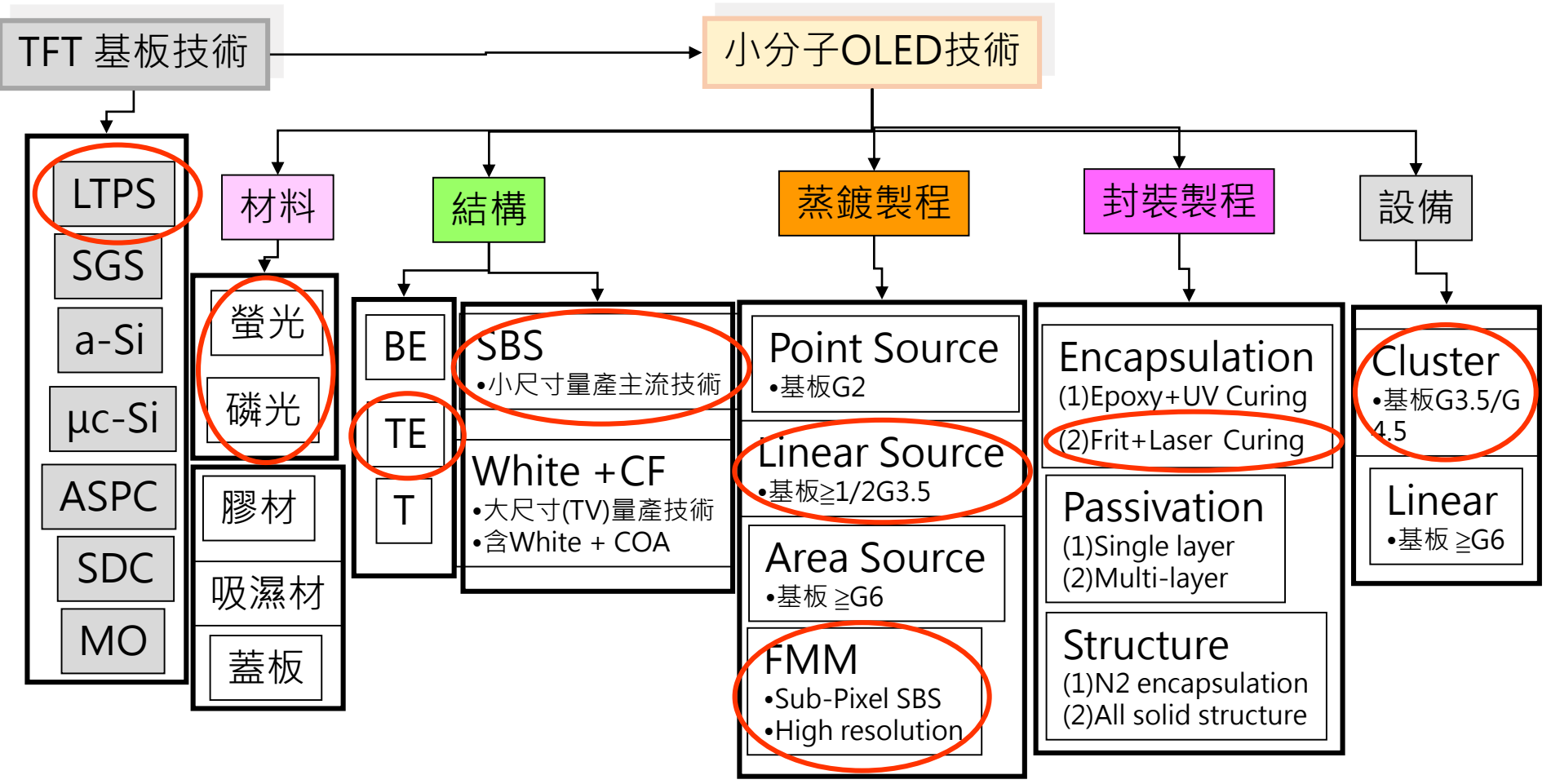
OLED封裝技術關鍵材料

	框膠	全面封止膠		玻璃膠	吸濕材
代表公司	NAGASE 長瀨產業株式会社 ThreeBond	ThreeBond	SEKISUI	Nippon Electric Glass Co., Ltd. CORNING	saes getters
圖示					
製程	· Dispensing ·UV + Thermal Curing	Lamination (Film type)	ODF (Liquid type)	· Screen Printing · Laser Curing	Lamination (Film type)
AMOLED 應用型態	Bottom Emission	Bottom Emission Top Emission		Top Emission	Bottom Emission
材料特性	·Epoxy Base · Low WVTR · Low Out Gas · Low Shrinkage	·Good Filling Property ·Good Transparency		·Glass Like Barrier property ·Very Low WVTR	·Good Water Absorption

OLED蒸鍍封裝量產線Process Flow Design



AMOLED研發到量產技術選擇



備註：

SGS (Super Grain Silicon)

ASPC (Advanced Solid Phase Crystallization)

SDC (Sublimation Deposition Crystallization)

MO (Metal Oxide)

BE (Bottom Emission)

TE (Top Emission)

SBS (Side By Side)

CF (Color Filter)

COA (Color On Array)

FMM (Fine Metal Mask)

AMOLED 研發到商品化

1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010

AMOLED生產設備

Gen1
300x400mm

1/4Gen3.5
275x335mm(CPT)
305x310mm(AUO)

Gen2 370x470mm(SDI,LG)

1/2Gen3.5
620x375mm(CMEL,TPO)

1/2Gen4.5 730x460mm(LG)

Gen 3.5
600x720mm(SONY)

Gen3.5
(AUO)

1/2Gen4.5
730x460mm(SMD)

1/4Gen5.5
650x750mm(SMD)

AMOLED 雛型品


5.5吋 Poly-Si
SANYO-KODAK


13吋Poly-Si
SONY


4吋a-Si
AUO


17吋Poly-Si LITI
SANSUNG SDI


20.1吋Poly-Si
LG-Philips


20吋a-Si
IDTech


21吋 a-Si
SANSUNG Electron


25吋Poly-Si
CMEL


14吋Poly-Si/2.4吋MO
AUO


40吋SGS
SAMSUNG


3.2吋Poly-Si
TMD


19吋MO
SMD

AMOLED 商品化


2.2吋數位相機
KODAK


3.8吋 PDA
Clie-PEG VZ90
SONY


2吋手機
BenQ –Siemens
(AUO面板)


2吋Prism
NOKIA


2.6吋N86
NOKIA

SAMSUNG手機商品

SAMSUNG MOBILE DISPLAY


7.6吋Kodak 數位相框
(CMEL面板)

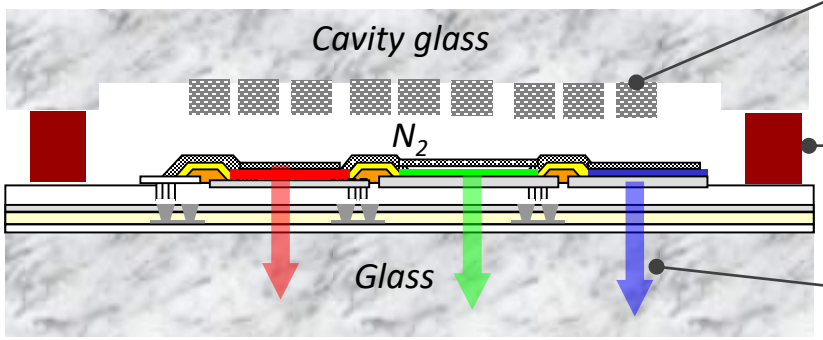

Sony 11" XEL-1


LG 15" OLED TV

World's First AMOLED Product

2003

- Display : 2.2 inch AMOLED
- Production company: SANYO KODAK(SK)



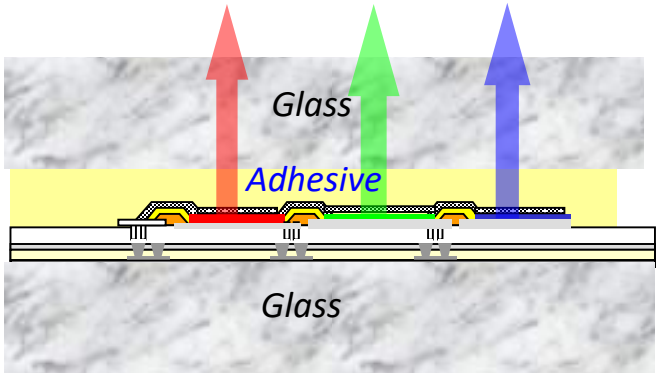
Cavity glass with **liquid getter**

Epoxy resin

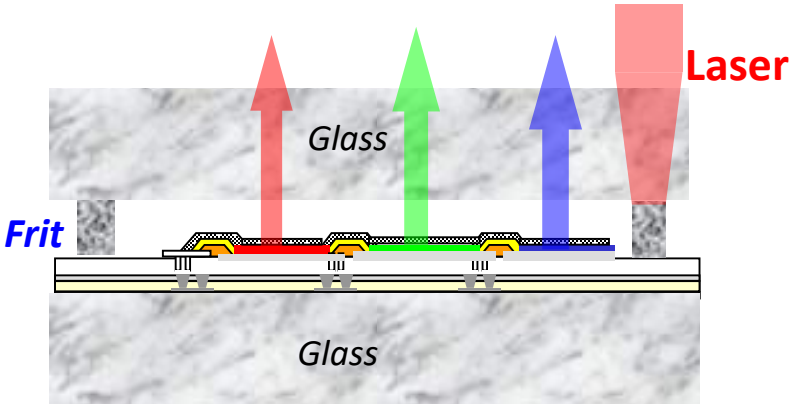
Bottom emission type

Top Emission AMOLED Encapsulation

2004 → 2009 → 2010



✓ Encapsulation: **Film type adhesive**



✓ Encapsulation: **Frit by laser**

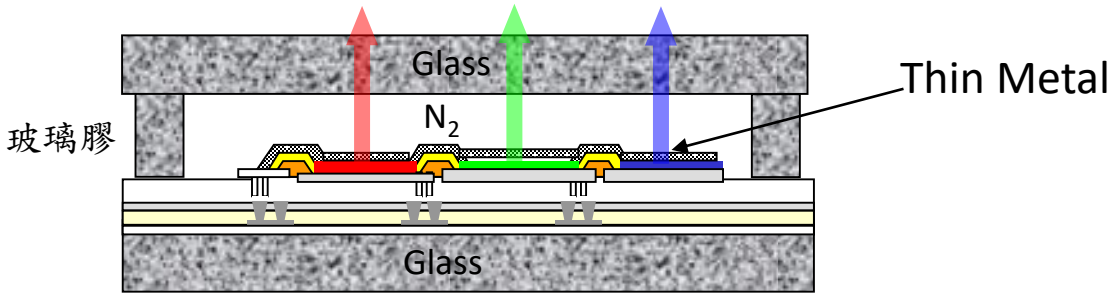
SONY 3.8” PDA

SAMSUNG 3.5” smart phone (Haptic)

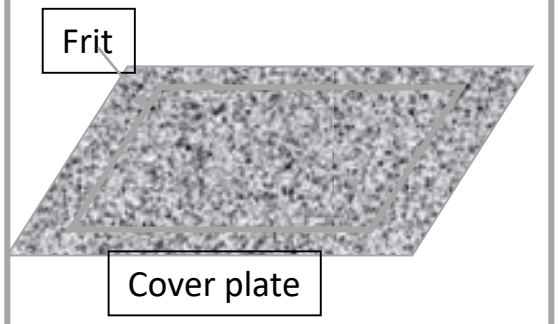
SAMSUNG 4” smart phone (Galaxy S)

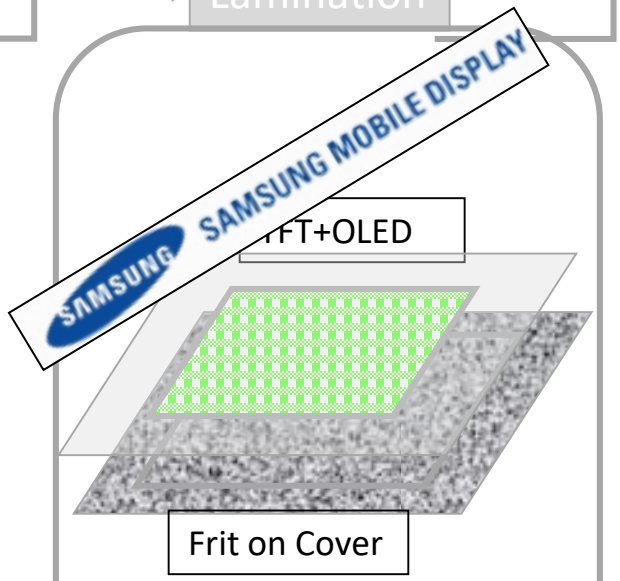
AMOLED產品化關鍵封裝技術

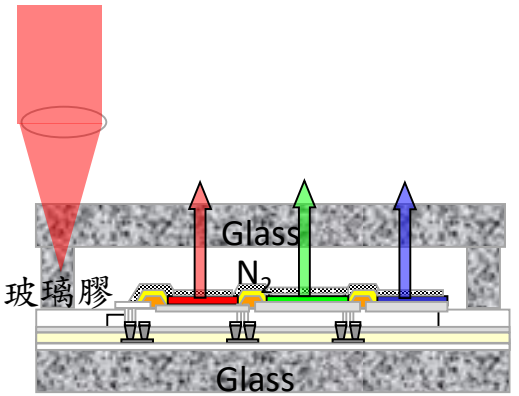
玻璃膠：Frit



Screen Printing → Lamination → Laser curing





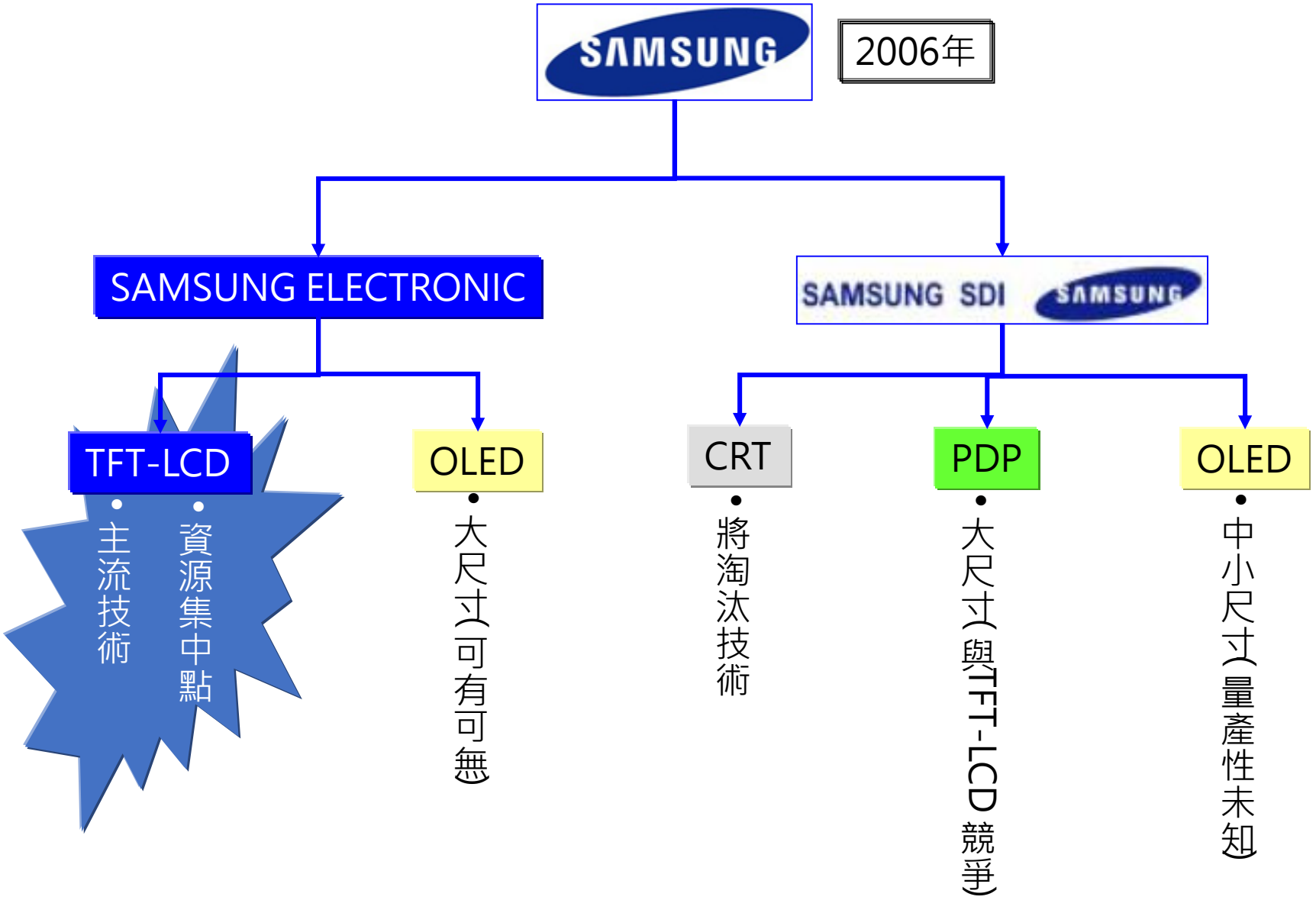


SID2010 :三星The Next Big Thing in Displays

AMOLED !

資料來源 :SAMSUNG SID10’

SAMSUNG OLED開發



SAMSUNG SDI破釜沉舟

SAMSUNG SDI

2006年

G4.5 Half OLED 量產線

FMM 關鍵技術自主研發

2007年

AMOLED 開始量產

低解析度

2008年

良率提升

AMOLED 產品推出

2009年

Samsung S8300 2.8" Touch

解析度 240x400 WQVGA

SAMSUNG產、學、研 (Display)

人才挹注

組織改組

先進技術

訓練有素人才

高階重要人才

慶熙大學

教授(大部分來自業界)

(實驗室=Pilot line)

SAMSUNG ADVANCED INSTITUTE OF TECHNOLOGY

ETRI 한국전자통신연구원 Electronics and Telecommunications Research Institute

成均館大學

防止人才外流

SAMSUNG 集中火力進攻AMOLED

SAMSUNG

LCD部門

併入

SAMSUNG MOBILE DISPLAY

SAMSUNG DISPLAY

獨立

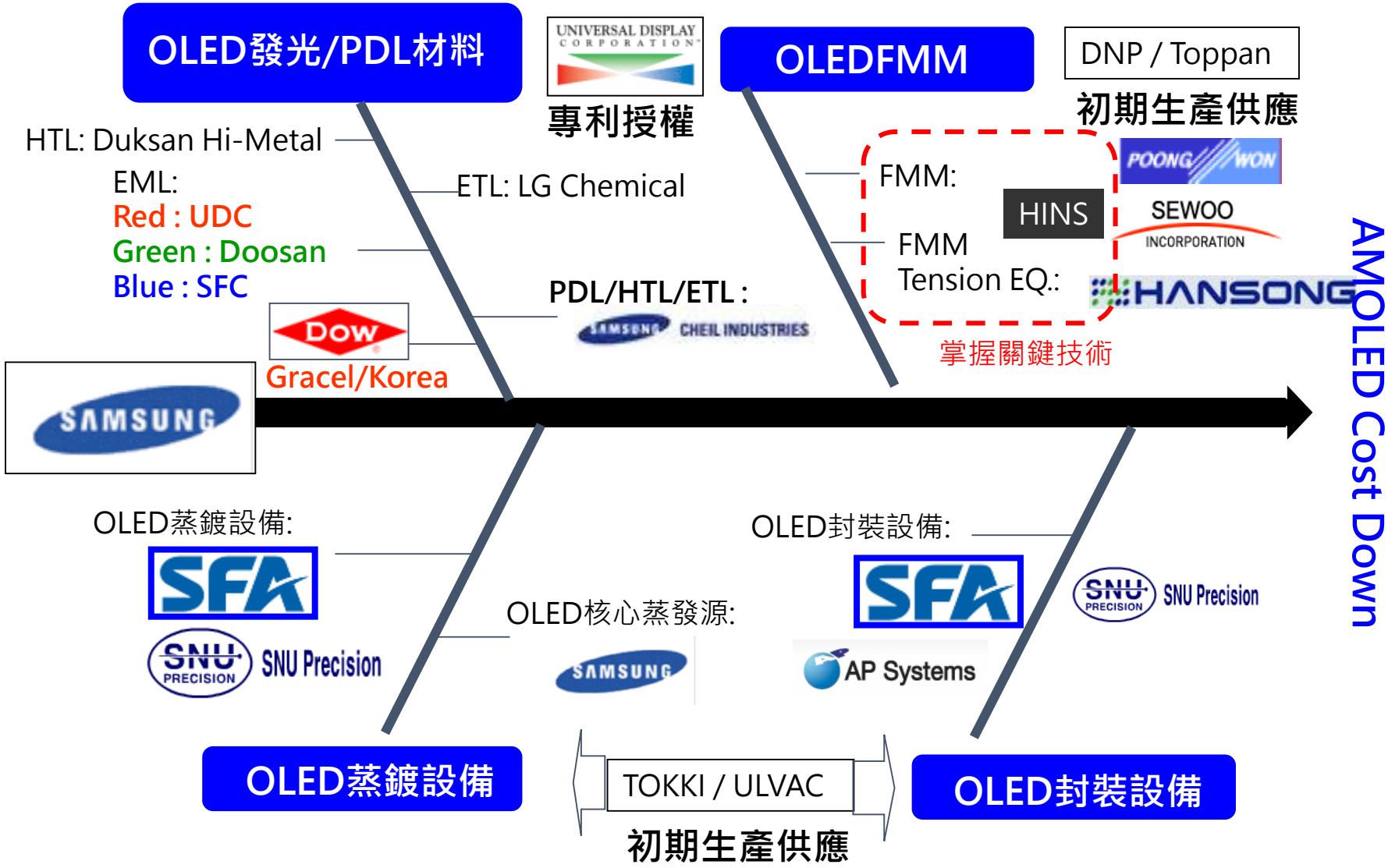
LCD人力轉向OLED

資本支出向OLED集中

OLED TV

Flexible AMOLED

SAMSUNG AMOLED自主化關鍵整合



SAMSUNG OLED材料自主化

SAMSUNG CHEIL INDUSTRIES

Materials for OLED (Organic Light Emitting Diode)

Organic materials which are used in a variety of advanced devices such as smart phones, tablet and computer screens,and televisions.The Electron Transfer Layer(ETL),Hole Transfer Layer(HTL), Green Phosphorous Host Layer(GPHL) and Pixel Defining Layer(PDL) allow the efficient transfer and combination of electrons and holes to produce vivid colors and high contrast while promoting low power consumption,long life and reliable operation.

Flexible AMOLED

UBE 宇部興産株式会社

Polyimide (PI)

Polyimide is used in LCD manufacturing, providing the means to make liquid crystals align in one direction. This allows the LCD to provide sharper, clearer, high quality picture images.

PSPI

PSPI (Photo Sensitive Polyimide) is an advanced material used to protect delicate semiconductor circuits against the damaging effects of electrical and mechanical shock and temperature that are transmitted through the packaging of the device to the circuit.

FPD materials

Color Resist (CR)

Color resists consist of three types of organic materials through which the three primary colors (red, green, and blue) emitted by the TFT-LCD backlight are filtered. Color resists are an essential core component of LCD production technology.

Anisotropic Conductive Film (ACF)

Anisotropic conductive film is an essential adhesive material used for connecting flat panel display circuits.
It provides electric anisotropy with electrical conductivity in the direction of the thickness of the film and electrical insulation in all other directions.

Paste

Paste can provide both insulation and conduction. For multi layer ceramic capacitor (MLCC) electrodes, paste promotes even flow of electricity inside electronic parts. It is also used to form an insulation layer for address or bus electrodes of PDP (plasma display panel) for display devices.

Light Diffusion Plate (LDP)

Light diffusion plate is an optical dispersion plate that protects supporters and lamps of various optical film in the backlight assembly. It also disperses backlight to ensure consistent light contrast throughout the LCD TV screen.

Multi Angle Surface (MAS)

Multi angle Surface provides more and brighter light for LCD, which cannot self-generate light. It also provides various additional functions for the conventional prism films, resulting in vastly improved performances such as wider viewing angle and elimination of the upper protective film.

Polarizing Film

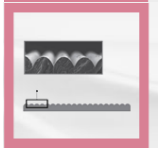
Polarizing film changes the incidental light vibrating in several directions into light that vibrates in only one direction (polarized light). Since LCD uses double refraction of liquid crystals, it is very important to control the vibrational directions of light coming into liquid crystals.

Flexible Copper Clad Laminate (FCCL)

Flexible copper clad laminate, a multi-layered stack of polyimide and thin layers of copper, is used in flexible circuit boards to provide three-dimensional flexibility. This essential material enables design and miniaturization of electronic devices such as mobile phones and digital cameras.

LED SE (LED Silicone Encapsulant)

Silicon materials that protect LED chips from external environments such as air and moisture and fluorescent substances



LGP(Light Guide Plate)

Optical, high penetration material that induces the point light source to the front direction

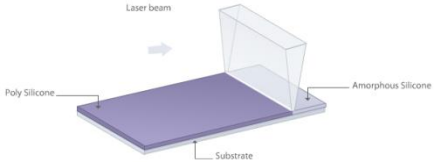
資料來源：http://www.cii.samsung.co.kr

SAMSUNG OLED設備國產化

AP Systems

RTP Rapid Thermal Process

LTP Laser Thermal Process



AMOLED Encapsulation

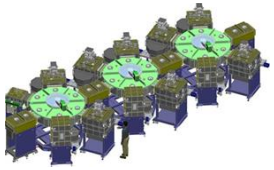
VAS Vacuum Assembly System

Seal/Short Dispenser

http://www.apsystems.co.kr

SFA

ORGANIC DEPOSITION SYSTEM



ENCAPSULATION SYSTEM

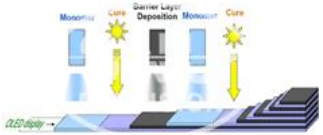
SCRIBER (STICK CUT / CELL CUT)

http://www.sfa.co.kr

SNU Precision

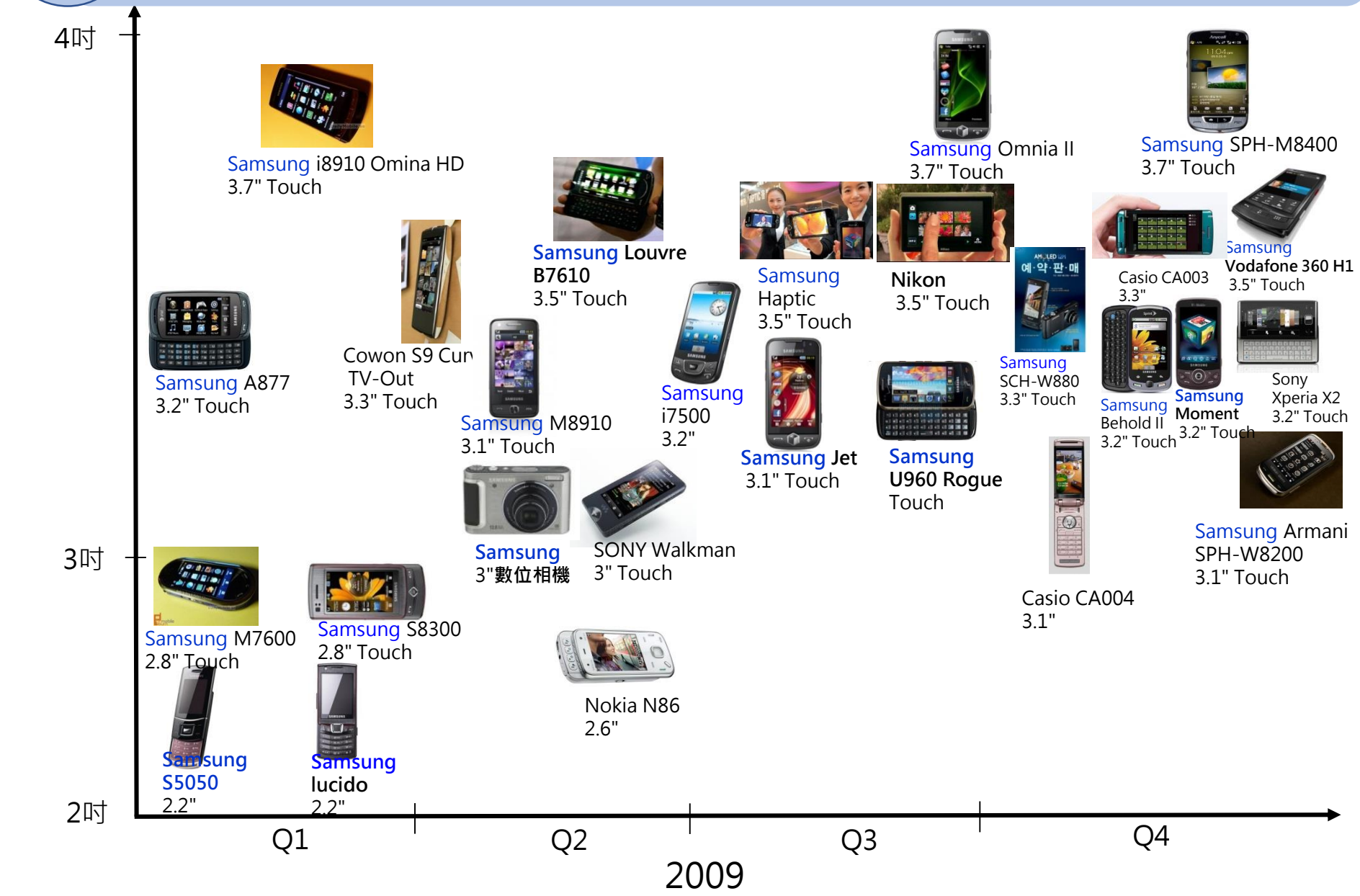
DSP

TFE System Thin Film Encapsulation



http://www.snuprecision.com/english/

2009 AMOLED 小尺吋產品



2010 AMOLED 小尺吋產品

4吋

3吋

韓國國內(7/4 News)
10天銷售 20萬支
全球超過500萬支(2010.10)

Samsung Galaxy S
4”WVGA Super AMOLED

Samsung Sprint
Epic 4G4”WVGA
Super AMOLED

Microsoft
Window 7
4”Super
AMOLED

Samsung
Omnia 7
4”Super
AMOLED

NOKIA E7
4” Touch
AMOLED

DELL Venue Pro
4.1” Super AMOLED

Google Nexus One
3.7" Touch

HTC Incredible/Desire
3.7”AMOLED

Samsung Projector
phone
Galaxy Beam 3.7”
Super AMOLED

Samsung CL80
Digital Camera
3.7”Touch AMOLED

Samsung Galaxy K
3.7”AMOLED plus

Samsung S8500
3.3" Super AMOLED

Samsung Projector phone
W9600 3.3 touch AMOLED

San Francisco
3.5” Touch
AMOLED

NOKIA C7
3.5” Touch
AMOLED

Nikon S80
3.5”Touch
AMOLED

NOKIA N8
3.5” Touch
AMOLED

NOKIA C6
3.2” Touch
AMOLED

Motorola Ming
A1680 3.1”
Touch AMOLED

Samsung Craft
3.3“ AMOLED

Samsung NX100
3“ AMOLED

Samsung DSLR NX10
3“ AMOLED

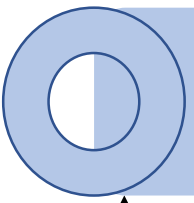
Samsung HZ35W
3“ AMOLED

Samsung
WB2000
Digital Camera
3”AMOLED

Samsung TL500
3“ AMOLED

Q1 Q2 2010 Q3 Q4

2011 AMOLED 小尺吋產品



10 million in 5 months

4吋

3吋

Q1

Q2

2011

Q3

Q4

Samsung
Galaxy S2
4.3”Super AMOLED-Plus

Samsung
Focus S
WP7.5
4.3”Super AMOLED-Plus

Motorola
Droid ZARA
4.3” Super AMOLED Advanced

Galaxy Nexus
4.65”Super AMOLED HD

Google Nexus S
4”Super AMOLED

NOKIA X7
Clear Black
4”AMOLED

NOKIA N9
3.9”AMOLED

NTT Docomo
4” AMOLED

LG Optimus-Sol
3.8”AMOLED

NOKIA Lunina800
Clear Black
3.7”AMOLED

SONY TX100V
Digital Camera
3.5” AMOLED

Nikon S100
3.5”AMOLED

NOKIA 700
3.2”AMOLED

Olympus XZ1
Digital Camera
3.0” AMOLED

Olympus E-P3
Digital Camera
3.0” AMOLED

SAMSUNG手機產品線布局策略

- SAMSUNG從機海戰術策略，走向明星產品

2012 AMOLED 小尺吋產品

5吋

4吋

3吋

20 million (25% of South Koreans own this phone)

Samsung Galaxy S2 4.3”Super AMOLED-Plus

Panasonic ELIGA 4.3"AMOLED

ASUS Padphone **4.3”Super** AMOLED

HTC One S 4.3”Super AMOLED

HUAWEI Ascend P1 S 4.3”Super AMOLED

20 million in 100 days

Samsung Galaxy S3 4.8”Super AMOLED-Plus HD

Samsung Window8 phone 4.8”Super AMOLED-Plus HD

印度Micromax Pixel A90 4.3"AMOLED

AT&T Pantech 4.3“qHD Super AMOLED

Google’s Motorola RAZR i 4.3“qHD Super AMOLED

NOKIA Lumia820 4.3“qHD clearblack AMOLED

Google’s Motorola 4.7“HD Super AMOLED

AT&T Pantech 4“ Super AMOLED

AT&T 3.7“ Super AMOLED

NOKIA 808 Clear Black 4”AMOLED

SONY TX-66 3.3”AMOLED

Samsung NX -20/200 3”AMOLED

Olympus Tough TG-1 iHS **3”**AMOLED

Samsung MV900F 3.3”AMOLED

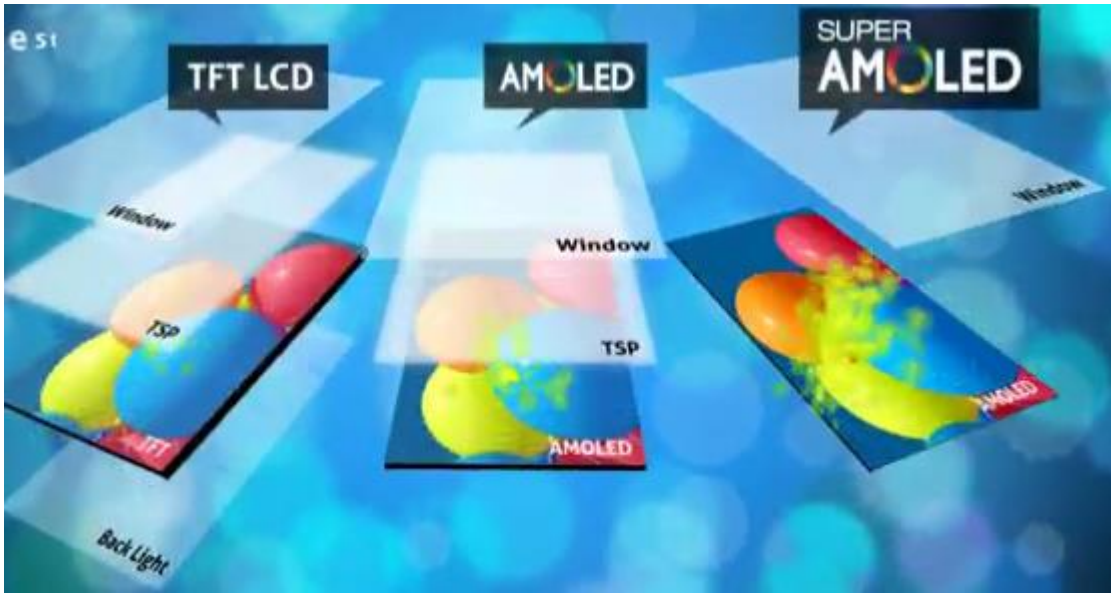
Samsung EX2F 3”AMOLED

Panasonic LUMIX GH3 3"AMOLED

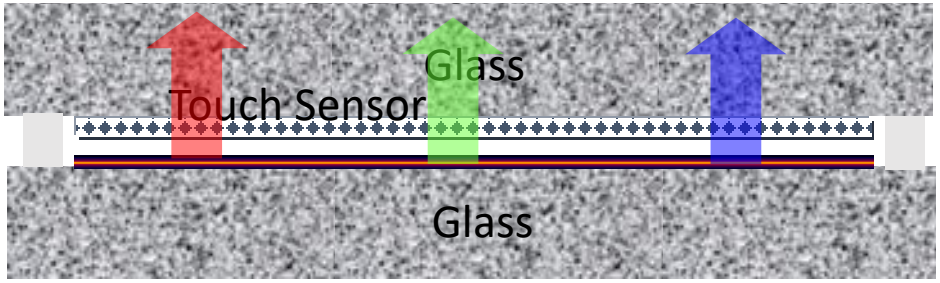
Q1 Q2 Q3 Q4

2012

2012 SAMSUNG Super AMOLED



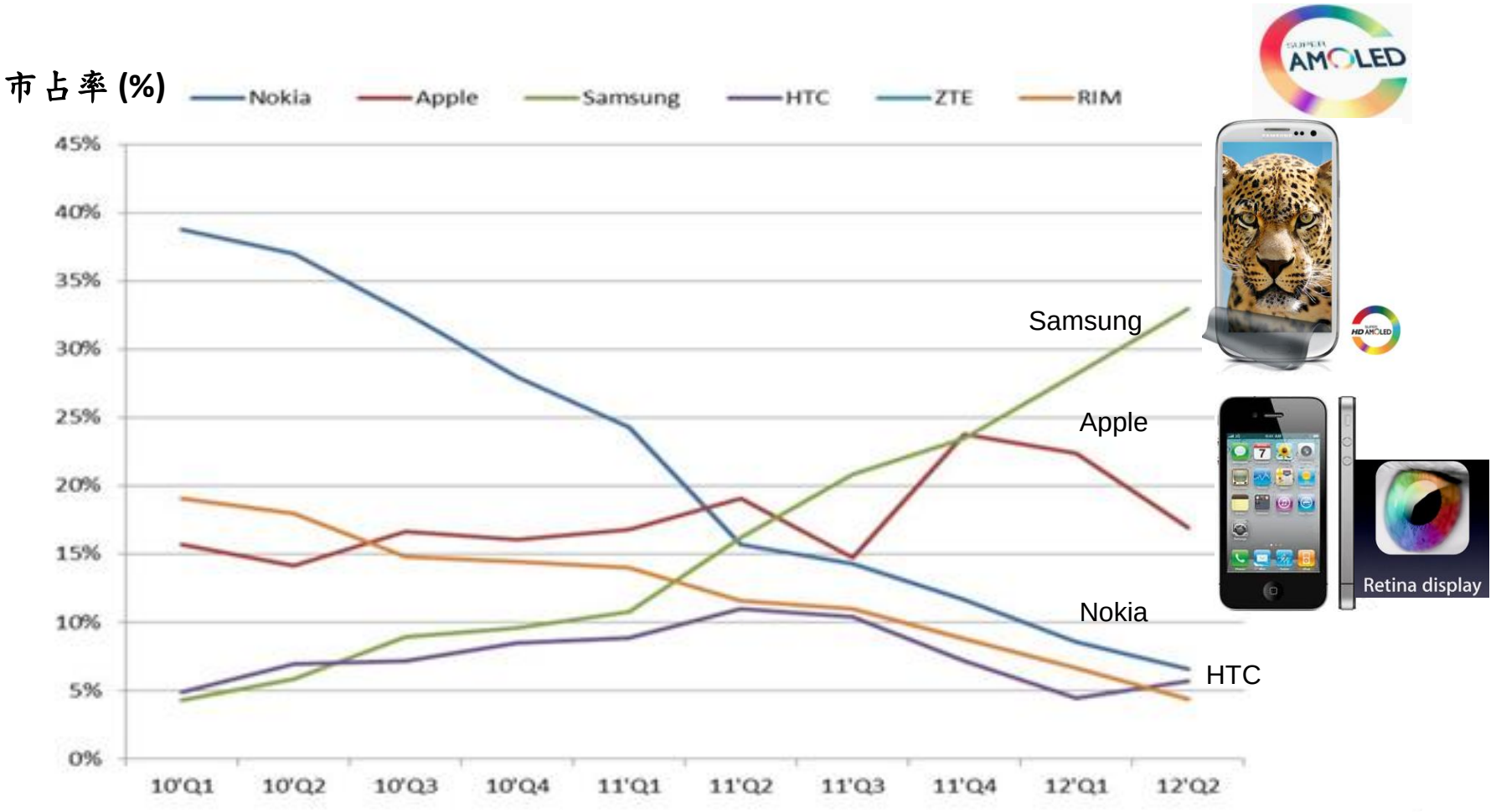
4 Glass　　4 Glass　　3 Glass



2 Glass

AMOLED

2011年 SAMSUNG 市占率超越Apple



Source：IDC/ iSuppli 2012

2013 AMOLED 小尺吋產品

5吋

4吋

3吋

NTT's MEDIAS X phone
(made by NEC Casio)
4.7”AMOLED

20 million in
68 days

Samsung
Galaxy S4
5” 1080P AMOLED

Moto X
4.7" 720p
AMOLED,
316 ppi,

NOKIA
Lumia820
4.5" 1,280x768
ClearBlack
AMOLED

Samsung
Galaxy S4 mini
4.3” AMOLED

NOKIA
Lumia1020
4.5" 1,280x768
ClearBlack
AMOLED

SONY TX-30
3.3” AMOLED

Blackberry 3.2"
720x720 (330
ppi) Super
AMOLED

Nikon S9500
3” AMOLED

Nikon AW110
3” AMOLED

OLYMPUS TG-2 iHS
3” AMOLED

Q1 Q2 2013 Q3 Q4

AMOLED 中、大尺吋雛型品到產品

40吋
20吋
10吋

2008 2009 2010 2011 2012

Sony 11" XEL-1

LG 15” OLED TV

SONY 24.5”
OLED TV Monitor

SONY 16.5”
OLED TV Monitor

SAMSUNG MOBILE DISPLAY

Gen 5.5 Start to MP

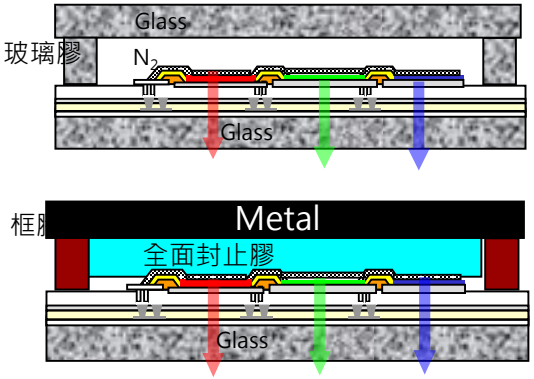
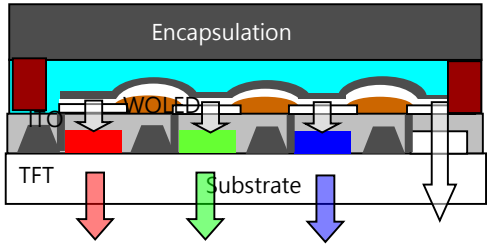
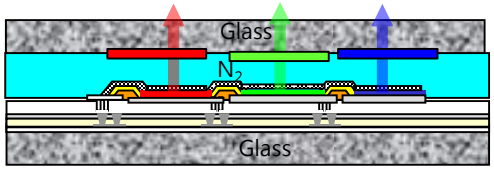
Prototype

LG 55”OLED TV

SAMSUNG 55”OLED TV

Sold 15,000 Unit

OLED TV結構開發

公司	AMOLED結構	說明	產品
SAMSUNG MOBILE DISPLAY		*衍用小尺寸玻璃膠雷射封裝結構 *開發Dam and Fill封裝全固態結構	 55吋OLED TV
LG Display		*WOLED+COA結構	 55吋OLED TV
SONY		*Top Emission R/G/B+CF 結構	  17/25吋OLED Monitor

LG 面板技術策略

中、小尺寸

~~Glass AMOLED~~

IPS LCD

LG Display

In Plane Switching

Flexible AMOLED

LG Life's Good

大尺寸

IPS LCD

OLED TV

LG AMOLED國產化關鍵整合

OLED發光/PDL材料

UNIVERSAL DISPLAY CORPORATION

專利授權

HTL/ETL :

LG Chem

DOW

Gracel/Korea

OLEDFMM

DNP / Toppan

初期生產供應

FMM: SEWOO INCORPORATION

FMM Tension EQ.: HANSONG

LG Display

AMOLED Cost Down

OLED蒸鍍設備:

Sunic system

JUSUNG ENGINEERING

OLED核心蒸發源:

VAS Your Artistic Solution

OLED封裝設備:

AVACO

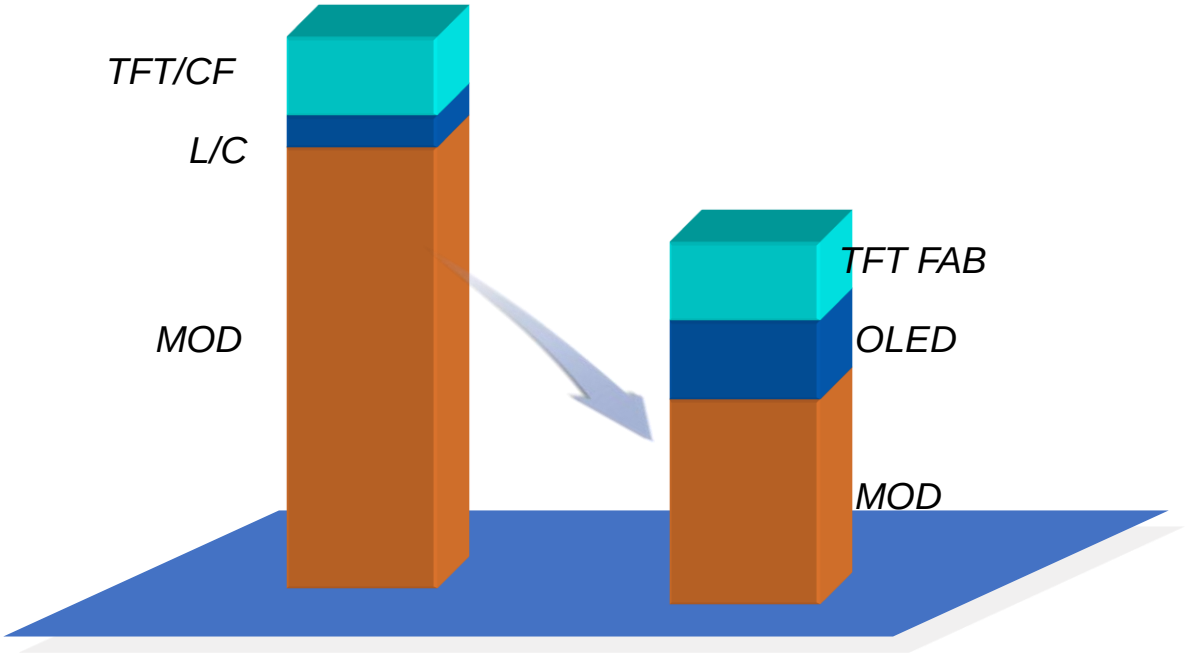
OLED蒸鍍設備

TOKKI / ULVAC

初期生產供應

OLED封裝設備

SAMSUNG對OLED TV看法

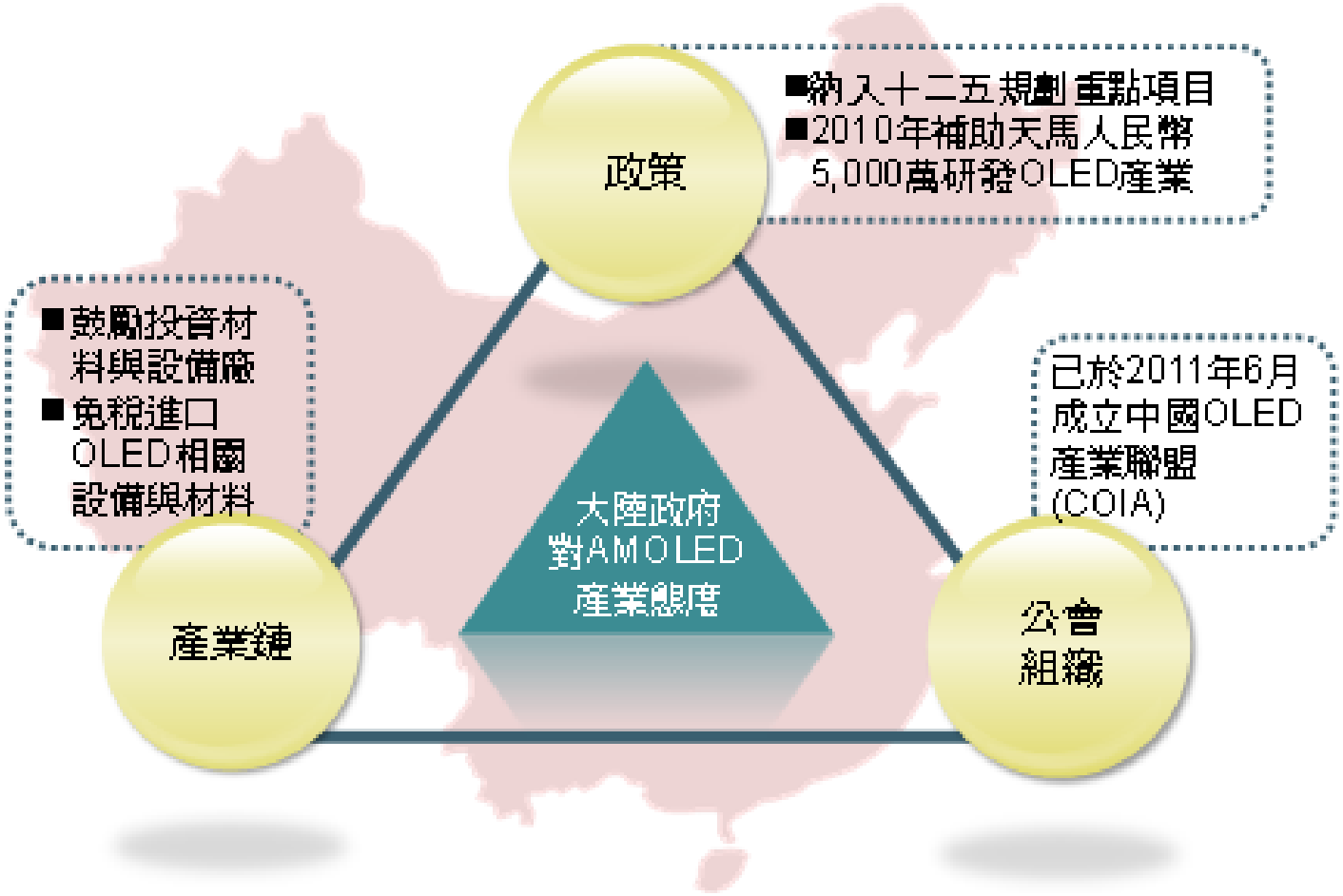


資料來源：SAMSUNG

OLED TV未來BOM Cost是有機會比LCD還低!

*If Gen8.5 OLED FAB Yield is no problem

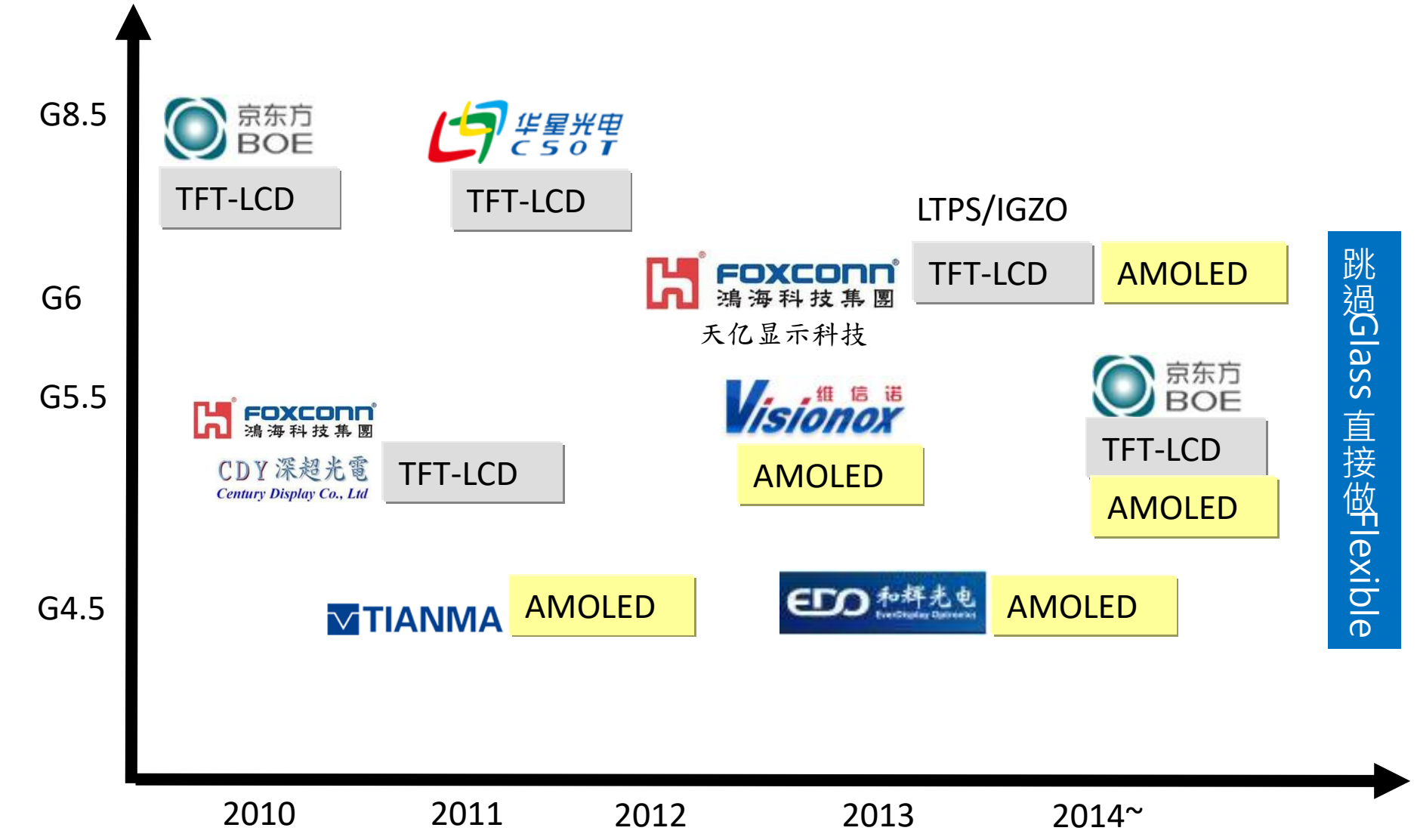
2012 開始大陸政府積極輔導AMOLED產業



資料來源：天馬，2012/4；DIGITIMES整理，2012/5

台灣(TFT/OLED)人才外移

大陸面板產業發展快速


G8.5
G6
G5.5
G4.5
京东方 BOE
TFT-LCD
华星光电 CSOT
TFT-LCD
FOXCONN 鴻海科技集團
天亿显示科技
LTPS/IGZO
TFT-LCD
AMOLED
FOXCONN 鴻海科技集團
CDY 深超光電 Century Display Co., Ltd
TFT-LCD
維信諾 Visionox
AMOLED
京东方 BOE
TFT-LCD
AMOLED
TIANMA
AMOLED
EDO 和辉光电
AMOLED
跳過Glass 直接做Flexible
2010
2011
2012
2013
2014~

大綱

- 過去 : OLED研發到量產
- **過去 : Flexible AMOLED研發到量產**
- AMOLED現在
- AMOLED未來

Flexible Display 研發歷程

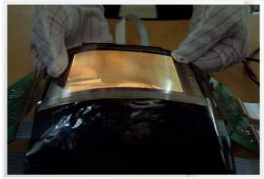
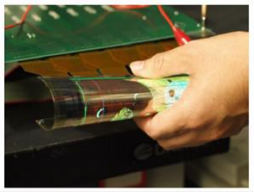
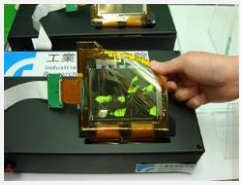
Flexible LCD

E-paper

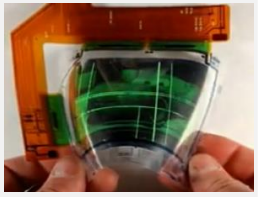
Flexible OLED

2000 ~ 2005 ~ 2010

Flexible AMOLED技術研發(2007~2008)

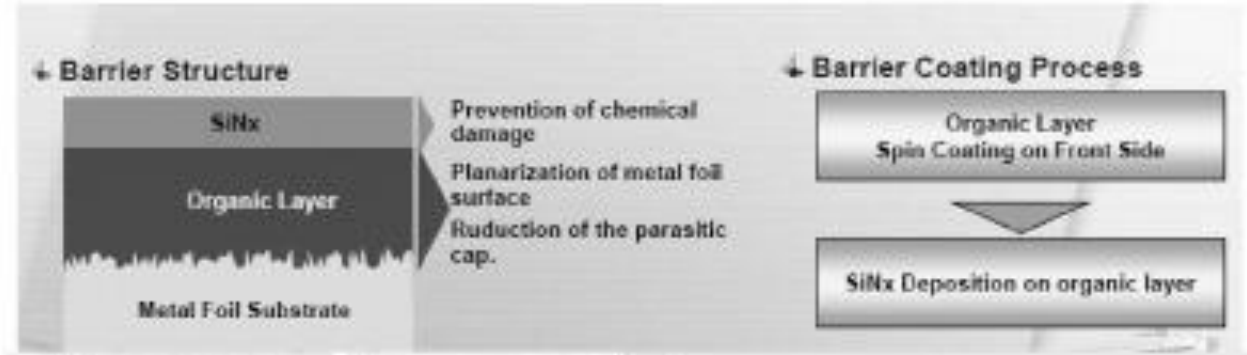
公司	LG (2007)	Sony (2007)	LG Display (2008)	NHK (2008)	ITRI (2008)
面板雛型	•3.5″ •QCIF+ •Color	•2.5″ •QQVGA •Color	•4″ •QVGA •Color	•5.8″ •QQVGA •Color	•4.1″ •QVGA •Mono.
TFT	•Metal Oxide •2T1C	•OTFT •2T1C	•a-Si •2T1C	•OTFT •2T1C	•a-Si •2T1C
基板	•Metal Foil	•PES or PEN	•Metal foil	•PEN	•Clear PI
OLED type	Top Emission	Top Emission	•Top Emission	•Bottom Emission	•Bottom Emission
Demo.					

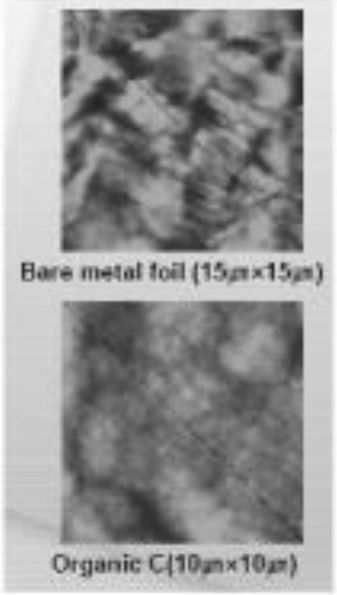
Flexible AMOLED技術研發(2009)

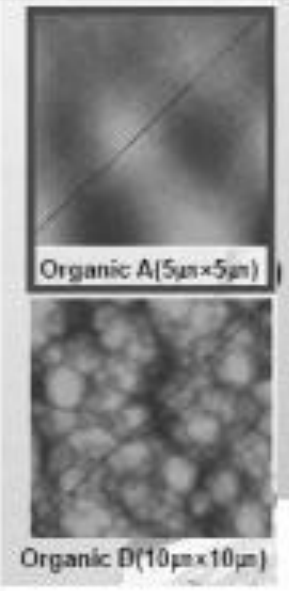
公司	UDC&LG (2009)	SMD (2009)	FDC & UDC (2009)	Sony (2009)	SMD (2009)	SMD (2009)
面板雛型	•4” •QVGA •Color	•6.5” •Color	•4.1” •QVGA •Mono.	•2.5” •QQVGA •Color	•6.5” •WQVGA •Color	•2.8” •166ppi •Color
TFT	•a-Si	•NA	•a-Si	•OTFT •2T1C	•Metal Oxide •3T1C	•NA
基板	•Metal Foil	•NA	•PEN	•NA	•Plastic	•Plastic
OLED type	Top Emission	•NA	•NA	Top Emission	•Top Emission	•Top Emission
Demo.						

Metal Foil Substrate for TFT Process

- ***Organic layer for planarization of metal foil surface***
- ***SiNx to prevent chemical damage of organic layer***



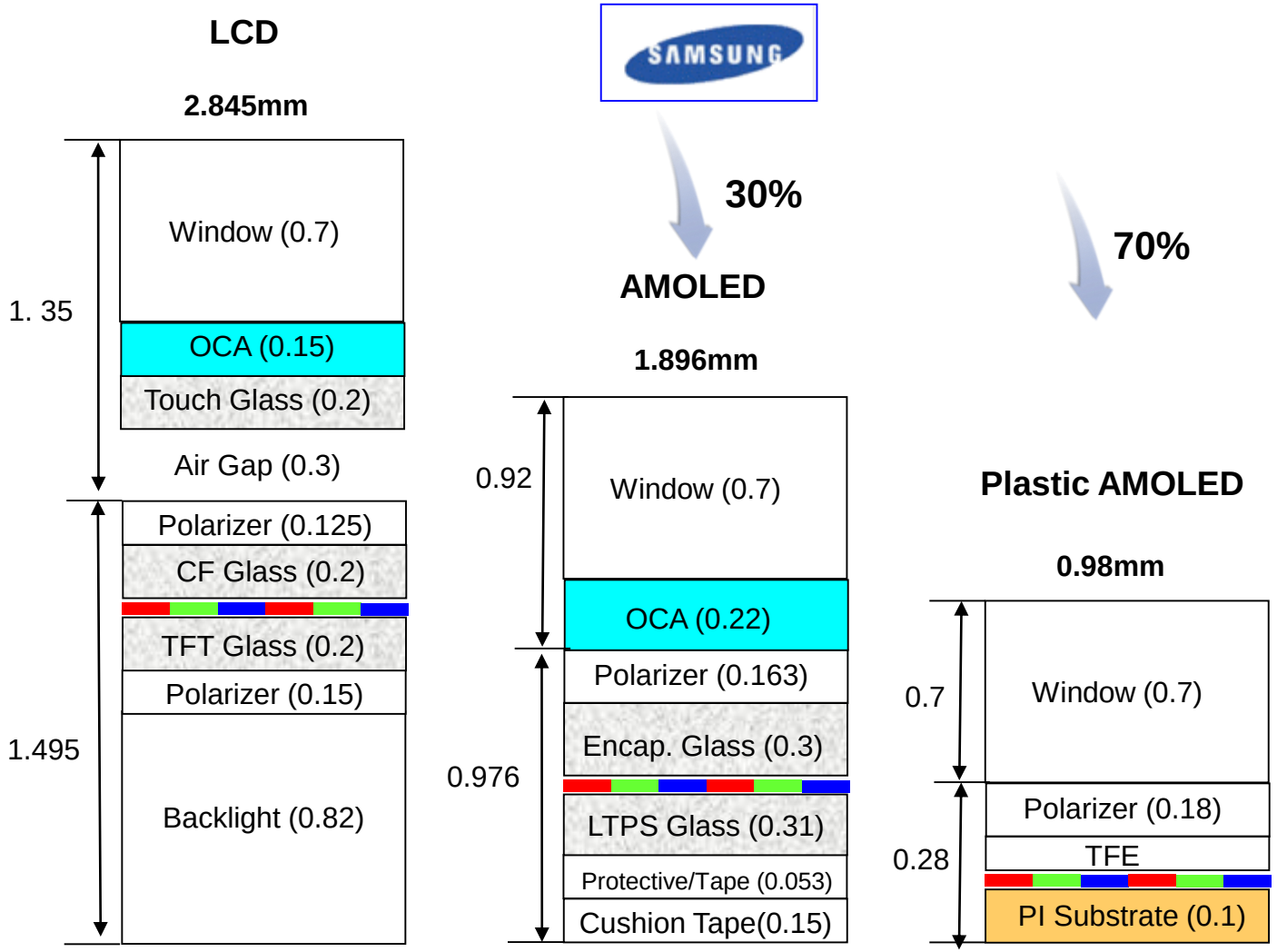




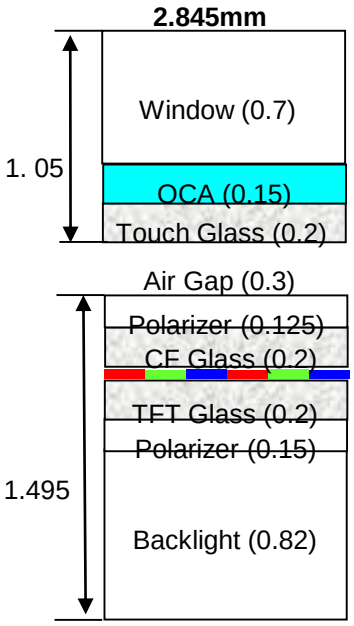
Substrate	RMS(Å)
Glass	41Å
Bare SUS	964Å
SiNx	994Å
Organic A	29Å
Organic B	39Å
Polyimide	89Å
Organic C	335Å
Organic D	526Å

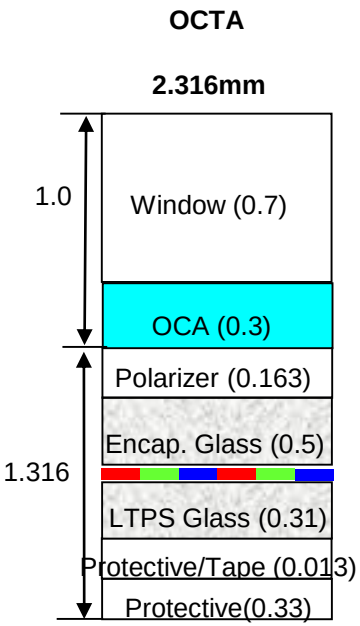
Source: USDC2008／LGD，2008／02

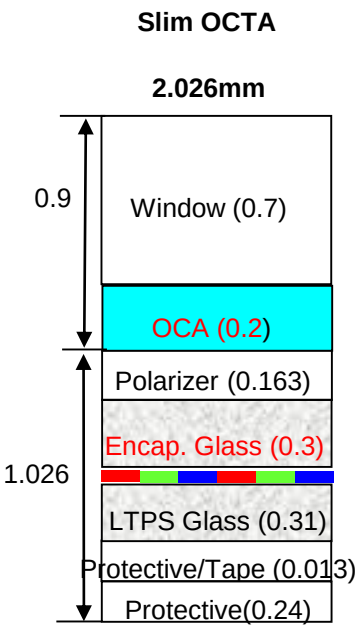
SAMSUNG AMOLED瘦身計畫

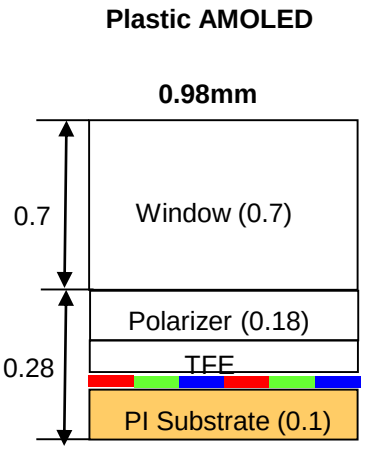


SAMSUNG Super AMOLED



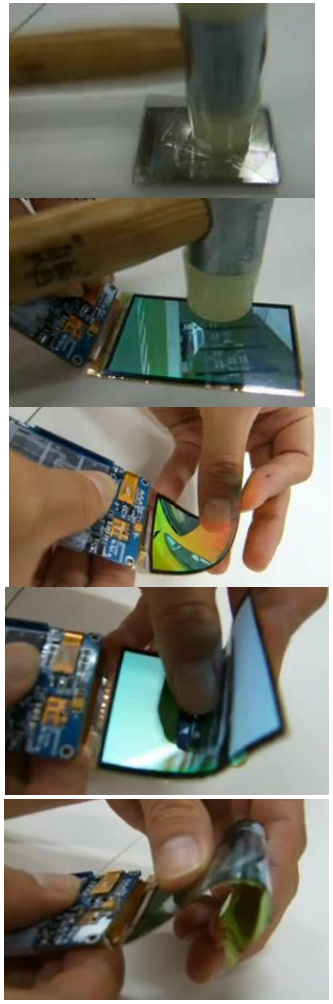


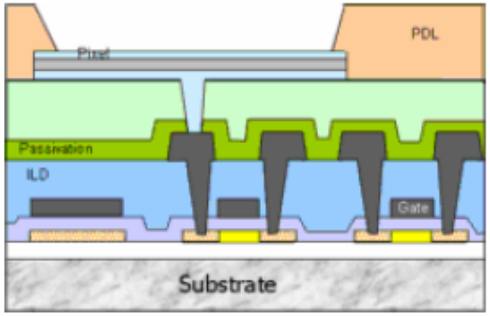


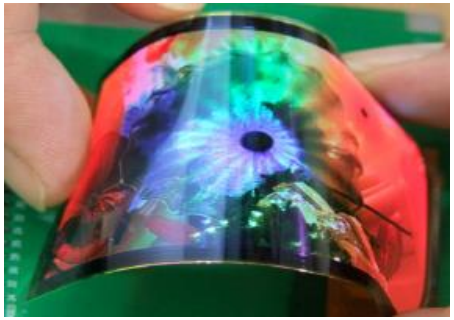


資料來源：SAMSUNG

Flexible AMOLED重要一篇論文(SAMSUNG)







Items	Specification
Diagonal size	2.8 inch
Pixel arrangement	240 x RGB x 400 (166 ppi)
Pixel element	6T-2C, 3:1demux
Brightness	250 cd/m2
Bending radius	< 10 mm
Structure	Top emission
Flexible substrate	**PI**
Thickness	0.24mm
Weight	0.29 g

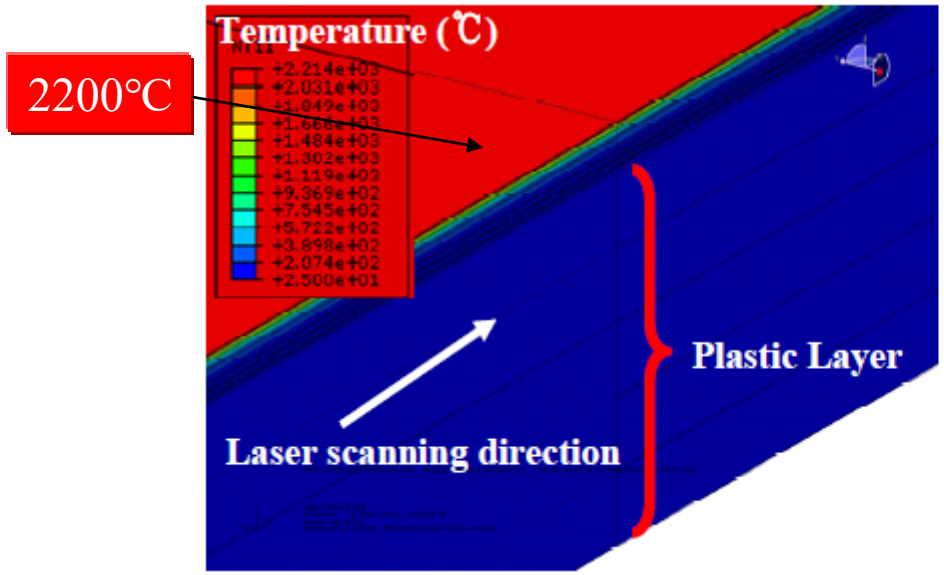
Substrate	V_{th}	Mobility (cm^2/V-s)	SS	I_{off_max} (pA/μm)
Glass	-0.28	110.0	0.36	0.25
Plastic	-2.03	124.1	0.30	0.20

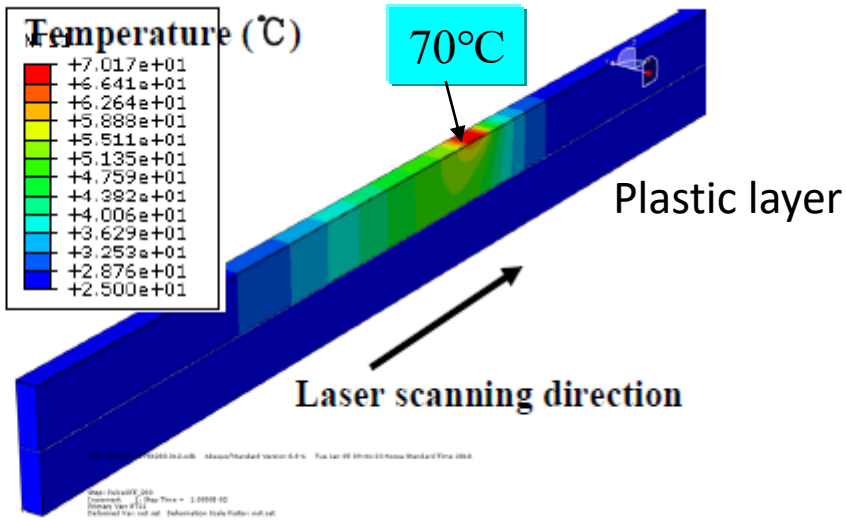
Oct.2009_Video

資料來源： http://www.oled-info.com/new-video-samsung-flexible-oled-prototype
SID 10 DIGEST 706~709

Plastic Substrate上可以做LTPS TFT製程

$$\int_V \rho \dot{U} \delta\theta \, dV + \int_V \frac{\partial \delta\theta}{\partial \mathbf{x}} \cdot \mathbf{k} \cdot \frac{\partial \theta}{\partial \mathbf{x}} dV = \int_V \delta\theta \, r \, dV + \int_{S_q} \delta\theta \, q \, dS$$



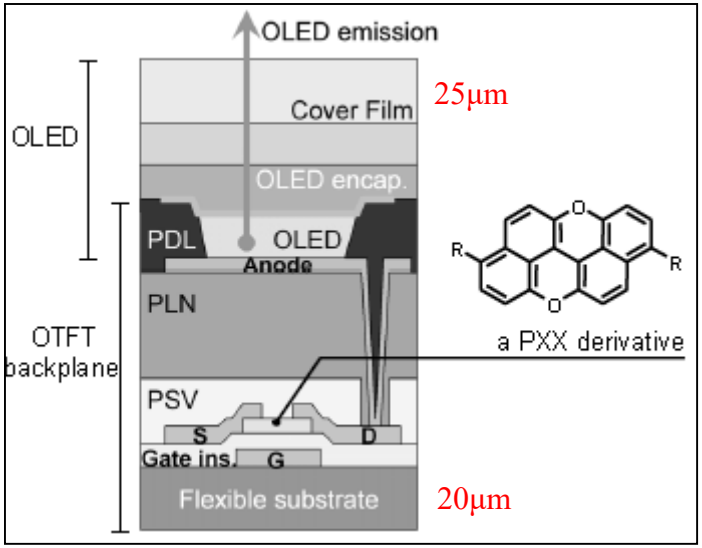


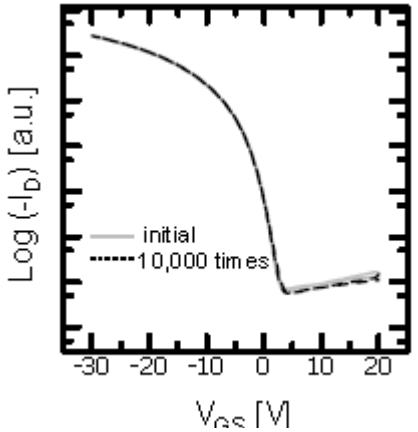
資料來源：SID 2011 Jin Jang

Flexible AMOLED技術開發 (2010)

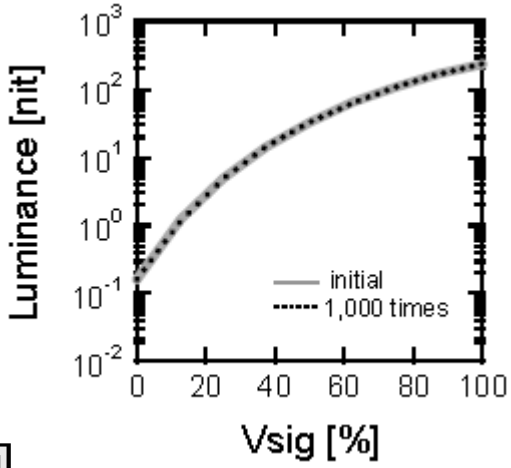
公司	NHK	ASU Arizona State University / Universal Display Corporation	SONY	SAMSUNG MOBILE DISPLAY	ITRI Industrial Technology Research Institute
面板雛型	•5" •320x240(QVGA) •Color	•3.8" •320x240 (QVGA) •Color	•4.1" •432 x 240 x RGB •Color	•4.5" •800X480 •Color	•6" •320X240 •Color
TFT	•OTFT	•a-Si TFT	•OTFT •載流子遷移率為0.4cm2/Vs	•LTPS	•a-Si TFT
基板	•PEN	•Duponts Teijin Teonex film	•20μm flexible substrate	•Polyimide	•Polyimide
OLED type	Bottom Emission	Top Emission	Top Emission	Top Emission	Bottom Emission
Demo.				 	
說明	•Curve fixed	•NA	•Rolling 4mm 10萬次[TFT特性及顯示性能（伽馬特性及亮度等）沒有變化]	•Radius=10mm (FPD-International) •Video on Web	•Radius=50mm 15,000次

SONY Roll able AMOLED (2010)

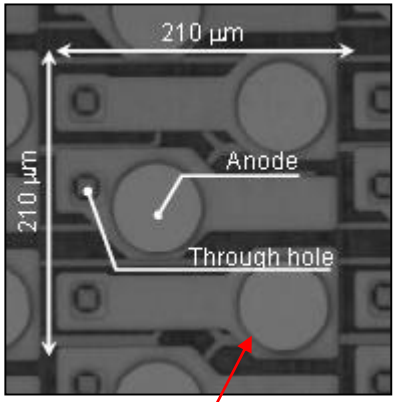




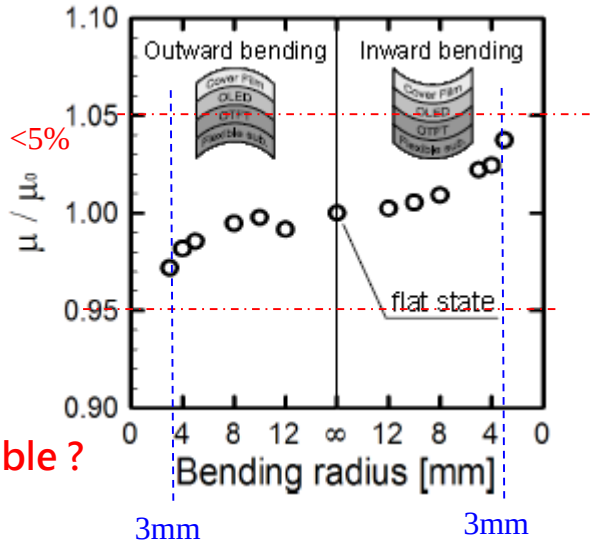
Active layer	μ_{FE} [cm²/Vs]	S.S. [V/dec.]
pentacene	~0.1	1.2
PXX derivative	~0.4	0.6



Display Size	4.1" Wide
Number of Pixels	432 × RGB × 240 (FWQVGA)
Pixel Size	210 μm × 210 μm
Resolution	121 ppi
Number of Colors	16,777,216
Peak Luminance	> 100 cd/m²
Contrast Ratio	> 1000:1
Operation Scheme	2T-1C Voltage Programming
Scan Voltage	20 V p-p
Signal Voltage	< 10 V p-p
Vcc - Vcath	20 V
Thickness	80 μm
Bending Radius	< 5 mm

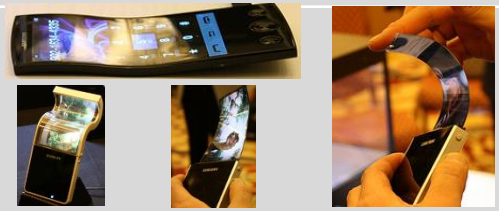


TFT special design for Roll able ?



資料來源：SID 10 DIGEST 710~713

Flexible AMOLED技術開發 (2011)

公司	SAMSUNG MOBILE DISPLAY	AUO	TOSHIBA	ITRI Industrial Technology Research Institute
面板雛型	•4.5 ″ •WVGA 800X480 •Color	•4″ •320 x 240 •Color	•3″ •160XRGBX120 •Color	•6″ •320x240 •Color
TFT	•LTPS	•IGZO-TFT	•IGZO-TFT	•a-Si-TFT
基板	•Polyimide	•Polyimide	•Polyimide	•Polyimide
OLED type	Top Emission	Bottom Emission	Top Emission	Bottom Emission
Demo.				
說明	•CES2011 Demo	•R=10mm	•NA	•整合觸控功能 •Demo in Water

SMD準備量產Flexible AMOLED

Nov.2010_FPD日本

4.5吋Flexible AMOLED

Nov.2010_Video

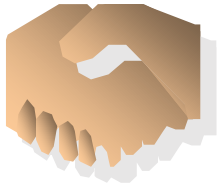
4.5吋Flexible AMOLED
解析度：WVGA 800x480

Jan.2011_CES

4.5吋Flexible AMOLED
解析度：WVGA 800x480
亮度: 300cd/m^2
厚度：0.27mm
Bending Radius <10mm

SAMSUNG SAMSUNG MOBILE DISPLAY

Joint Venture (50:50)



UBE 宇部興産株式会社

2011.May

Mass Production Flexible AMOLED

Flexible AMOLED封装阻隔水、氧要求

Devices Lifetime~10years

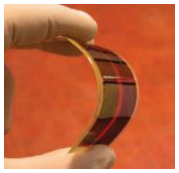
WVTR (g/m^2.day)

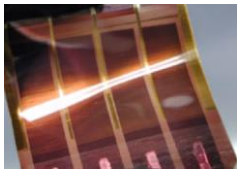
OTR (cm^3/m^2.day.bar)

WVTR	OTR
10^{-8}	10^{-8}
10^{-6}	10^{-6}
10^{-5}	10^{-5}
10^{-4}	10^{-4}
10^{-3}	10^{-3}
10^{-2}	10^{-2}
10^{-1}	10^{-1}
10^{0}	10^{0}

Flexible OLEDs

Thin film solar cells



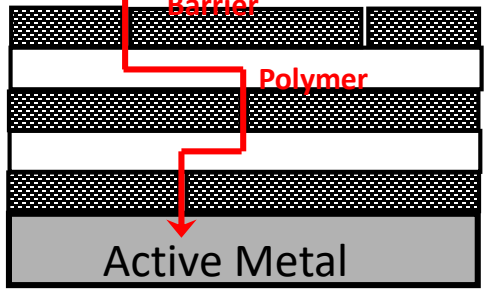


E-Paper

Flexible LCDs

RFID Tags

Food Package

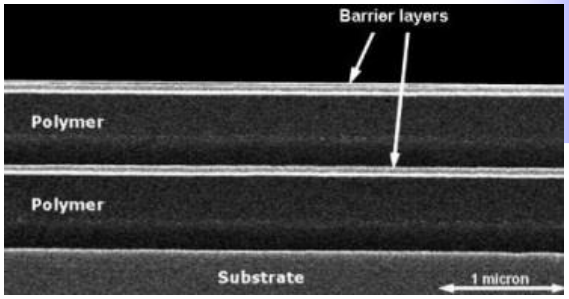


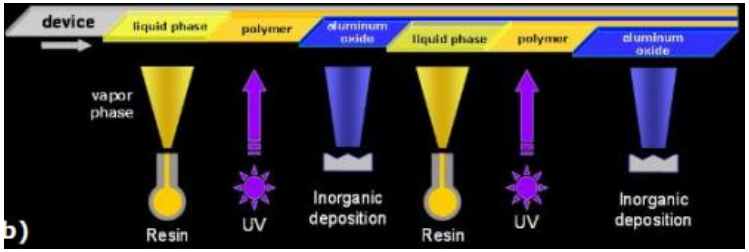
Time of H_2O and O_2 penetration
"Must "> Lifetime

Flexible Devices
Lifetime is Very Important !

Flexible AMOLED量產問題浮現

✓2010買下Vitex專利與技術





Source: Vitex

三星OLED柔性顯示屏設備因質量問題延期

2013-04-18 10:35 [編輯：jasminezhuang]
因顯示屏質量出現問題，三星的首款柔性顯示屏設備已經被延期。

南韓報紙ETnews日前報道稱，三星預計會在今年年末推出首款配備柔性顯示屏的設備。由於OLED面板不耐氧氣和濕氣，所以封裝步驟對於柔性顯示屏的商業化生產就顯得至關重要。據稱，三星顯示器公司（Samsung Display）正在評估多種封裝技術，以取代由Vitex System所開發的封裝技術。這對於三星來說無疑是個壞消息。

Consideration of OLED TFE Manufacturing

Inorganic Process

-Sputter Al_2O_3

-PECVD SiNx

APPLIED MATERIALS

ULVAC SOLUTIONS
Vacuum Technology and Innovative Ideas

Organic Process

-Polymer by Ink jet printing

-Polymer by screen printing

-Polymer by CVD shower

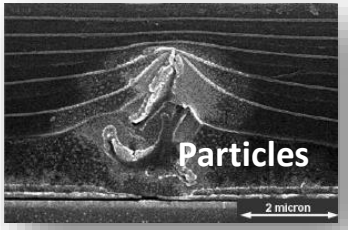
kateeva®

ULVAC SOLUTIONS
Vacuum Technology and Innovative Ideas

Particles Control

-PECVD self clean

-Maintenance

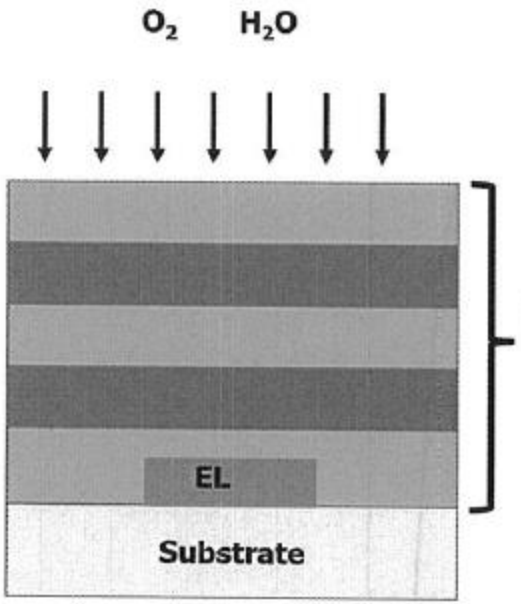


Source: Vitex

SMD在OLED TFE上要求

Flexible AMOLED

TFE(Thin Film Encapsulation) OLED薄膜封裝TFE

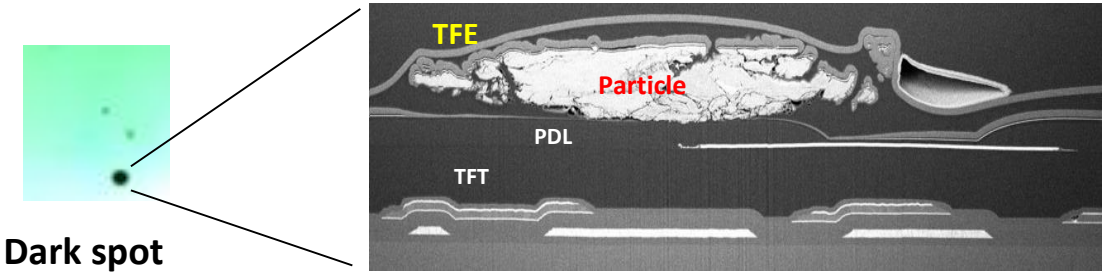


- **Requirement**
  - Low Temp. Deposition (due to deposition on EL)
  - $<10^{-6}$ g/m²/day @ 25℃, 40%RH WVTR
- **Issues**
  - Edge Seal
    : Protection from edge permeation
    ← Optimization of layer stack at edge
  - Particle
    : Reduction of particles & Increase of coverage of particle
- **Storage Lifetime**
  : > 700hr
  @High Temp. High Humidity RH

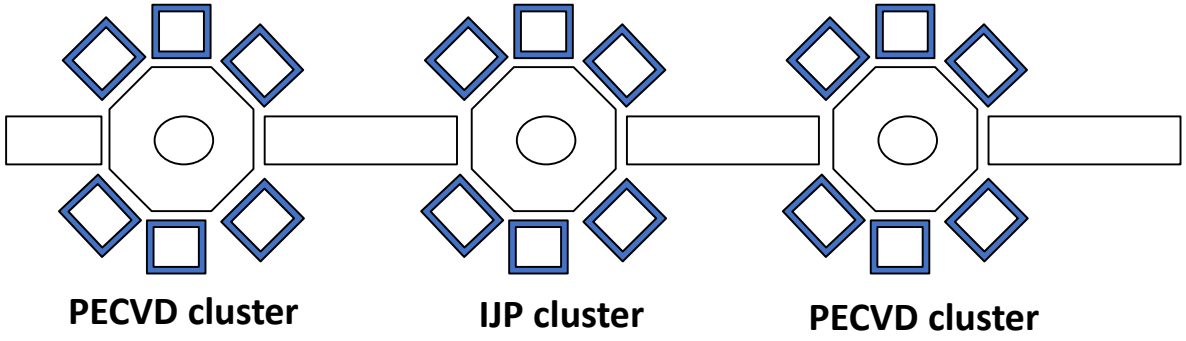
Source: SAMSUNG 2012 FINETECH JAPAN

Challenge of OLED TFE

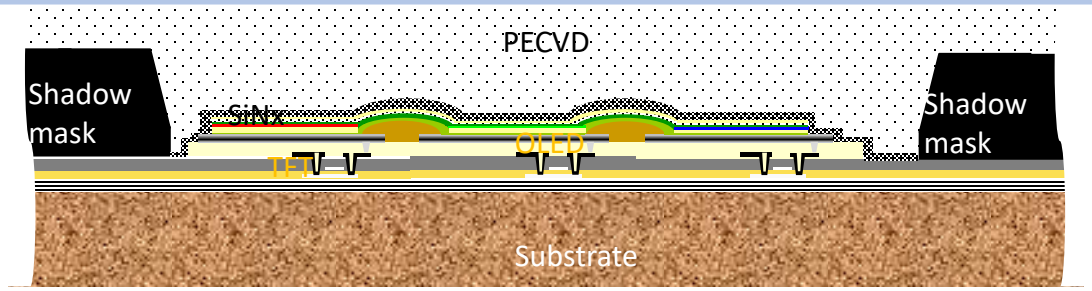
- ✓ *High equipment investment for OLED TFE facility.*
- ✓ *Long learning curve for OLED TFE manufacturing.*

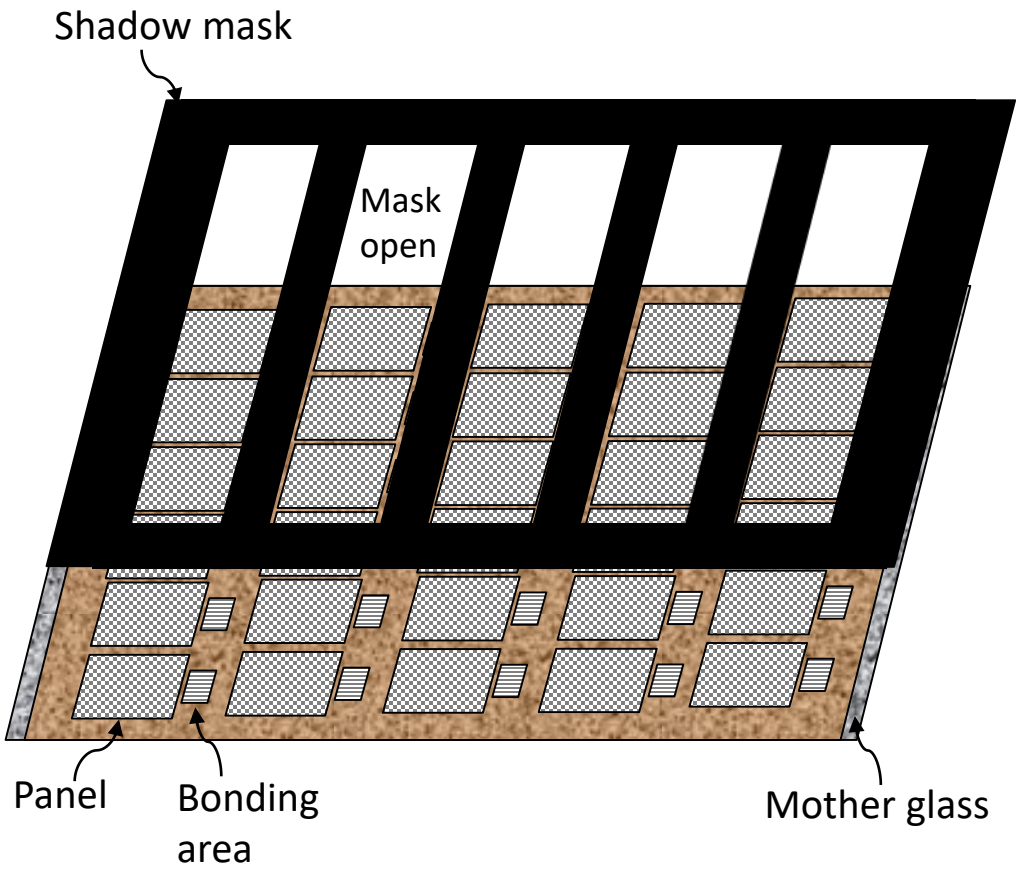


Source: ITRI



Patterned Inorganic on OLED

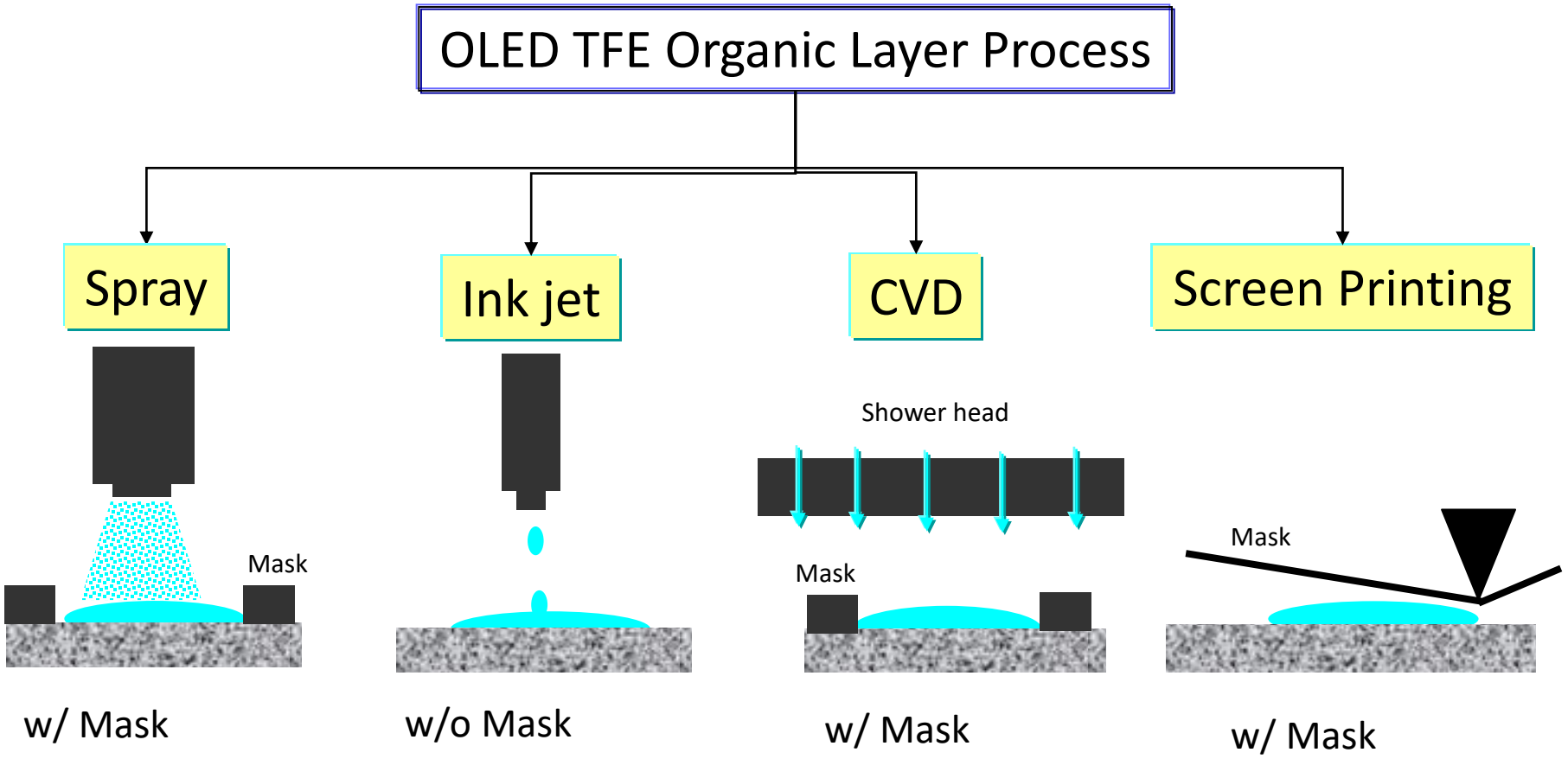




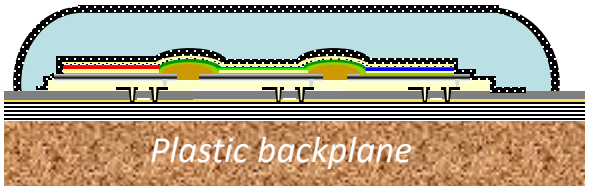
- SiNx for gas barrier
- Slot type open mask
- Material selection of shadow mask

Organic Buffer Layer Process of OLED TFE

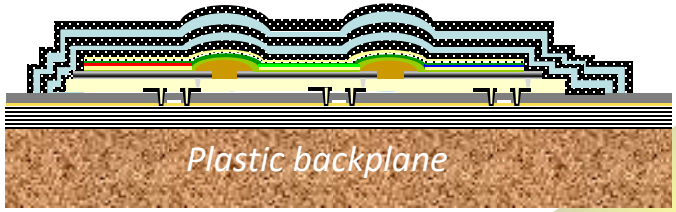
✓ ***Particles concern by using mask patterned process***



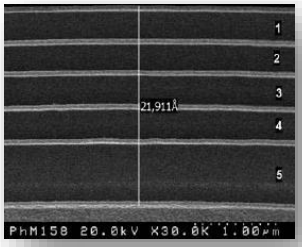
TFE Development for Plastic AMOLED



3 layers inorganic/organic stack



5 layers inorganic/organic stack



Source: Vitex

Multi-layer stack

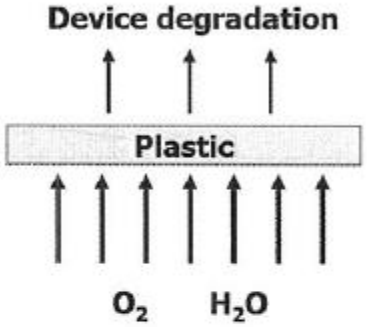
R&D

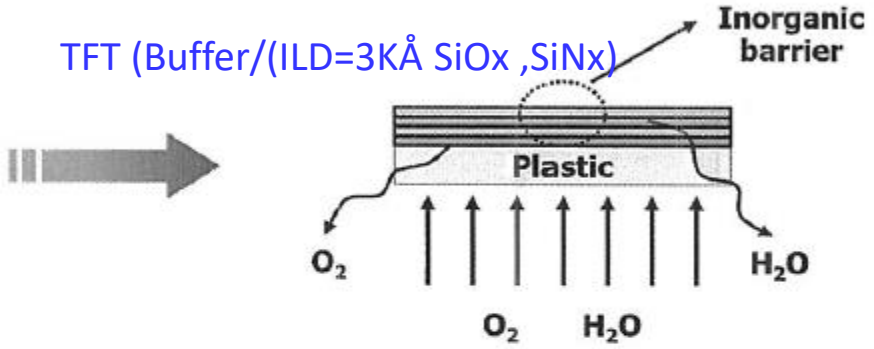
Product

SMD在PI上TFE上要求

- **Barrier on plastic**

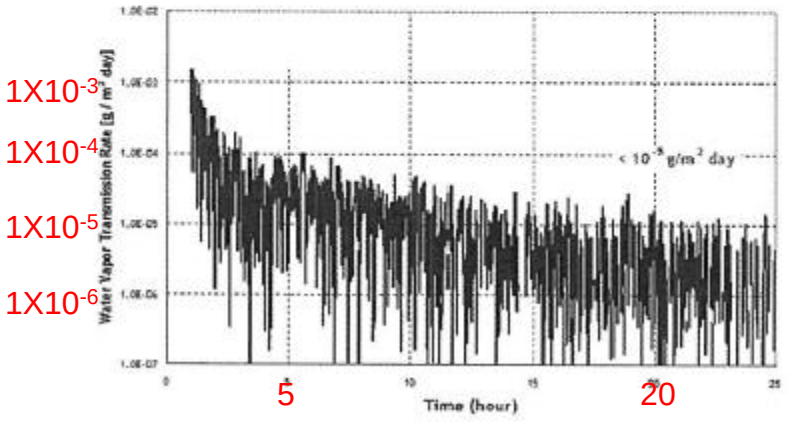
軟性基板(PI)封裝





- **Inorganic barrier**
  - . Stress < 120 Mpa
  - . WVTR < 10^{-5}g/m²/day @ 25℃, 40%RH

* WVTR : water vapor transmission rate



Source: SAMSUNG 2012 FINETECH JAPAN

Flexible Substrate 在 AMOLED上開發

2008 | 2009 | 2010 | 2011 | 2012

SAMSUNG

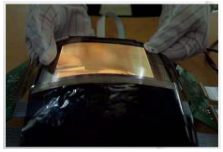

Polyimide

Polyimide

Polyimide

Mass production confirm → Polyimide

LG



Stainless steel

Stainless steel

Mass production confirm → Polyimide

SONY

PES

Polyimide

AUO

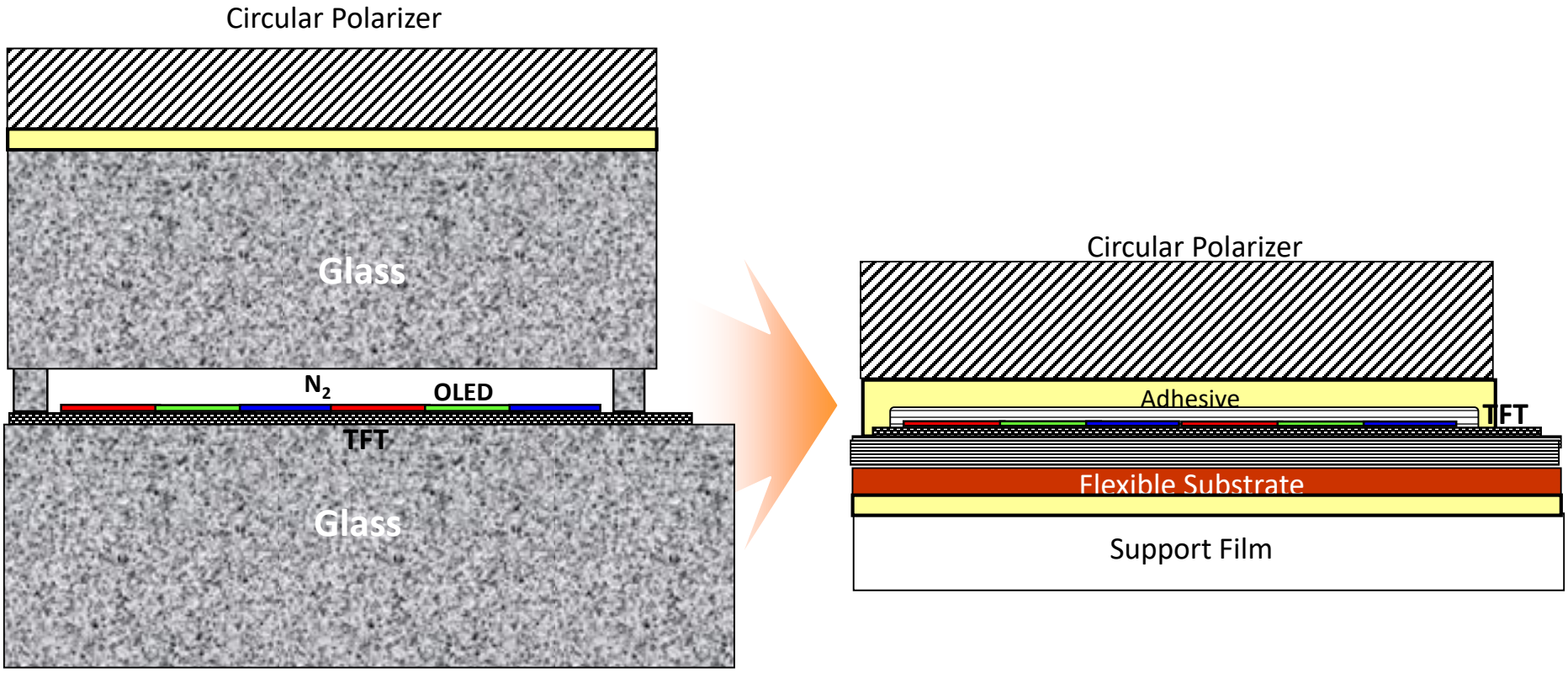
Polyimide

Mass production confirm → Polyimide

Glass to Flexible AMOLED

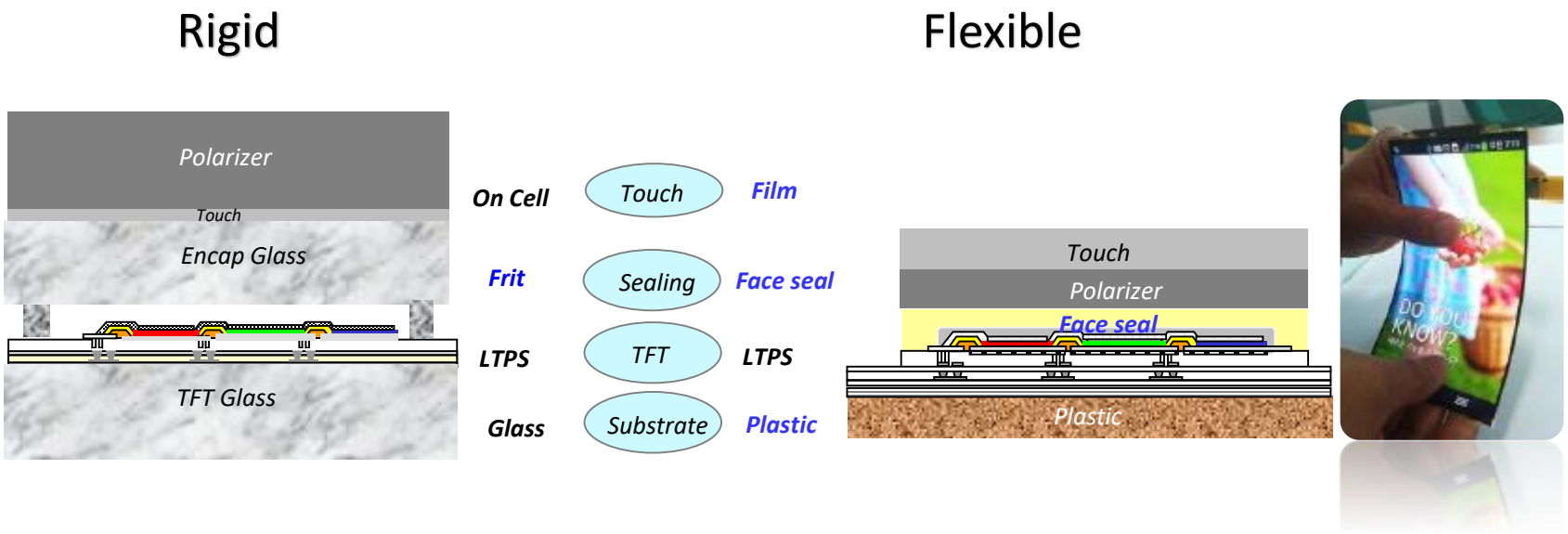
Glass AMOLED

Flexible AMOLED



LGD Face Sealing Technology

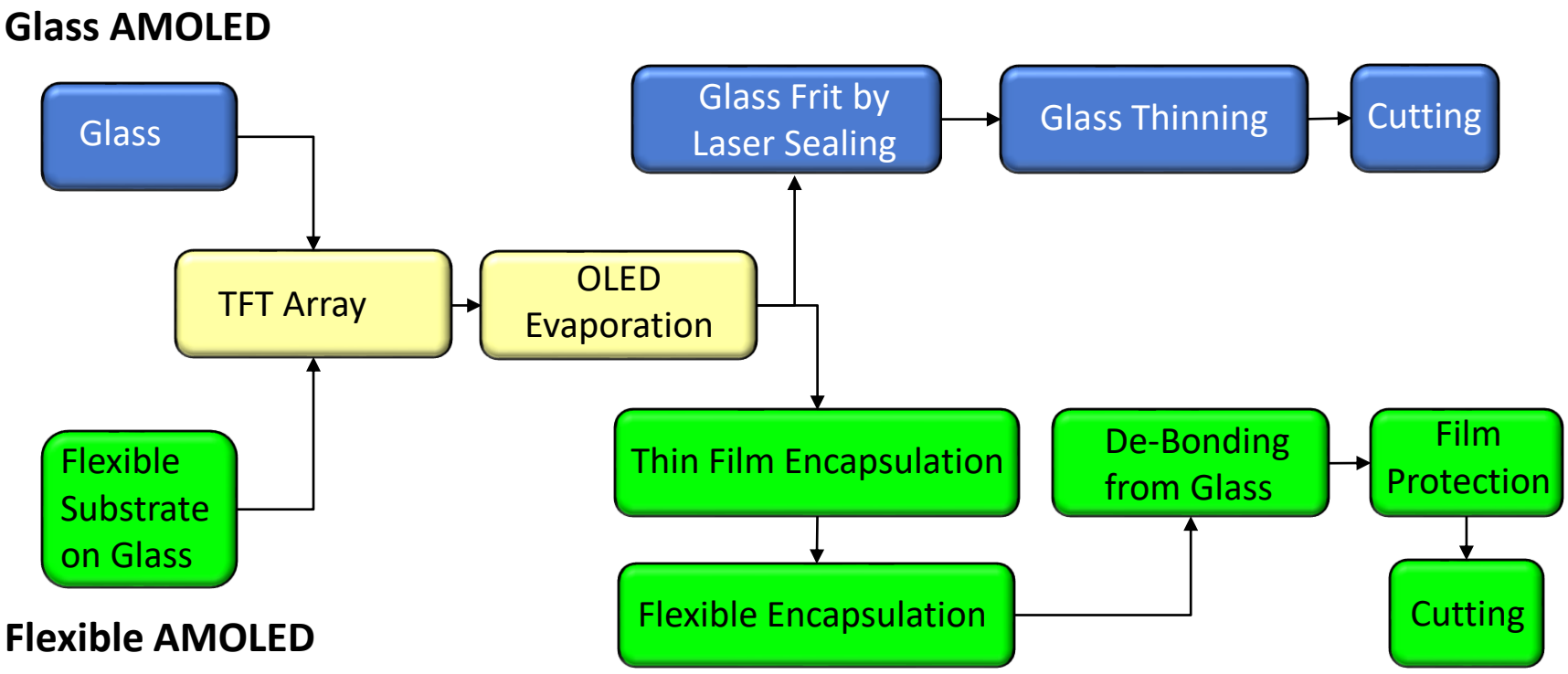
✓ **Face sealing technology was proposed by LGD for flexible AMOLED encapsulation**



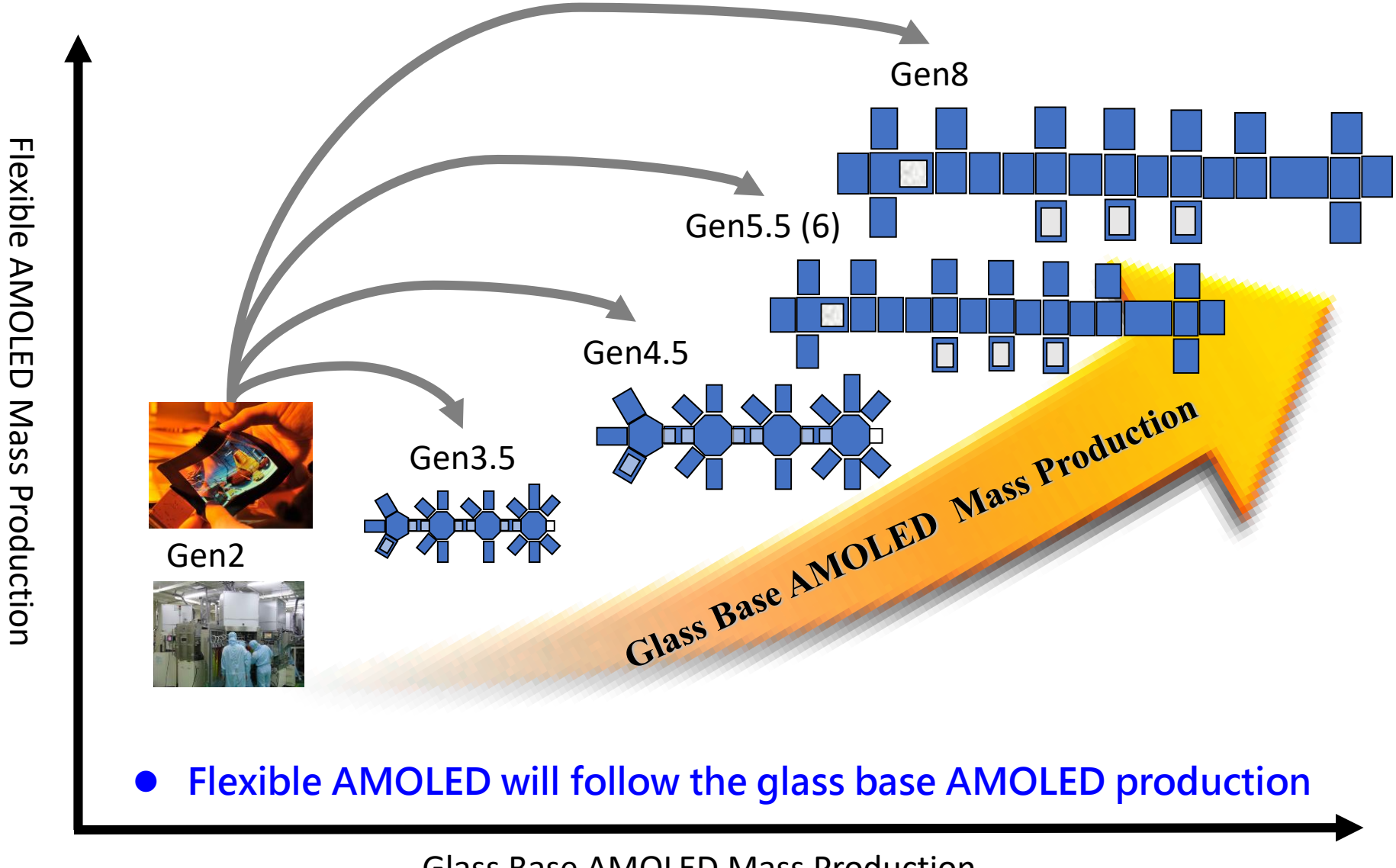
Source: SID'14 LGD Invited paper 25.4 Development of Commercial Flexible AMOLEDs

Glass vs. Flexible AMOLED Process Flow

✓ **Core technologies : TFT, OLED are the same process**



Glass 轉換 Flexible AMOLED 量產



- Flexible AMOLED will follow the glass base AMOLED production

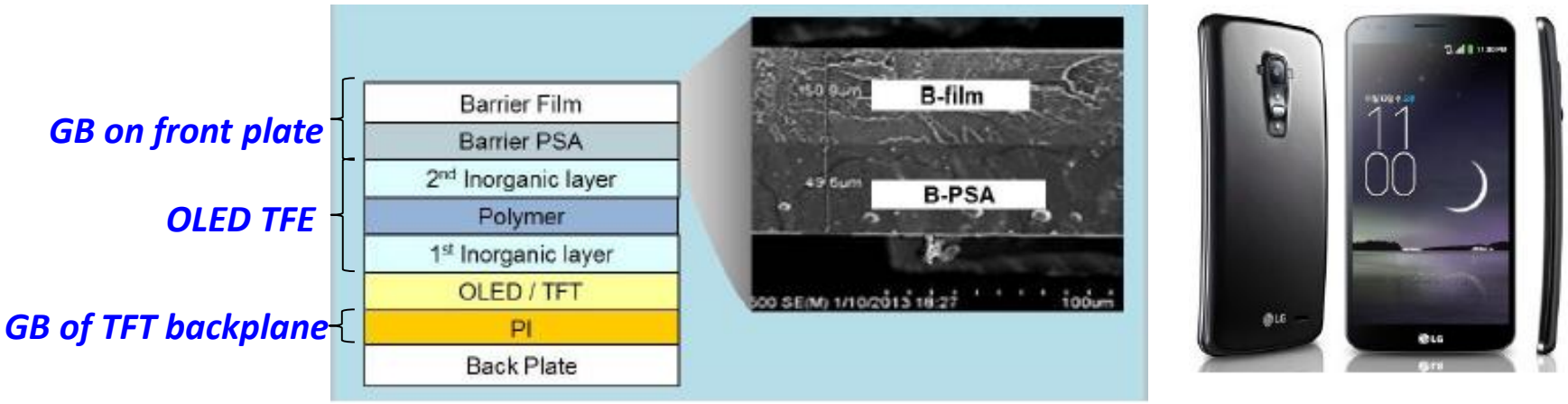
Flexible AMOLED 商品化元年2013

Samsung Galaxy Round

LG G Flex

Flexible Encapsulation Structure

✓ *The flexible encapsulation includes OLED TFE, GB of TFT backplane, and on the front plate.*



Source: SID'14 LGD Invited paper 25.4 Development of Commercial Flexible AMOLEDs

Note: GB (Gas Barrier) ; TFE (Thin Film Encapsulation)

Flexible AMOLED Substrate Development

	2008	2009	2010	2011	2012	2013	2014
SAMSUNG	Flexible substrate	 Polyimide	 Polyimide	 Polyimide	*Mass production with PI*	 Polyimide	 Polyimide
LG	Flexible substrate	 Stainless steel			*Mass production with PI*	 Polyimide	
AUO	Flexible substrate	Technology transfer to AUO		 Polyimide		 Polyimide	 Polyimide
ITRI		 Polyimide	 Polyimide	 Polyimide			

Plastic AMOLED Development in SAMSUNG

Prototype

Product

SDC becomes Apple iPhone FIRST supplier

6”

6.5”

4.5”

4.5”

4.5”

2.8”

5.7”
Galaxy Round

5.6”
Galaxy Note4 Edge

5.1”
Galaxy S6 Edge

5.5”
Galaxy S7 Edge

5.7”
Galaxy Note7

5.8” I 6.2”
Galaxy S8 I S8+

5.8” I 6.2”
Galaxy S9

6.3”
Galaxy Note 9

Samsung Gear Fit

Samsung Gear S

Gear S2

Gear S3

Galaxy Watch

2009 2010 2011 2012 2013 2014 2015 2016 2017 2018

Marketing Define the Technology

- Feature of Flexible AMOLED ?

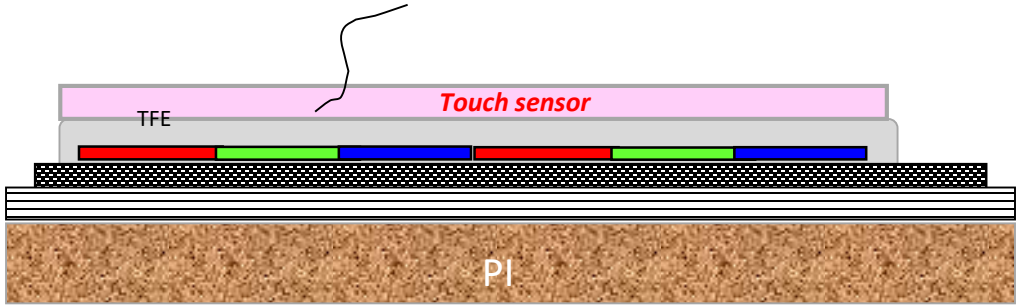
Curve design → **Edge design** → **Full Screen design**

2014 **2017**

SAMSUNG In-cell Touch AMOLED (Y-OCTA)

SAMSUNG NOTE 7

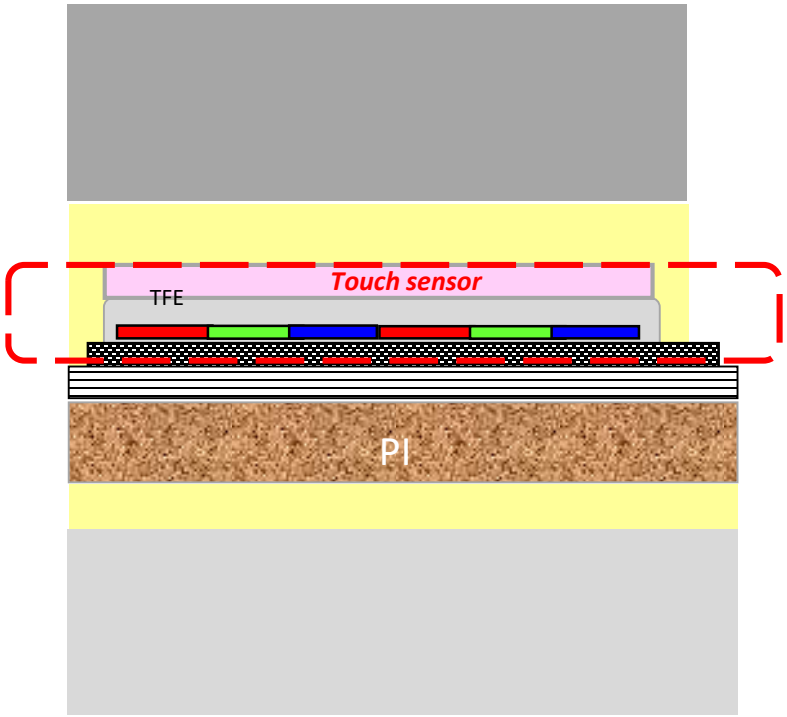
- Flat TFE surface for touch process
- Tx, Rx with metal mesh structure
- Metal mesh using TFT line facility



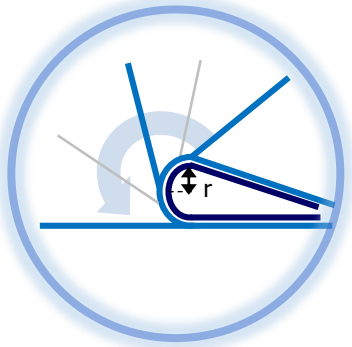
三星顯示器湯井A3廠8條產線中，採用Y-OCTA製程的OLED生產成本可望較傳統方式節約約30%。

資料來源: DIGITIMES, 2017.08.01

Y-OCTA for Foldable Touch AMOLED

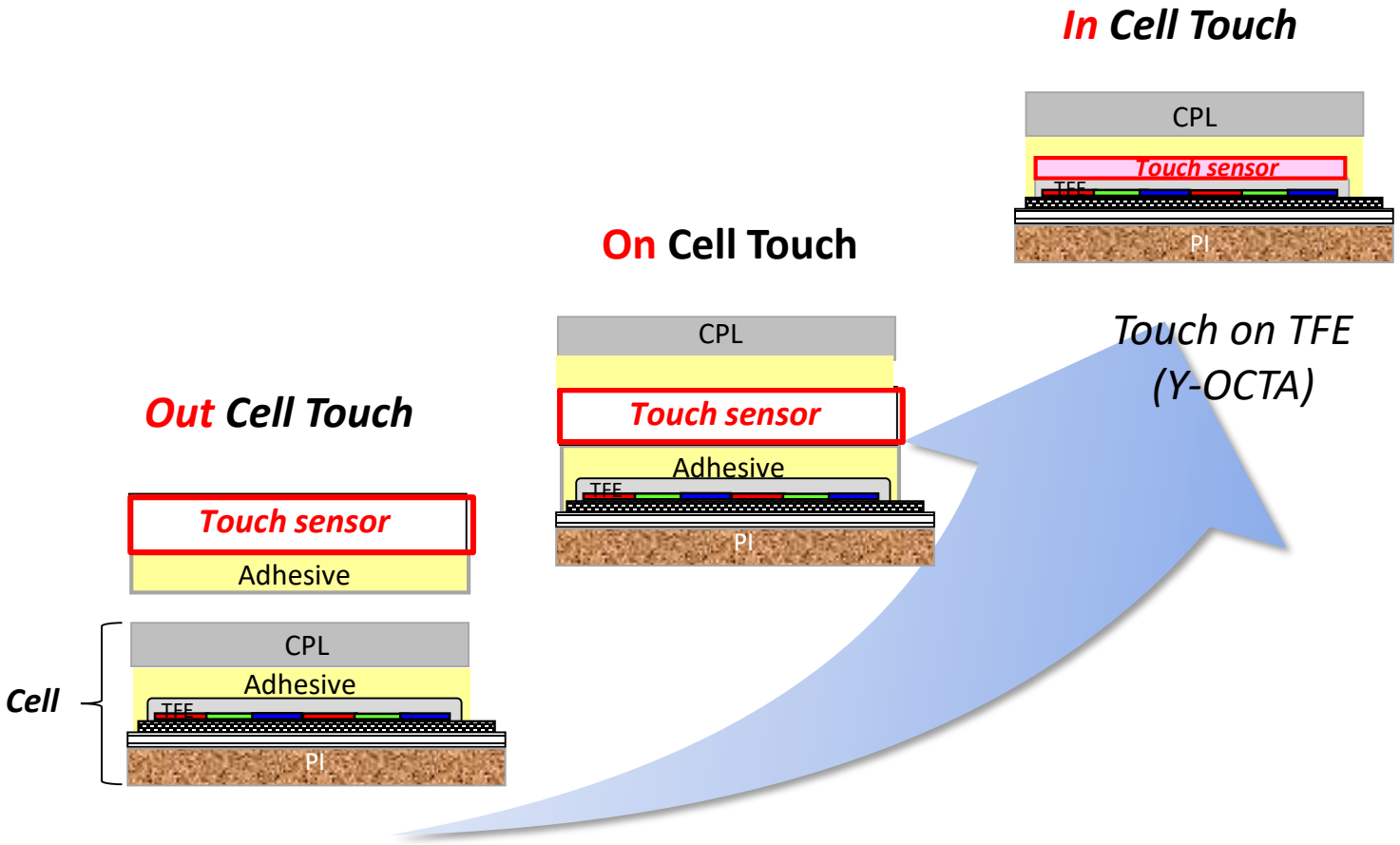


Neutral Plane



YOUM Foldable

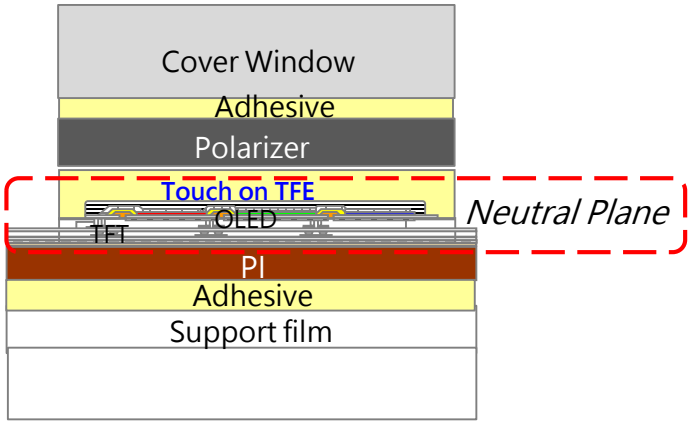
Flexible Touch AMOLED Structure



Note: OCTA (On-Cell TSP AMOLED)

採用Touch On TFE觸控技術優點

✓ Touch On TFE, TOT

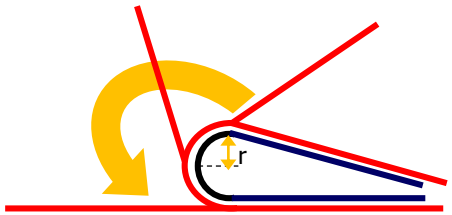


- ✓ 面板廠In house TOT生產的OLED成本，較外購TSP方式節省25~30% (參考s公司資料)
- ✓ 最接近Neutral plane觸控結構，為Foldable Touch AMOLED最佳解法
- ✓ 預期未來發展Slidable, Rollable, Stretchable AMOLED將採此觸控解決方案

2018 SAMSUNG Galaxy Fold發表

厚度6.9公釐

7.3 inch



厚度17公釐

4.6 inch

Source: 2018.11.08 SAMSUNG

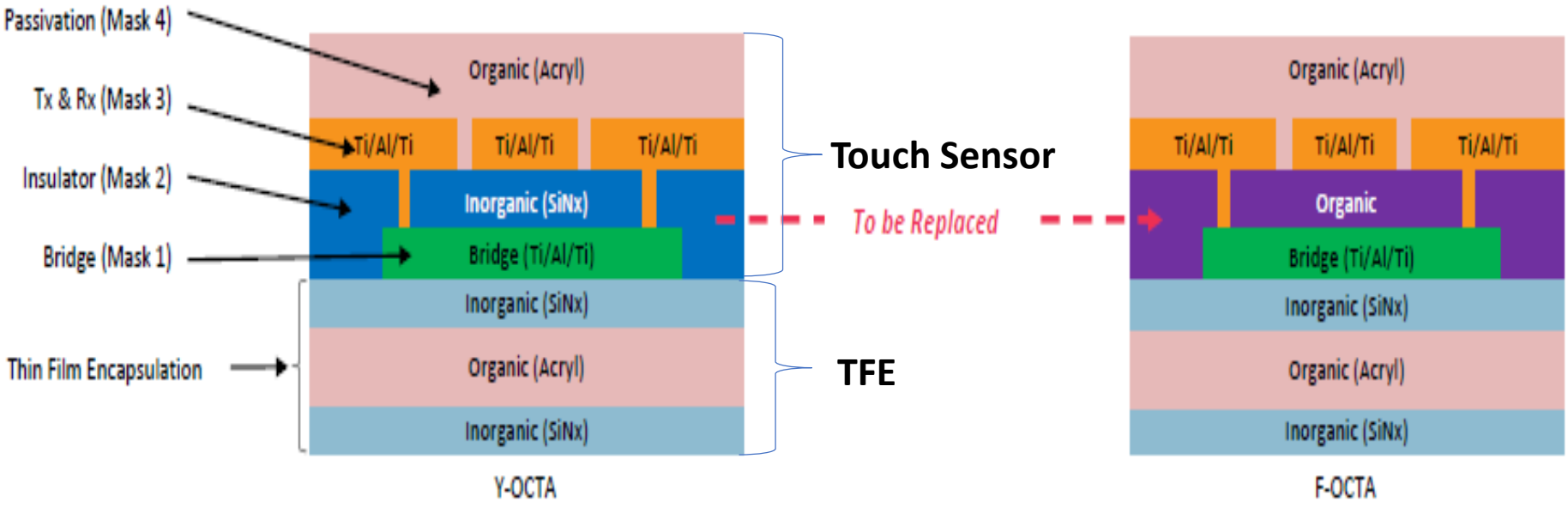
折疊手機元年2019

- ✓ 手機開闔次數可達近20萬次的使用性，以單日開闔100次計算，將可使用近5年時間。
- ✓ Galaxy Fold將推出分別支援4GLTE與5G版本，最低售價由1980美元起跳，預計 4月26日起啟動相關銷售活動。

資料來源: DIGITIMES 2019-02-21

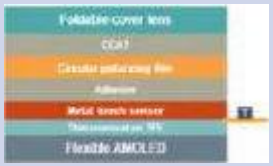
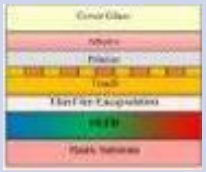
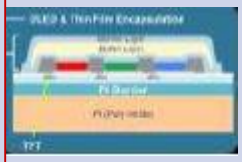
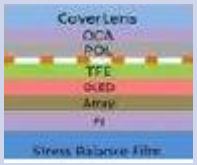
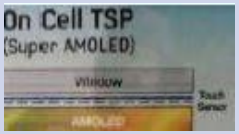
折疊觸控技術再進化

✓ Y-OCTA結構更柔軟



Source: OMIDA 2020.6

2020年AMOLED面板廠採用TOT量產概況

Company	SAMSUNG Display	LG Display	BOE	Tianma	Visionox	China Star
Structure						
OLED Touch Technology	**Y-OCTA** (YOUM On Cell Touch AMOLED)	**TOE** (Touch On Encapsulation)	**FMLOC** (Flexible Multiple Layer On-Cell)	**TPOT** (Touch Panel On TFE)	**TOT** (Touch On TFE)	**DOT** (Direct On-Cell Touch)
Status	MP	MP	MP	Small MP	Small MP	Small MP
Customer	SAMSUNG, Apple…	Apple…	Apple, Huawei…	Xiaomi,…	Huawei, Xiaomi…	Xiaomi,…
Products	Galaxy serious, iPhone 12~	iPhone 12~	Mate X…	NA	NA	Xiaomi 10/10+…

Source: OMIDA 2020.6.29, G Summarized

SAMSUNG DISPLAY擴大Y-OCTA量產

Technology	Allocation	2019	2020	2021	2022
LTPS	SEC	30k	15K	-	-
	Apple	105k	105K	45K	-
	Others	30k	30K	30K	30K
Total		165K	150K	75K	30K
LTPO (HOP)	SEC	-	13.5K	27K	27K
	Apple	-	-	54K	90K
	Others	-	-	-	-
Total		-	13.5K	81K	117K
Y-OCTA	SEC	30K	27K	27K	27K
	Apple	-	60K	90K	90K
	Others	15K	18K	18K	18K
Total		45K	105K	135K	135K

Source: OMIDA 2020.6

Flexible AMOLED Development in LGD

Prototype

65" Rollable OLED TV

77" Transparent flexible OLED

18" Flexible AMOLED

12.3"Automotive Display

Product

6”

Flexible Substrate: PI

6” LG G Flex

5.5” LG G Flex2

LG V30

Full Screen Design

LG V40 6.4"
(537 PPI) notch-type P-OLED

LGD becomes Apple iPhone 2nd supplier

4” 4” 4”

Flexible Substrate: Stainless steel

LG G WatchR

LG Watch Urbane

LG Watch Sport

6”

2007 2008 2009 2013 2014 2015 2016 2017 2018

Full Screen Design by Marketing Request

Full Screen Design

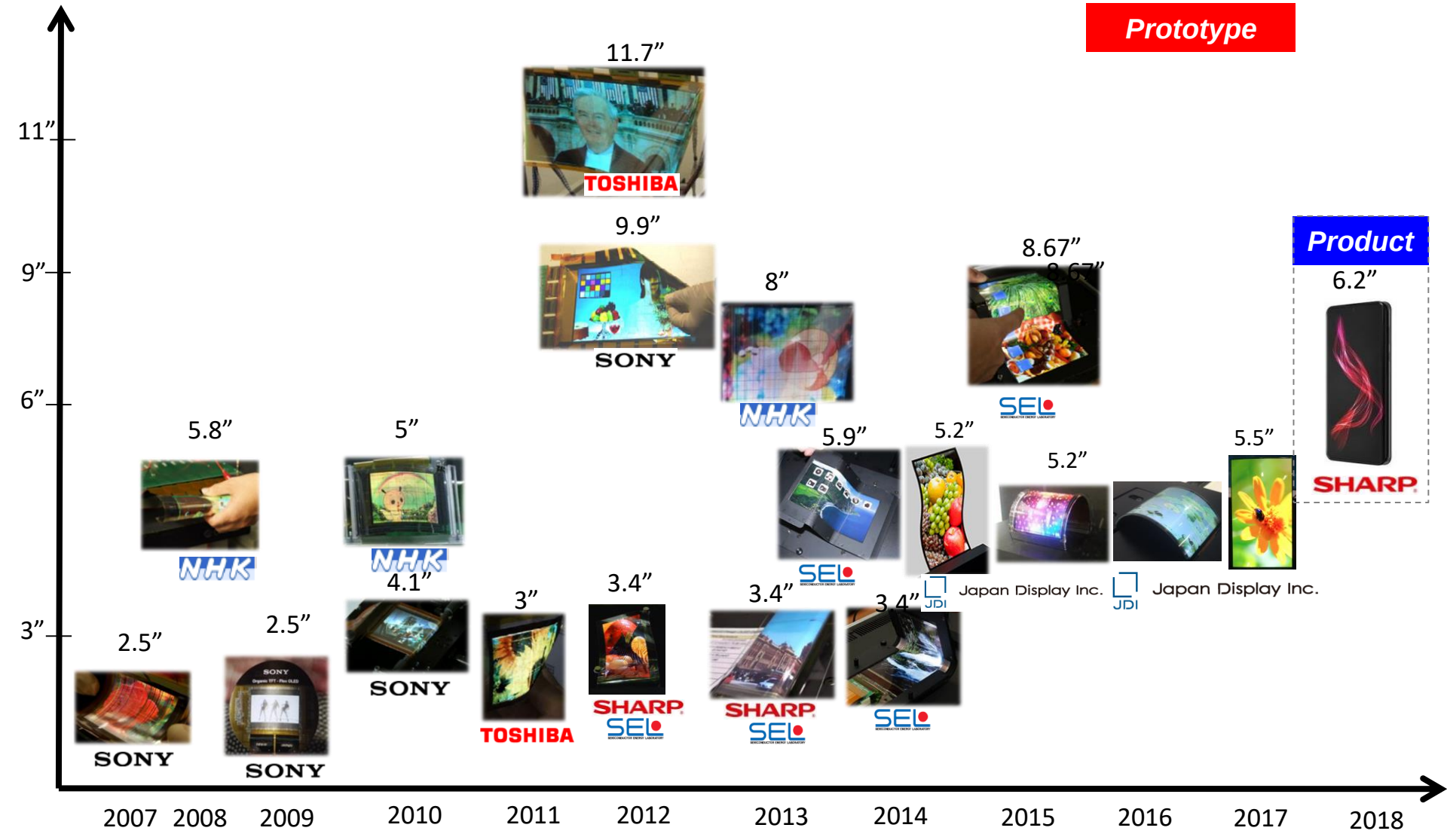
LG V30 (2017)

LG V40 (2018)

Curve Design

LG G Flex2 (2015)

Flexible AMOLED Development in Japan



SHARP's Flexible AMOLED Development

SHARP FOXCONN 鴻海科技集團

2018/8 集合各部門
共400名人員　成立
OLED面板部門

G4.5 Flexible AMOLED production line
(15k/M)

Product

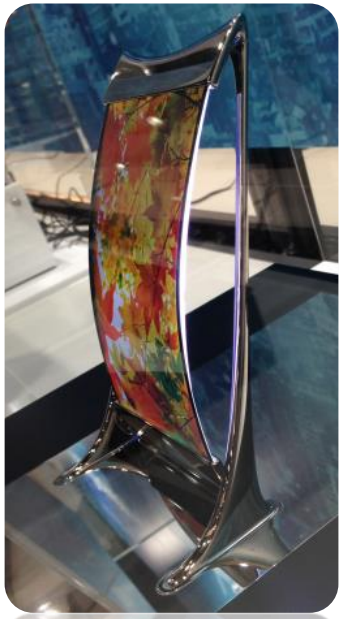
Specification	6.2”
Resolution	WQHD
Backplane	LTPS
Contrast ratio	1,000,000 : 1
Weight	146 g

JDI Flexible AMOLED or LCD?

5.5” Flexible OLED Display

Source: SID’17 JDI

5.5” Curved LCD Display



Source: SID’17 JDI

JDI 沒有OLED手機事業就沒未來 合資對象來者不拒

日本顯示器(JDI)因經營始終未有起色，決定組織改造。會長兼CEO東入來信博甚至表示，這是最後的機會，沒有OLED則手機事業就沒有未來，將轉向此方向發展，並於2019年量產.....

資料來源: DIGITIMES 2017/08/10

(Apple)的iPhone XR減產，連帶讓日本中小型面板大廠日本顯示器(JDI)減產，從12月開始，日本顯示器的產能利用率將降低，庫存則將增加，對該公司的業績帶來負面影響，也讓該公司2018會計年度(2018/4~2019/3)轉虧為盈目標出現新變數。

資料來源: DIGITIMES 2019/01/09

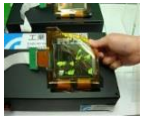
Flexible AMOLED Development in Taiwan

Prototype

Product

2008

4.1”



ITRI

2009

4.1”

ITRI

2010

6” Bendable AMOLED

ITRI

2011

6” Flexible AMOLED Demo in an Aquarium

ITRI

2012

4.1” Bendable AMOLED

AUO

6” Curved Touch AMOLED

ITRI

2013

4.3” Curved AMOLED

AUO

6” In-fold Touch AMOLED

ITRI

2014

5” Wearable AMOLED

AUO

7” In-fold Touch AMOLED

7” Z-fold Touch AMOLED

ITRI

2015

5” Bendable AMOLED

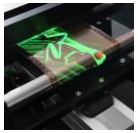
AUO

2016

5” In-fold Touch AMOLED

AUO

7” Rollable Touch AMOLED



7” In-fold Touch AMOLED

ITRI

2017

7” Foldable Phone

Ball drop In-fold

ITRI

Out-fold AMOLED

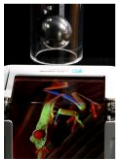
Rollable AMOLED

AUO

2018

7” Out-fold (r=3mm) Hardness: 7H

Ball drop Out-fold



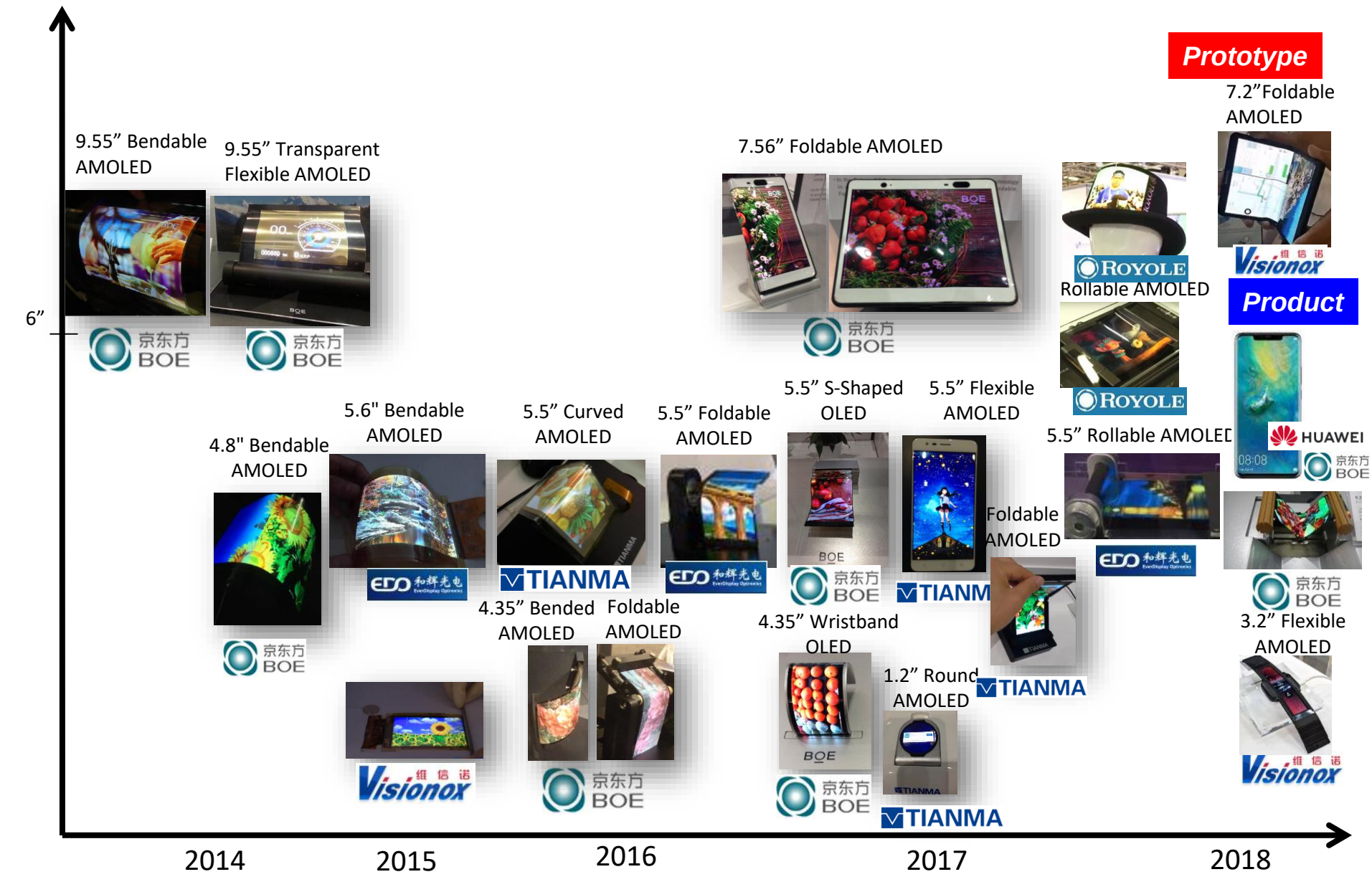
ITRI

AUO

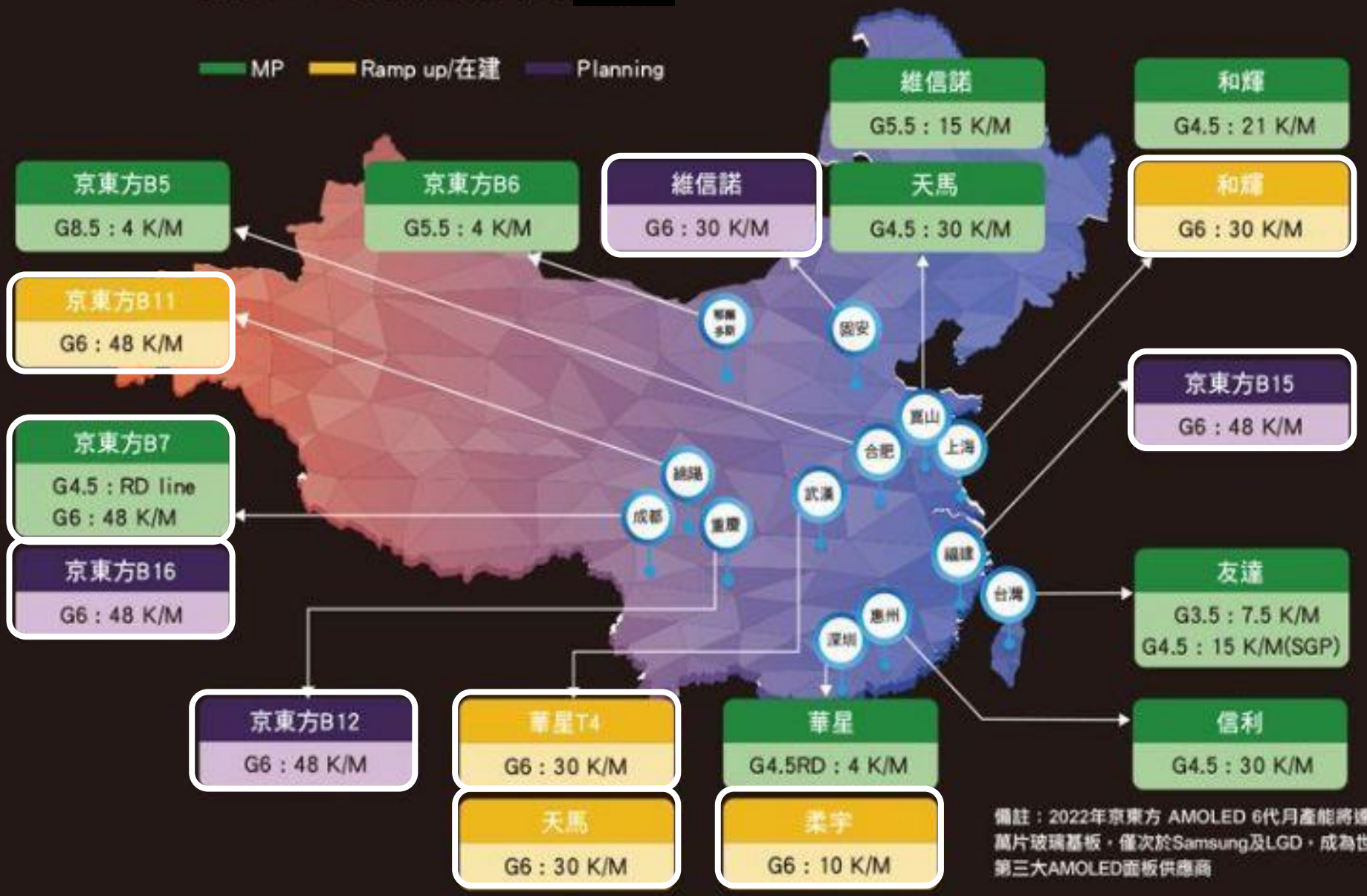
INNOLUX

Discovery 台灣建國百年 創新(Flexible AMOLED)

Flexible AMOLED Development in China



兩岸OLED面板產能布局 2018



大綱

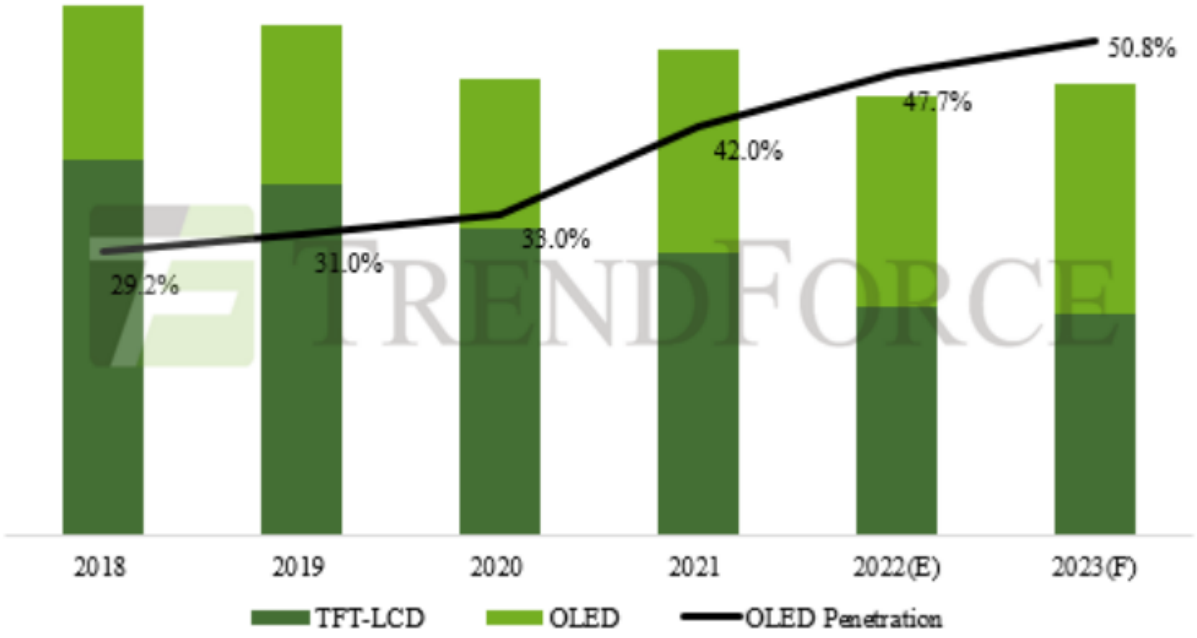
- 過去 : OLED研發到量產
- 過去 : Flexible AMOLED研發到量產
- **AMOLED現在**

手機、平板、NB、Monitor、電視、AR/VR/MR、Automotive、Transparent

- AMOLED未來

OLED 面板手機滲透率

- 2020年蘋果(Apple)推出iPhone 12全系列新機開始採用OLED面板的帶動下，其他手機品牌紛紛開始擴大在高階的機種導入OLED面板

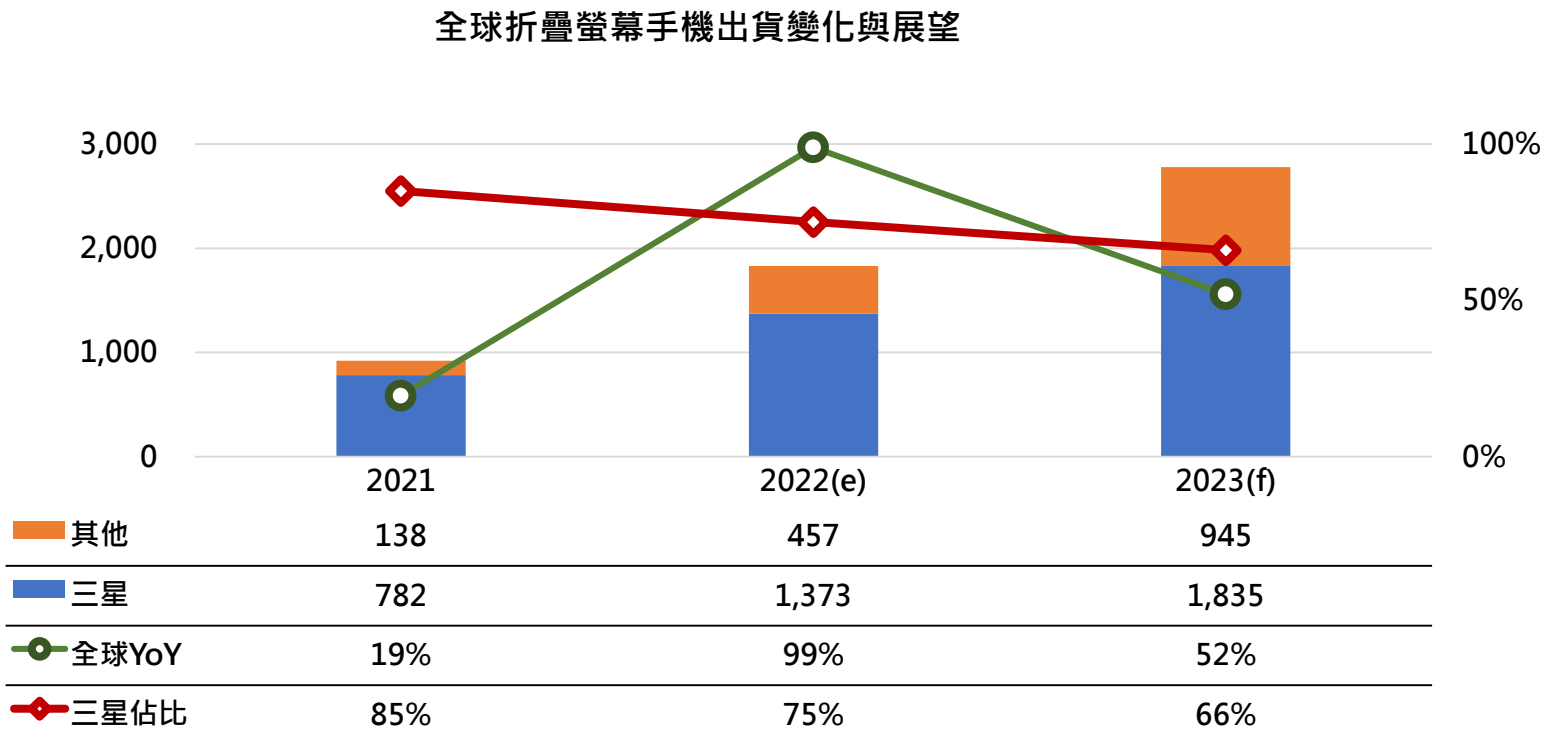


2018~2023年TFT-LCD、OLED面板智慧型手機市場規模及滲透率。

(來源：TrendForce)

2023年折疊螢幕手機出貨有望近3,000萬支

- 三星比重仍達6成以上

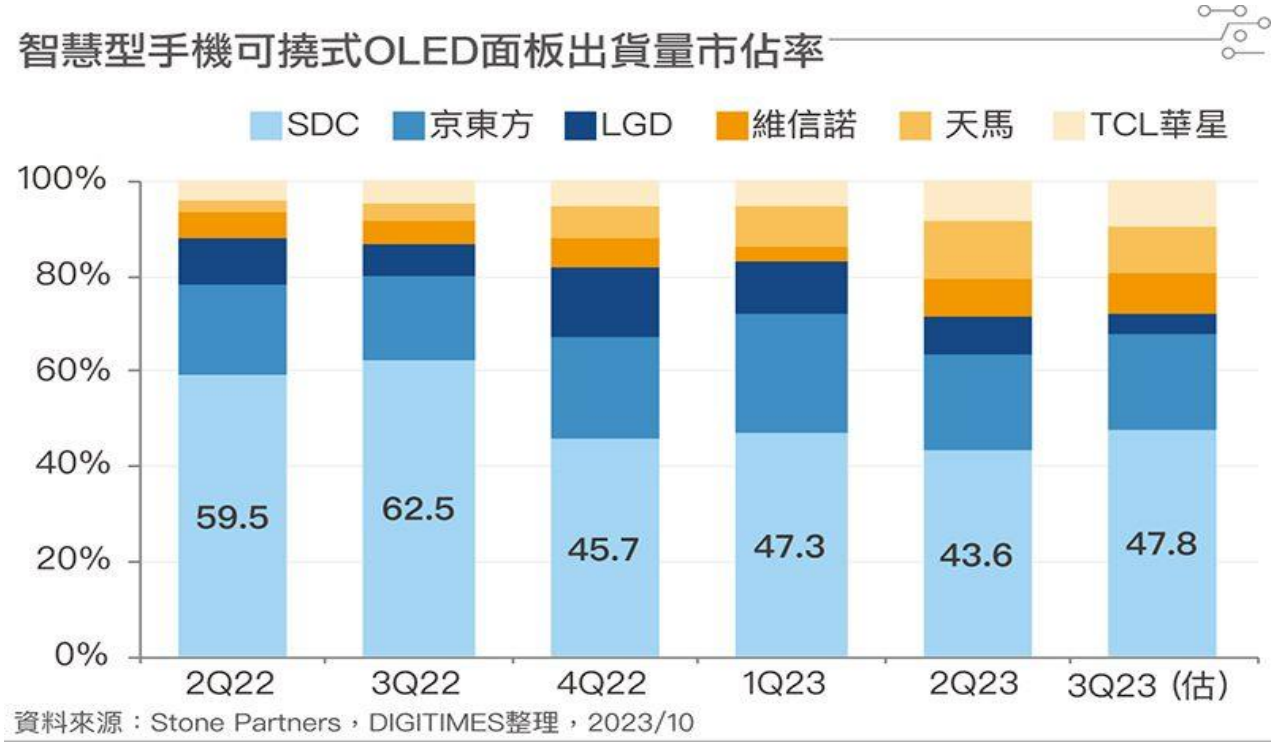


	2021	2022(e)	2023(f)
其他	138	457	945
三星	782	1,373	1,835
全球YoY	19%	99%	52%
三星佔比	85%	75%	66%

資料來源：DIGITIMES Research，2022/12

手機可撓式OLED出貨　SDC連4季不過半

- Stone Partners表示，三星顯示器雖然維持市佔率第一，卻已連續4個季度市佔率不到50%，主因是蘋果持續追加採購樂金顯示器（LG Display；LGD）與京東方面板，中國手機業者也增加本土面板業者單價約20美元的低價位可撓式OLED面板採購量。

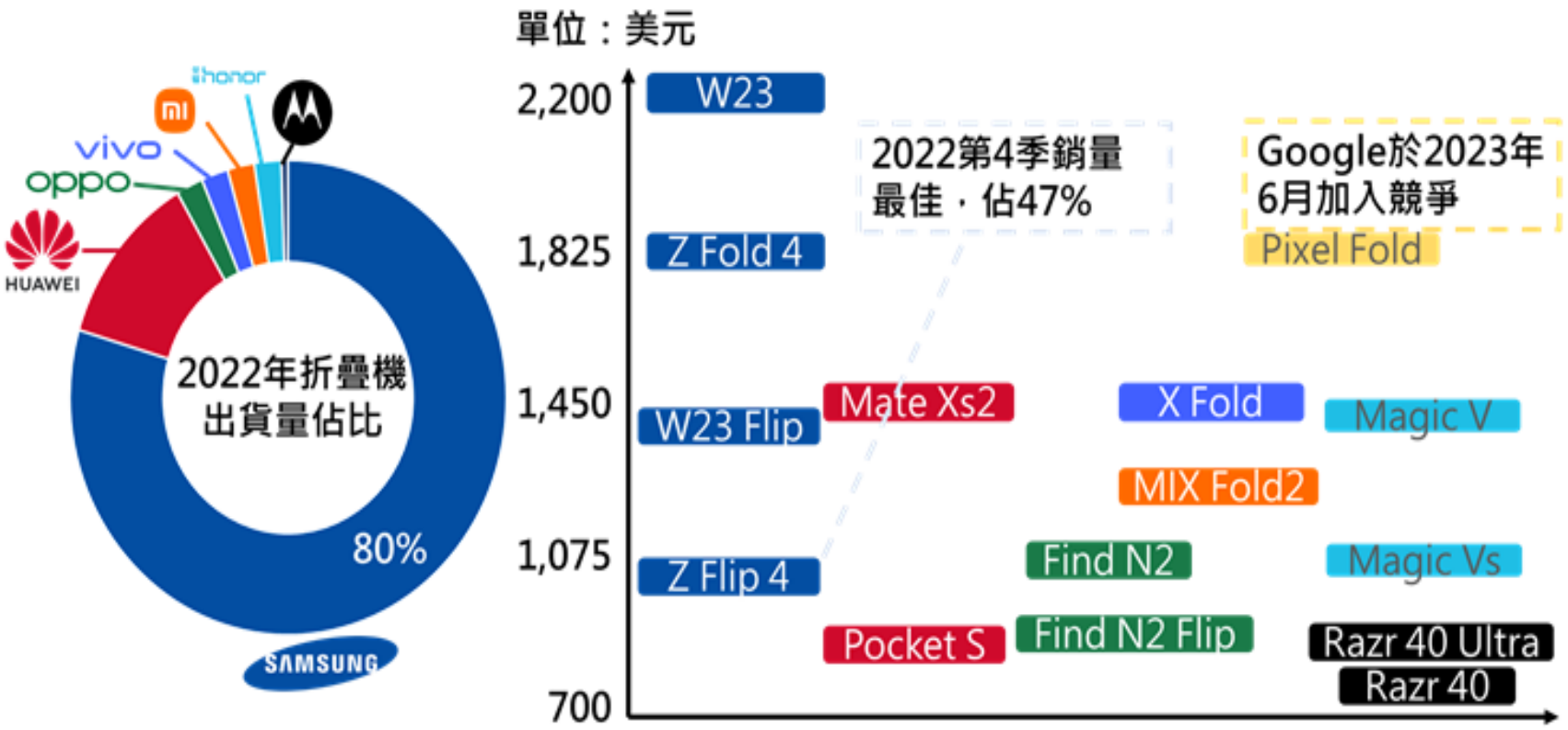


OLED手機兩大陣營

- 折疊機售價，降價幅度較緩且較長

(其他產品大概銷售2~3個月就需要降價，然折疊機的價格卻很穩，這些特點都讓愈來愈多客戶導入折疊機)

2022年折疊手機出貨佔比與折疊機價格分布



資料來源：Canalys、各業者，DIGITIMES Research整理，2023/7

SAMSUNG GALAXY Fold 5 / Z Flip 5 (2023)

三星帶頭衝　折疊機3Q23出貨將創高

- 全球手機市場景氣低迷，折疊式手機卻持續成長。據PhoneArena報導，全球折疊機出貨量持續上升，2023年第2季已經較第1季成長16%，達到220萬支。

資料來源: Digitimes 2023-09-06

榮耀Magic V2折疊機

- Magic V2採用7.92吋、解析度為2344 x 2156的內側主螢幕，外部螢幕則採用6.43吋、解析度為2376 x 1060設計，兩者均支援120Hz畫面更新率與LTPO面板技術，同時在主螢幕與外部螢幕都支援手寫筆操作。

- Magic V2 採用的魯班零齒輪結構鈦金鉸鏈，屏幕摺合時能作懸浮水滴支撐，主屏開展時基本不見摺痕。

資料來源: Digitimes 2023-07

OPPO Find N3 Flip發表

- Find N3 Flip 內頁螢幕為 6.8 吋 FHD+ 解析度 AMOLED 可摺面板，支援 10.7bit 色彩、DCI-P3 廣色域、1,200nits HBM / 1,600nits 峰值亮度，以及 1-120Hz LTPO 可變更新率外，也有自家高階機才有的 ProXDR 顯示功能；另外，表現也覆蓋了 UTG 超薄可摺式玻璃。

資料來源: Digitimes 2023-08

小米Mix Fold 3 「折疊旗艦」

- 水滴轉軸結構來說，其展開型態和摺疊型態的厚度分別較上代採用的微水滴更薄 8.6% 和 12.5%、轉軸厚度縮窄 8%、轉軸區空間縮小 17%

- Xiaomi MIX Fold 3的內螢幕採用超薄UTG玻璃，強度是傳統CPI材質的2.25倍，20萬次摺疊後，折痕深度變化僅10μm，可靠性和耐用性大幅提升

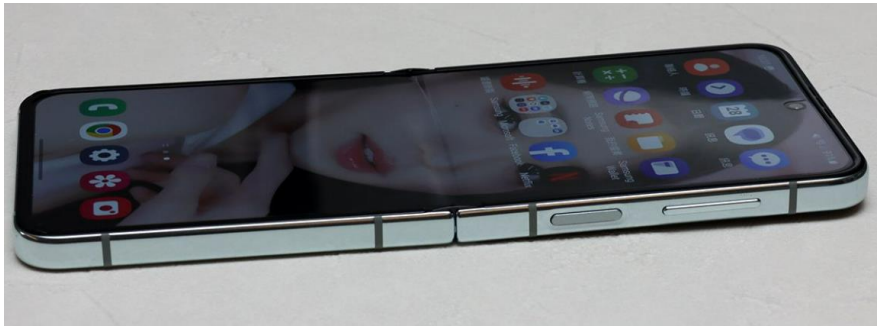
資料來源: Digitimes 2023-08

華為開賣折疊機X5

- 華為於9月8日在官網無預警開賣折疊機Mate X5

資料來源: Digitimes 2023-09-11

部分消費者開始接受折疊手機折痕



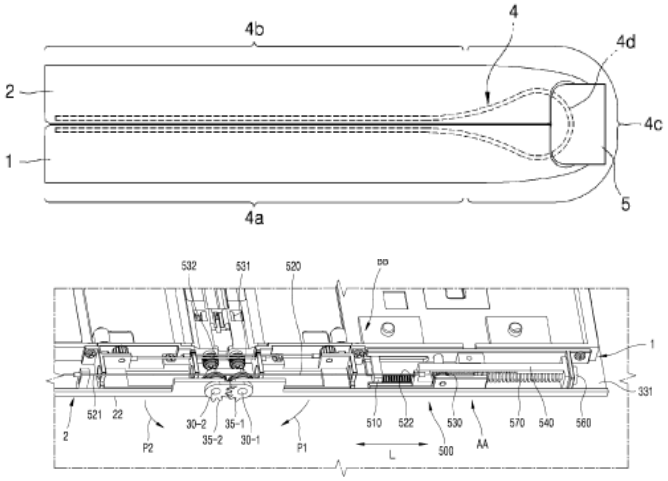
折疊手機關鍵零組件(1) Hinge鉸鏈

U型與水滴型鉸鏈特性比較

指標	U型鉸鏈	水滴鉸鏈
彎折半徑	較小 容納空間有限	較大 容納空間較大
折痕表現	折疊時受力集中 折痕較明顯	折疊時受力分散 折痕較淡
零件數 (傳統架構)	約60個	約130個
成本	20~27美元	90~110美元
代表業者	SAMSUNG	oppo, HUAWEI, honor

資料來源：各業者，DIGITIMES Research整理，2023/7

折疊手機關鍵零組件-Hinge (軸承)



- 折疊機售價較高，是影響市場接受度的主因之一，然售價要降低的空間有限，主因不論AMOLED或機構件設計都較複雜，良率偏低的結果，生產成本偏高，以關鍵機構件軸承為例，其零件多達上百件，為NB的5~10倍之多，也凸顯其量產難度

Source: DIGITIMES: 2021-04-19

折疊手機：水滴型鉸鏈

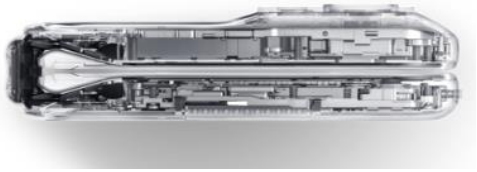
OPPO Fold N

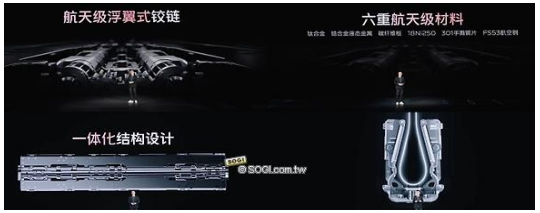
vivo X Fold

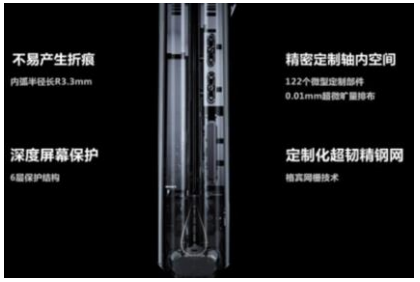
小米MIX Fold 2

Moto Razr

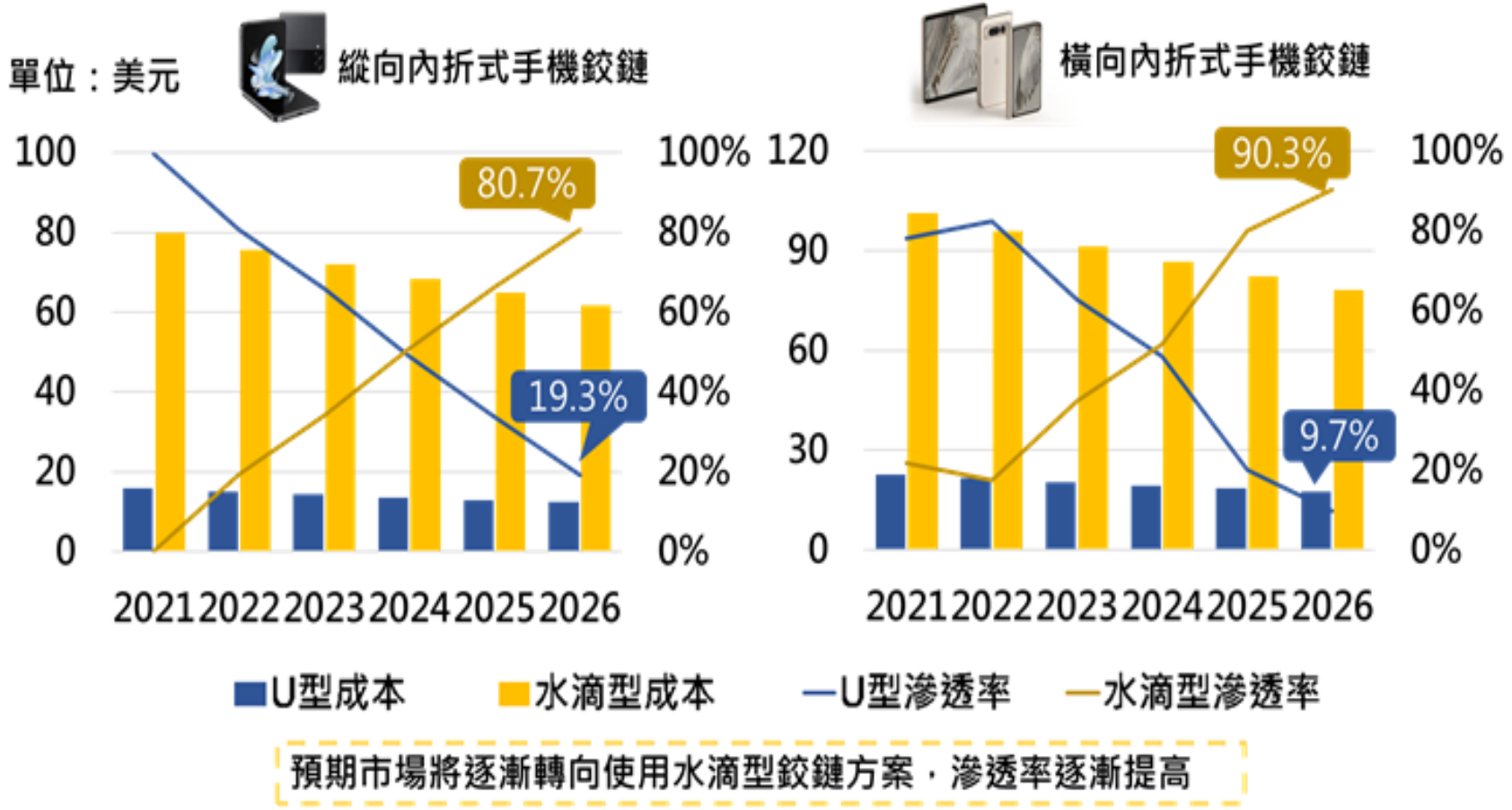
Flexion Hinge







U型與水滴型鉸鏈滲透率與成本走勢預測



資料來源：DSCC，DIGITIMES Research整理，2023/7

折疊手機關鍵零組件(2) Cover Window

Colorless PI

More cost effective

KOLON

- Huawei's Mate X,
- Motorola's Razr
- Lenovo's (Thinkpad X1 foldable laptop)
- Oppo
- Vivo

Ultra Thin Glass

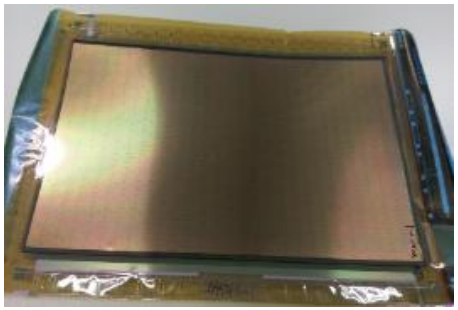
SCHOTT glass made of ideas

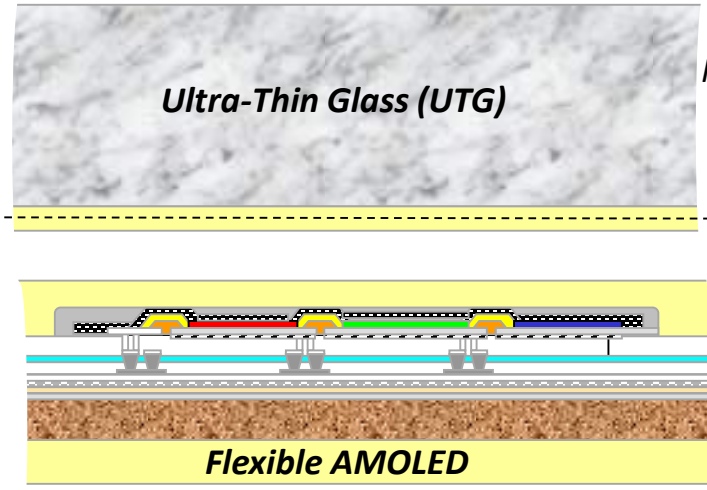
CORNING

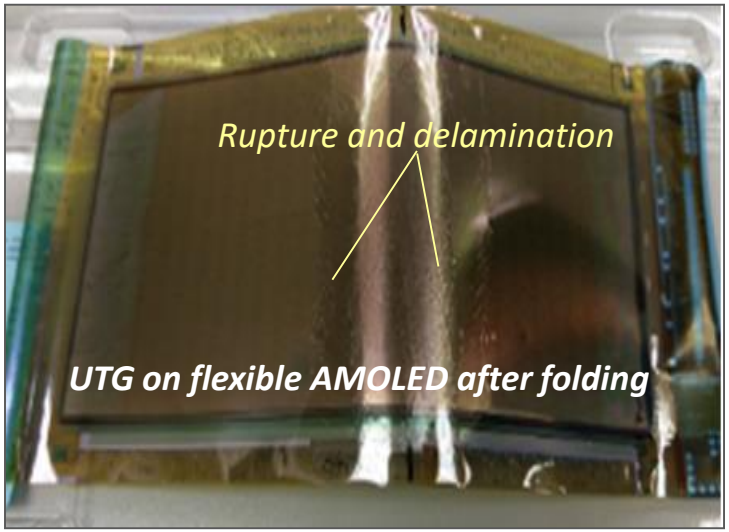
eCONY

- SAMSUNG

Consideration of UTG for Foldable AMOLED



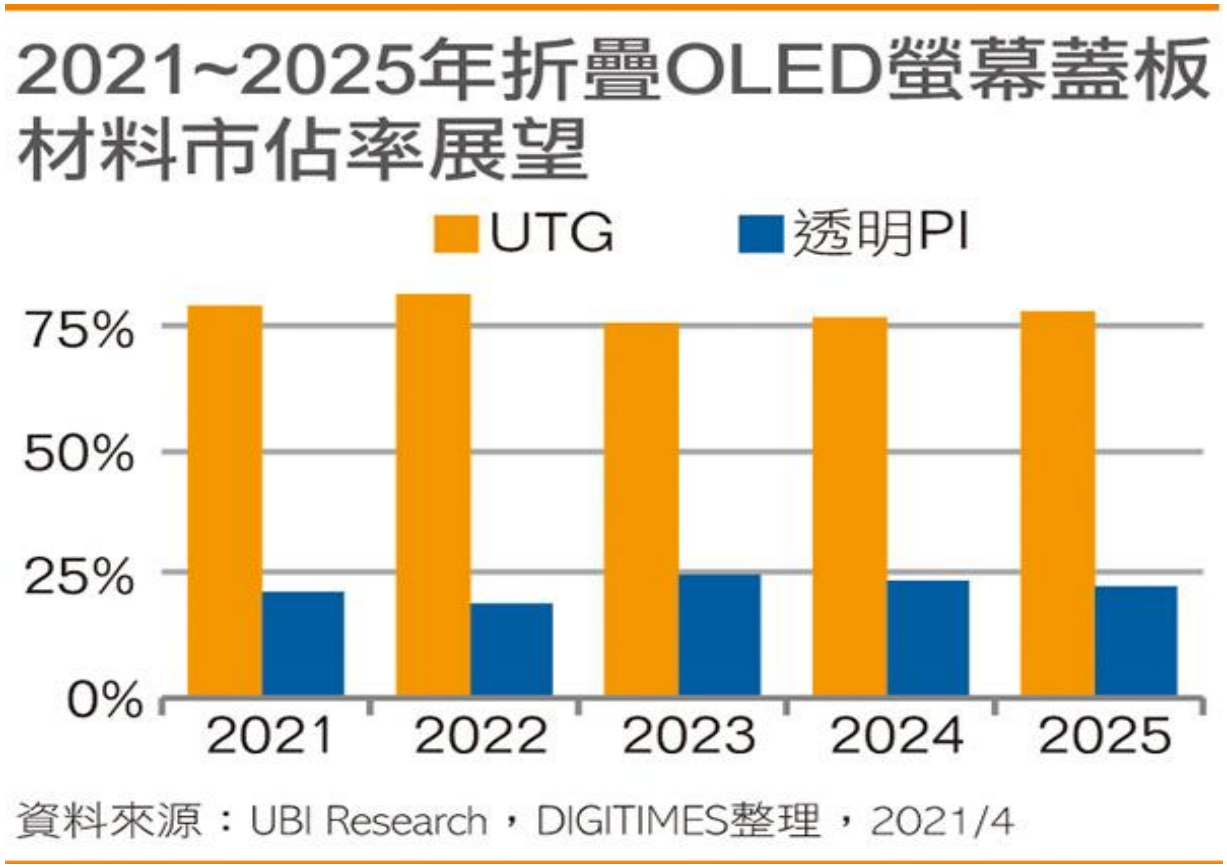




- ✓ ***Rupture and delamination after r=5mm folding***
- ✓ ***Flexible AMOLED fail***
- ✓ ***Challenged for small radius by using UTG***

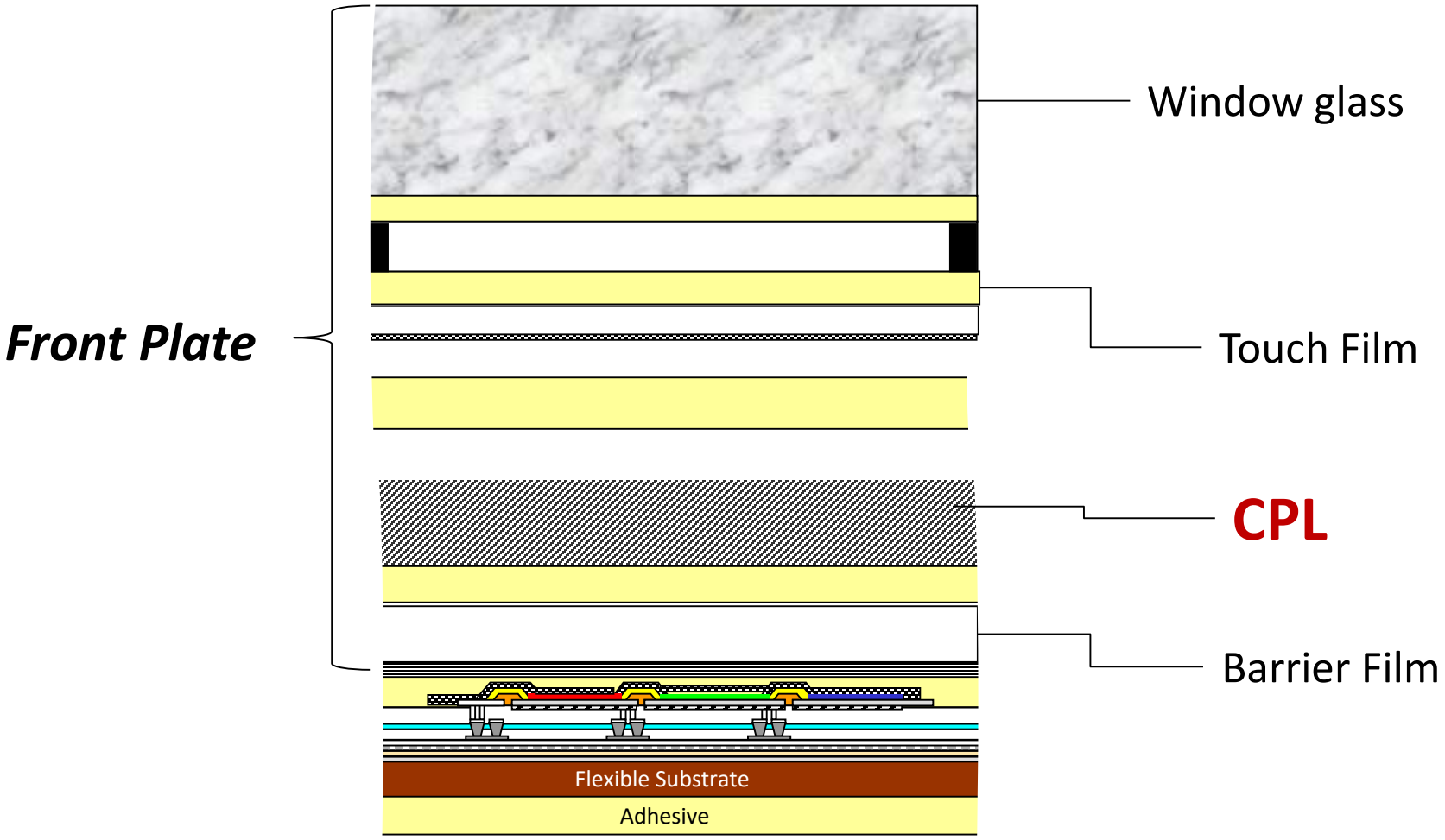
- ✓ ***High Young's modulus of UTG***

CPI與UTG在折疊手機Cover Window未來佔比



- 透明PI較容易搭載於低價機型，及10吋以上的產品，如平價機種、平板及NB
- 2021年折疊螢幕蓋板(cover window)材料超薄強化玻璃(UTG)的市佔率可望達80%，未來消長將取決於三星電子(Samsung Electronics)、蘋果(Apple)的選擇。

Flexible AMOLED折疊關鍵零組件CPL

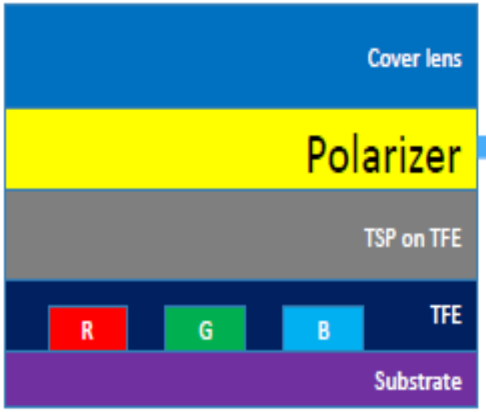


Note: CPL (Circular Polarizer)

SAMSUNG POL-Free OLED技術

- **POL Thickness : 50-100 micron**
- **CF Thickness : ~5 micron**

Common OLED stack-up structure



- *Anti-reflection*
- *Color enhancing*
- *UV absorption*

Pol-less, CF on TFE structure

- CF with a new black matrix

□ 將OLED PDL變黑

✓ Improve the brightness of Samsung's OLEDs by 20-30%

✓ POL-LESS with LTPO, power consumption reduction of more than 30% compared to current LTPO OLEDs

SAMSUNG GALAXY Z Flip 3 Polarizer-free技術導入

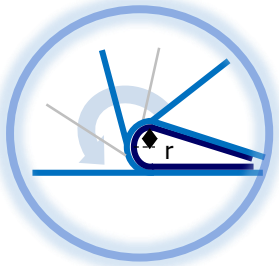
Polarizer-free技術導入

- **UTG** : not be exclusively produced by **SCHOTT**. Corning’ s UTG will be processed by Korean supplier **eCONY**
- **Under the display camera**
- **A polarizer-free design**

資料來源：DSCC 2021/06/15

折疊手機面板薄型化、降成本關鍵技術

- 關鍵技術(1) TSP on TFE : Touch線路於OLED Thin Film Encapsulation上製作
- 關鍵技術(2) Polarizer Free: 於Touch線路上再上Color Filter



TSP on TFE

Y-OCTA

2017

Polarizer Free

2021

折疊機面板無偏光片

- （Color Filter on Encapsulation；CoE）技術的機款包括三星Galaxy Z Fold5、Oppo FIND N3及N3 Flip、小米Mix Fold3、Vivo X Fold2、Google Pixel Fold、傳音Tenco Phantom V Flip、摩托羅拉（Motorola）Razr 40和Razr 40 Ultra等

資料來源: Digitimes 2023-09-27

OLED 平板 (2023)

SAMSUNG

Galaxy Tab S9

HUAWEI MatePad Pro

Xiaomi Pad 5

Lenovo Tab P11 Pro

各品牌廠開始採用OLED面板在Laptop

SAMSUNG

Galaxy Book I Pro I Pro 360

$1,200 (Book Pro 360 13.3 “)

hp

Spectre x360

$1,599

mi

Mi Laptop Pro 15

>$990 (2021/4)

Lenovo

Yoga Slim 7i Pro

ASUS

ZenBook Pro Duo 15

$2,200 (2021/4)

DELL

XPS 13

(2021/4)

XPS 15

(2021/Q3)

GIGABYTE

New AERO 15

RAZER

Blade 15 Advanced

$2,300 (2021/6)

OLED 筆電 (2023)

ASUS

ASUS Vivobook 13 Slate OLED

acer

Acer Swift Go 14

Lenovo

YogaBook 9i

SAMSUNG

Galaxy Book3 Ultra

DELL Technologies

XPS 13 Laptop

GIGABYTE

AERO 16 OLED

OLED Monitor (2023)

SAMSUNG

DELL Technologies

QD-OLED GAMING MONITOR

ASUS

OLED Gaming Monitor

CORSAIR

LG
Life's Good

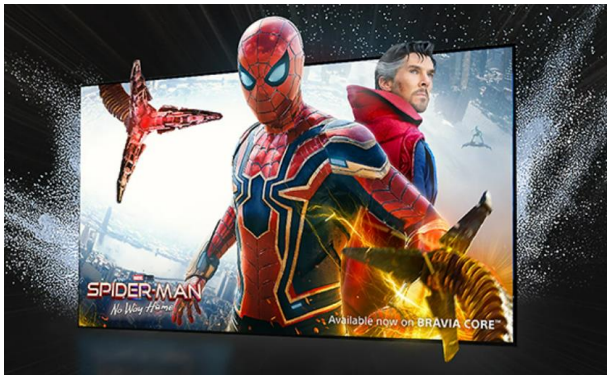
OLED TV (2023)

- OLED技術: LG Display採用 WOLED ； Samsung Display採用QD-OLED

SAMSUNG

LG
Life's Good

SONY



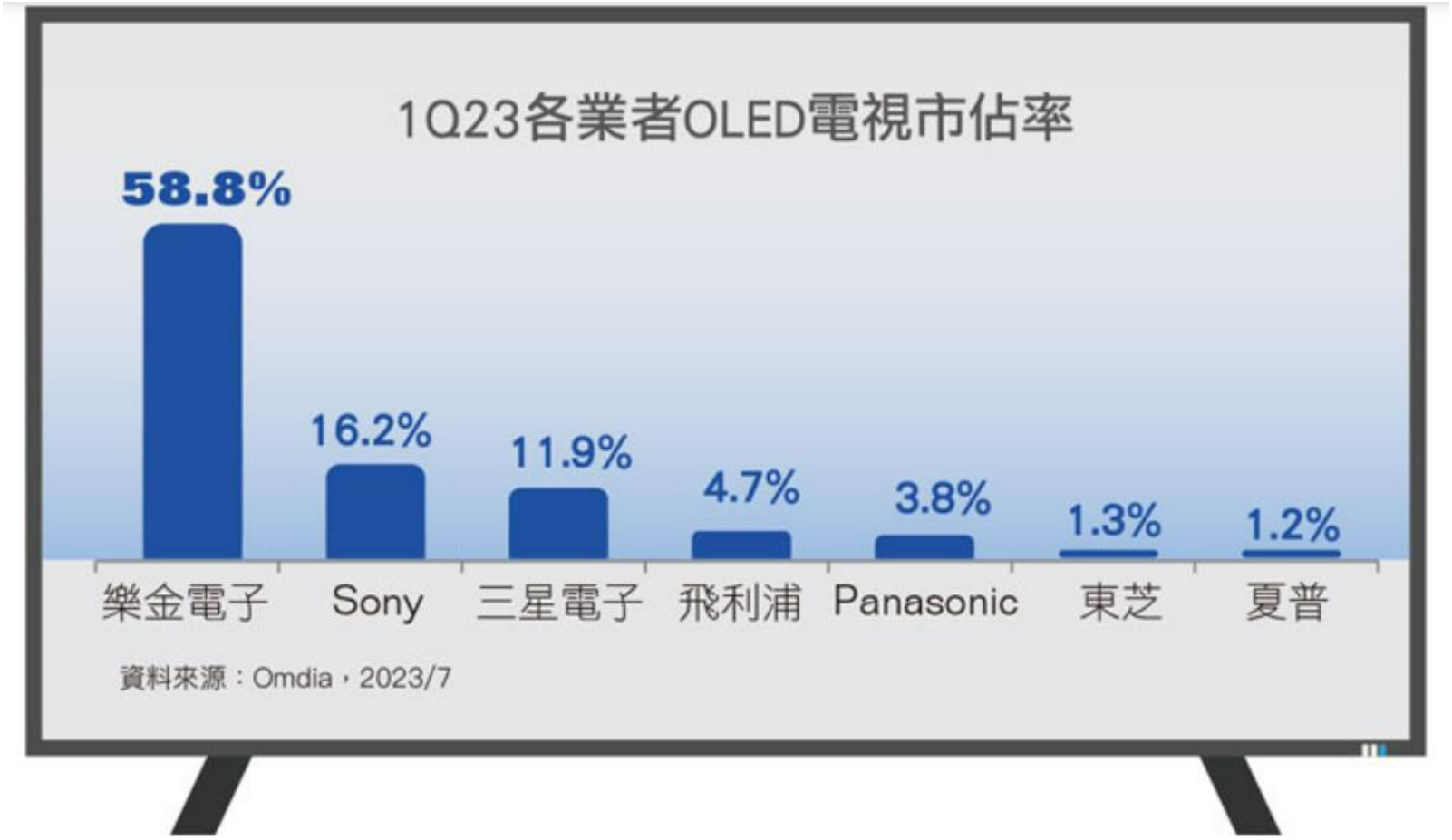
Panasonic

PHILIPS

Haier

OLED TV (2023)

- 2023年第1季，樂金全球OLED電視市佔率接近60%，Sony、三星分別以16%及11%

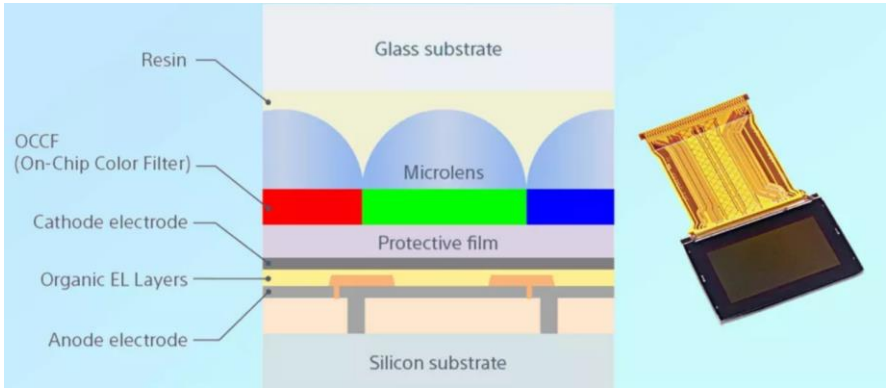


資料來源: Digitimes 2023-07

AR/VR/MR Apple Vision Pro採用Micro OLED

OLEDoS（OLED on Silicon），即是所謂的Micro-OLED

售價3,499美元（約新台幣10.7萬元）



SOURCE:https://www.techritual.com/2023/07/23/376546/

- 尺寸為2片約1.4吋Micro OLED，其畫素密度估計約4,000ppi(CMOS背板)
- Vision Pro推估的生產成本約高達1,500美元以上。其中，零件最昂貴就是Micro OLED面板，約佔700美元，這筆大單僅由Sony獨家提供。
- Sony Micro OLED年產能僅約90萬片，雖然蘋果要求Sony擴大產線供應，但Sony卻拒絕大客戶要求(年出貨超過100萬台)

Mercedes Benz S-Class (2021)

Mercedes-Benz 電動車採用LGD pOLED

Mercedes-Benz 的 MBUX 多媒體系統

- 主駕 12.3 吋、副駕 12.3 吋與中控 17.7 吋 P-OLED (LGD)

Transparent OLED

TDK 2010

· Size : 2.4inch QVGA
·Resolution : 240x320
· **Transparency : 40%**
·Brightness: 150 cd/m²

LG Display 2009 FPD

· Size : 15 inch
· **Transparency : 30%**
·Brightness: 200 cd/m²

SAMSUNG MOBILE DISPLAY 2011 CES

· Size : 14 inch QFHD
·Resolution : 960x540
·**Transparency : 40%**
·Brightness: 200 cd/m²
·Color Gamut > 100% (NTSC)

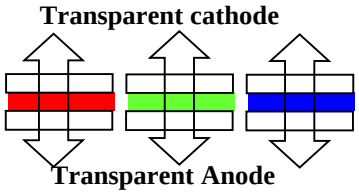
· Size : 19 inch QFHD
·Resolution : 960x540
· **Transparency : 30%**
·Brightness: 200 cd/m²
·Color Gamut > 100% (NTSC)

TDK

- **PMOLED**
- **Narrow Cathode Structure design**

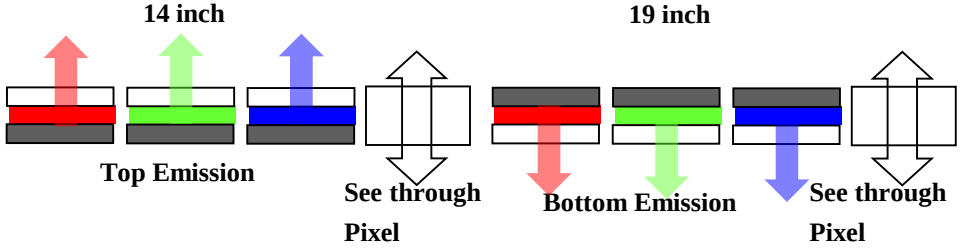
LG Display

R/G/B Transparent cathode

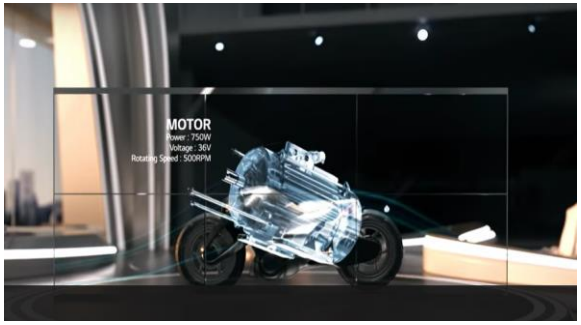


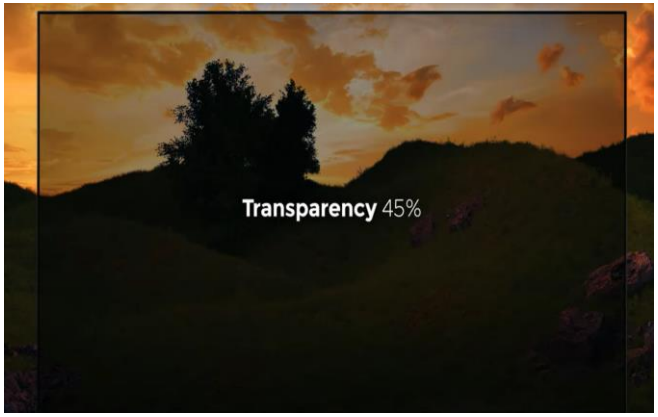
SAMSUNG MOBILE DISPLAY

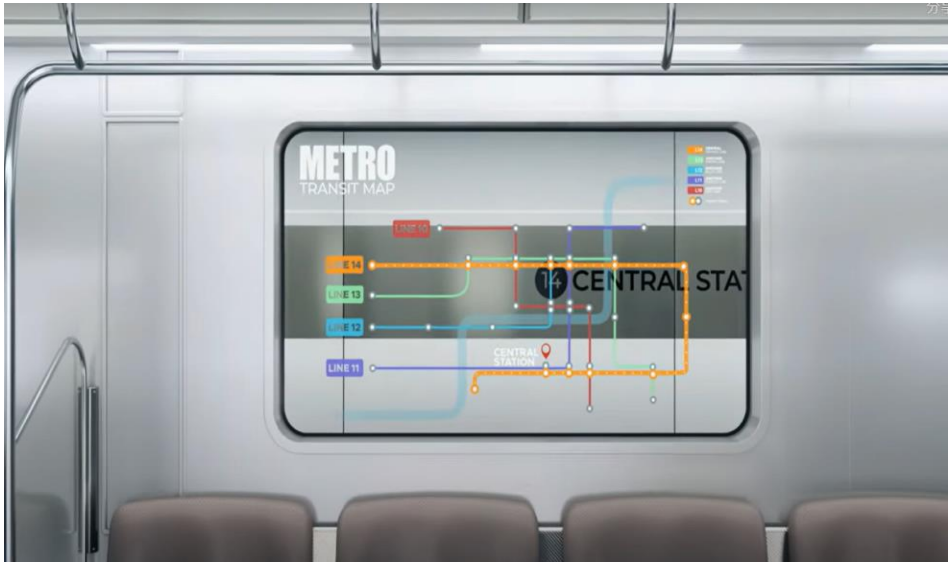
See Through Pixel



LG Transparent OLED Applications







大綱

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- 過去 : Flexible AMOLED研發到量產
- AMOLED現在

手機、平板、NB、Monitor、電視、AR/VR/MR、Automotive、Transparent

- **AMOLED未來**

Future OLED Form Factors and Applications

Form factors

- Foldable
  - -In-fold
  - -Out-fold
  - -Z-fold

- Slidable

- Rollable

- Transparent

Applications

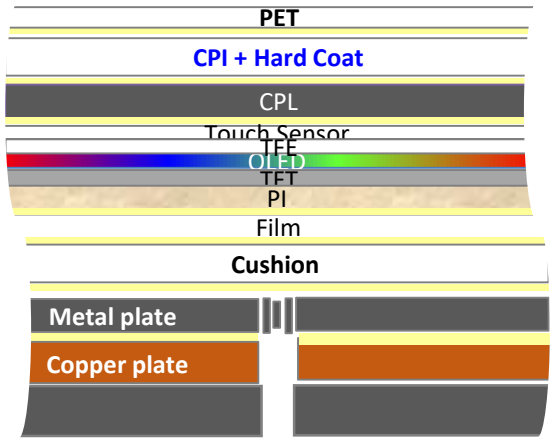
手機　平板　NB　Monitor　電視

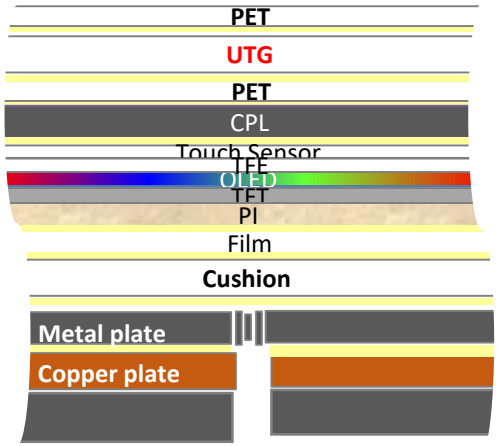
AR/VR/MR

Automotive

AR

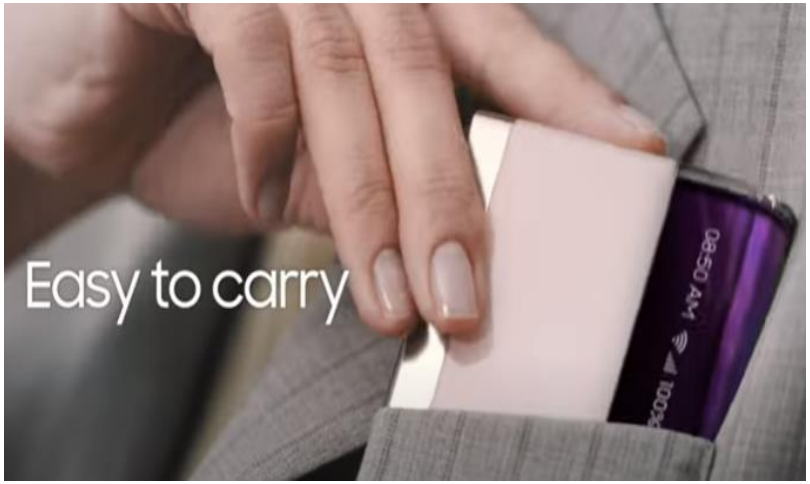
In-Fold內折未來挑戰：折痕





Z-Fold(雙折疊)手機 (SAMSUNG)

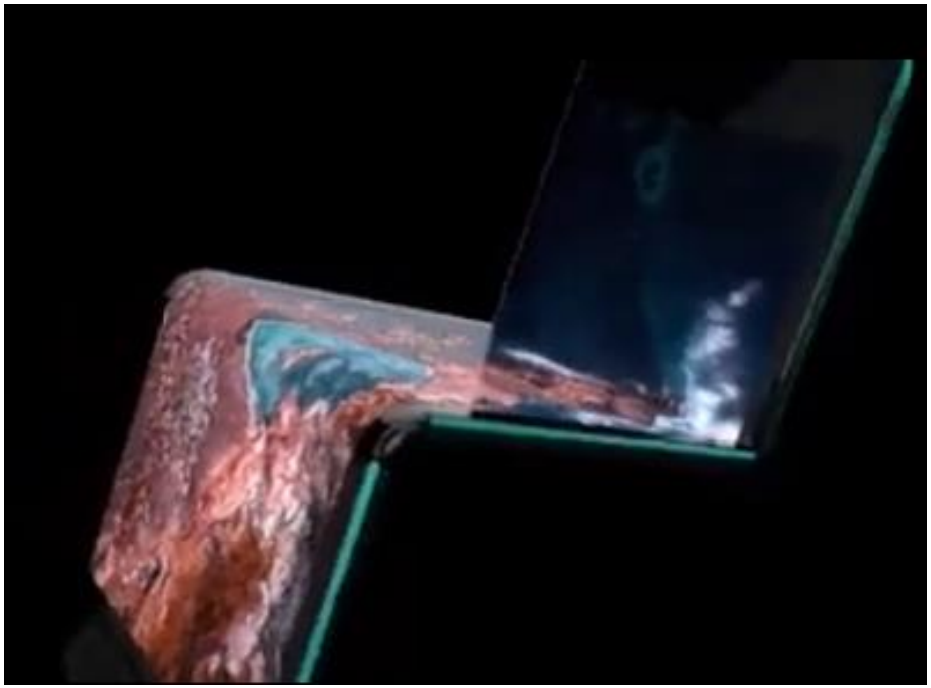
SAMSUNG DISPLAY OLED



Source: Display Week 2021

Z-Fold(雙折疊)手機 (Visionox)

- 展開顯示面板12.3吋
- 雙折後5.4吋



- 內折半徑 2.5 mm 外折 6.5mm

Source: Display Week 2021

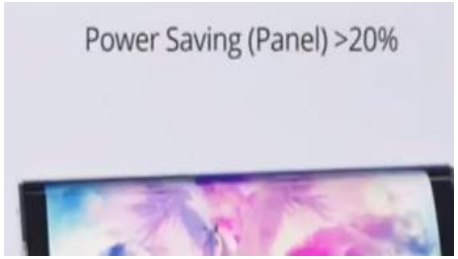
Curve Sliding Umbrella-like mechanism

可滑捲手機雛型機(Prototype)

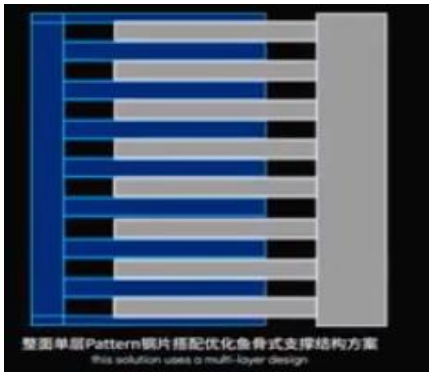
(LG)

(BOE)

(TIANMA)



(Visionox)



Source: CES 2021

可滑捲螢幕(Slidable AMOLED)

- 6.55吋的畫面，在1.2~1.3秒內就會為橫向拓展至7.11吋

- 中國手機業者傳出的幾款新型態手機消息，傳音稍早於2023年8月底曝光延伸式手機概念機「Phantom Ultimate」，最快有望在2024年底上市

可滑捲螢幕未來技術挑戰

□技術挑戰

- 面板滑捲應力與磨擦力較折疊挑戰高
- 展開模式後面板需要構件保護
- 展開後縫隙較折疊大，砂塵無孔不入

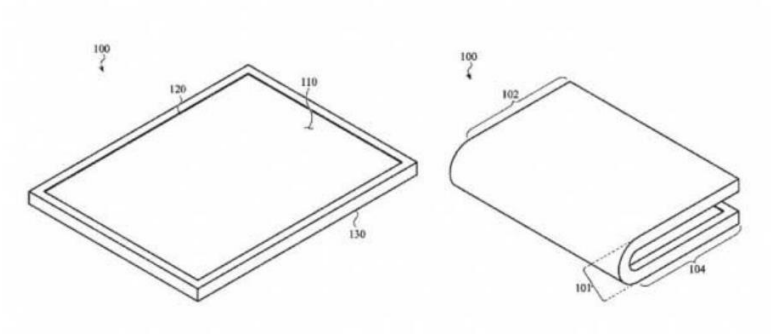
Umbrella-like mechanism

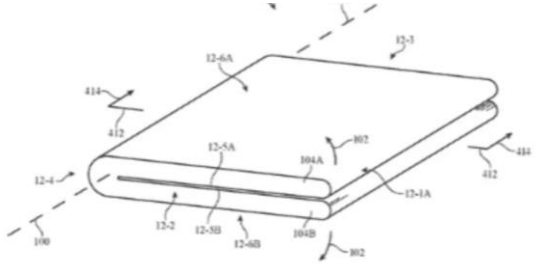
Source: http://www.concept-phones.com

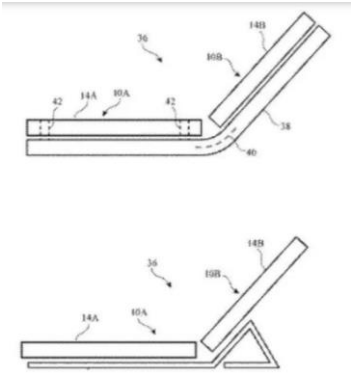
APPLE Foldable iPhone in 202X ?

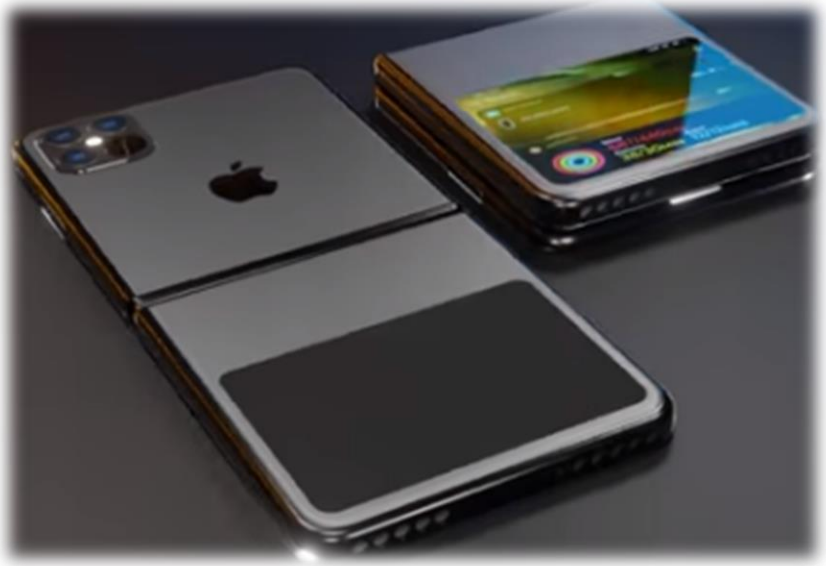
- 可折疊螢幕專利

等待完全解決折痕問題?









Roadmap for iPhone with Flexible AMOLED (Estimated)

iPhone X
Flexible AMOLED
5.85" 2436 × 1125
459 ppi (PenTile)
Add-On TSP / COF

iPhone Xs
Flexible AMOLED
5.85" 2436 × 1125
459 ppi (PenTile)
Add-On TSP / COF

iPhone 11 Pro
Flexible AMOLED
5.85" 2436 × 1125
459 ppi (PenTile)
Add-On TSP / COF

iPhone 12 Pro
Flexible AMOLED
5.42" 2340 × 1080
475 ppi (PenTile)
TSP on TFE / COP

iPhone Xs Max
Flexible AMOLED
6.45" 2688 × 1242
459 ppi (PenTile)
Add-On TSP / COF

iPhone 11 Pro Max
Flexible AMOLED
6.45" 2688 × 1242
459 ppi (PenTile)
Add-On TSP / COF

iPhone 12 Pro Max
Flexible AMOLED
6.68" 2778 × 1284
458 ppi (PenTile)
TSP on TFE / COP

Flexible AMOLED / LTPS / Add-on TSP / COF

iPhone 12 Pro
Flexible AMOLED
6.06" 2532 × 1170
460 ppi (PenTile)
Add-On TSP / COF

iPhone 11
LTPS LCD
6.06" 1792 × 828
325 ppi
Add-On TSP / COF

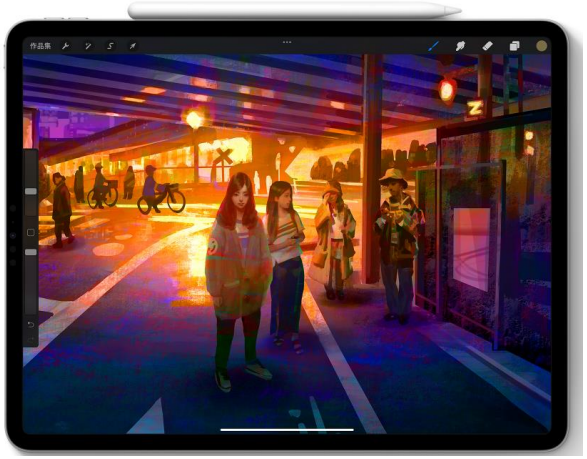
iPhone 12 Max
Flexible AMOLED
6.06" 2532 × 1170
460 ppi (PenTile)
Add-On TSP / COF

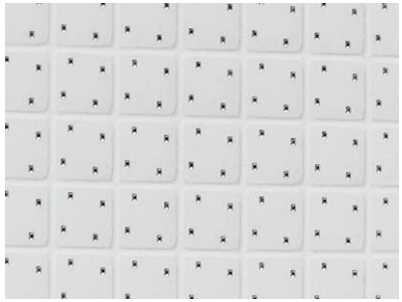
- Technologies
  - ✓ LTPO TFT
  - ✓ Touch on TFE

✓ R&D Foldable
- UTG Foldable Window

Apple平板將採用OLED

iPad Pro





- 超過10,000 顆mini-LED
- 4顆一組，超過2,500區局部調光

折疊式iPad Pro？

蘋果OLED產品藍圖

產品	尺寸(吋)	發布日期(預期)	年產量(百萬台)
iPad Pro	11.0	2025年	8~10
	13.0	2025年	4~6
	20.3(折疊式)	2027年	1
MacBook Air	13.6	2027年下半	9~10
	15.2	2027年下半	9~10
MacBook Pro	14.2	2026年下半	4~6
	16.2	2026年下半	4~6
iMac	21.5	2028年	2~3
	27.0	2028年	1~2
	32.0	2028年	< 0.5
	42.0	2029年	< 0.5

資料來源：Ravegnus，WccfTech，DIGITIMES整理，2023/11

Asus ZenBook 17 Fold OLED

- 17.3" 2560x1920 foldable OLED display (supplied by BOE)

Source: ASUS

Lenovo ThinkPad X1 Fold

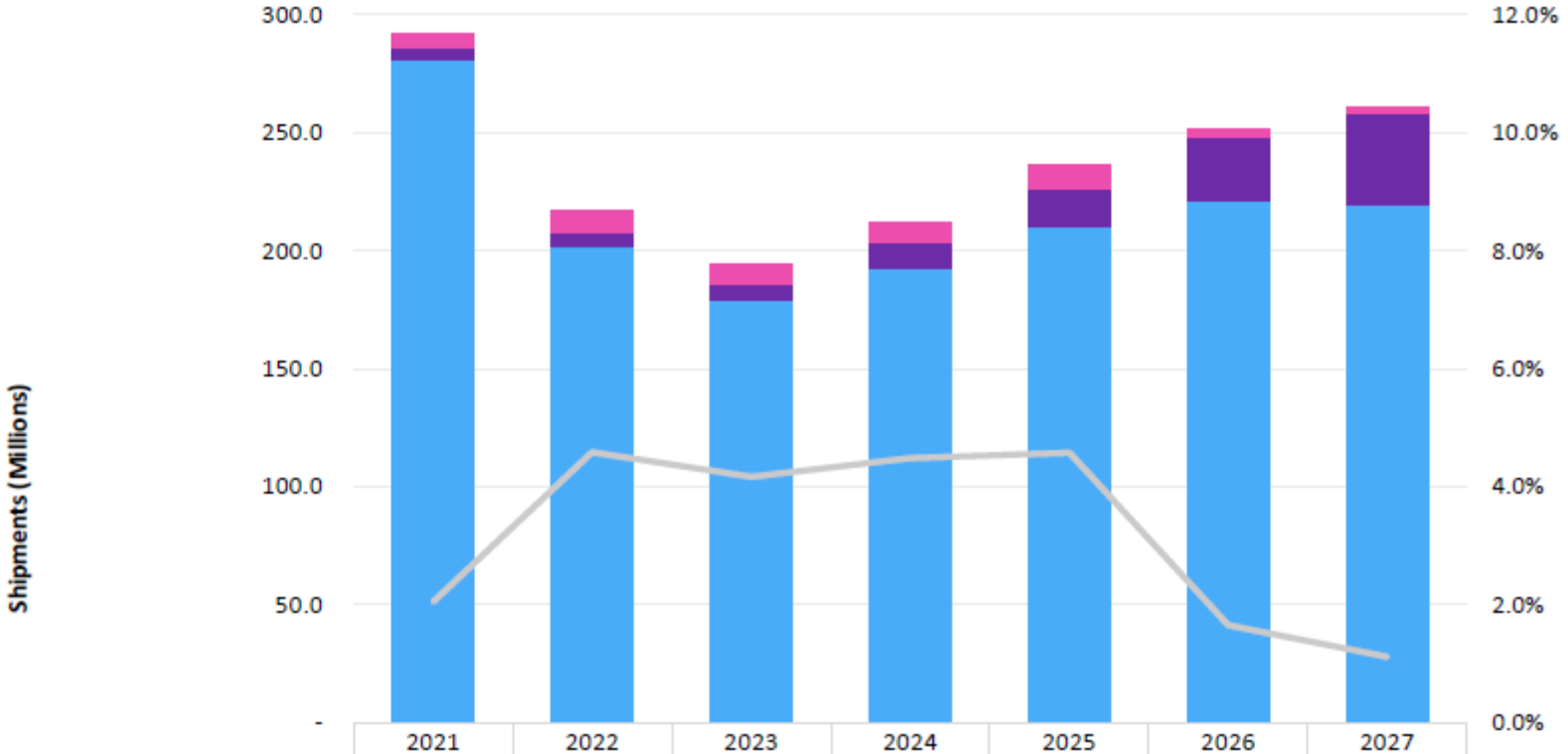
- 16.3" 2560 x 2024 foldable OLED display (supplied by LGD)

Source: Lenovo

LG Gram Fold

- LGD獨家研發的串聯（tandem）OLED技術，將此技術從車用擴大至IT OLED面板，有機發光堆疊為2層，可提升亮度與使用壽命，讓OLED面板更適用於NB、平板電腦等，螢幕使用時間較長的產品。

2026~2027年NB將加速採用OLED



	2021	2022	2023	2024	2025	2026	2027
Mini LED	5.9	9.7	7.8	9.0	10.1	3.7	2.5
OLED	5.0	5.5	7.0	10.6	16.1	27.0	39.0
Normal LCD	281.0	202.0	179.2	192.6	210.3	220.9	219.6
Mini%	2.0%	4.6%	4.2%	4.5%	4.6%	1.6%	1.1%

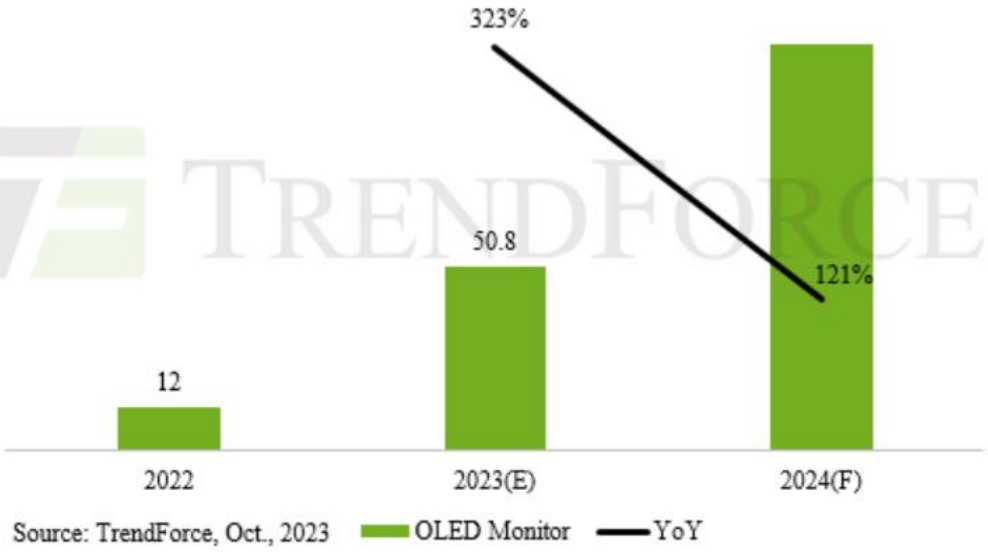
Notes: Mini LED backlighting is defined as a direct backlighting with 2D array of significant number of ≥100µm-sized LEDs in multiple separate dimming zones.

Source: Omdia 2023.06

OLED Monitor出貨預估

- 2023 年 OLED 監視器（Monitor）出貨量達 50.8 萬台，年增率高達 323%。2024 年 OLED 產品尺寸及規格將更豐富，加上兩家韓系面板廠 27 吋及 31.5 吋 OLED 產品上市後，競爭趨白熱化，進一步推動 OLED 監視器出貨超過百萬台。

圖、OLED監視器年出貨量（單位：萬台）



- 以OLED監視器尺寸別看，2023年仍以34吋為大宗，市占率預計為37%；第二則為27吋，市占率約32%；第三高為49吋，市占率約14%，接續為市占率10%的45吋。展望2024年，TrendForce預估，27吋的監視器市占率將持續擴展，並成為OLED產品市占率第一尺寸，31.5吋OLED產品也將在三星顯示器（SDC）及樂金顯示（LGD）皆陸續量產後，明年市占率有機會逾10%。

OLED TV出貨預估

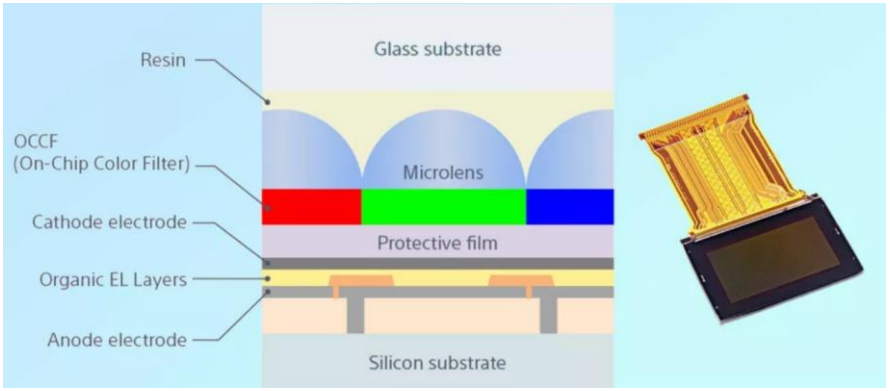
- Omdia預估，2023年全球OLED電視出貨量逾740萬台，其中在1,500美元以上高階電視市場，OLED電視佔比將上升至46.1%（金額基準），相較2022年佔比36.7%，短短一年提升近10個百分點。

資料來源: Digitimes 2023-07

AR/VR/MR Apple Vision Pro採用Micro OLED

OLEDoS（OLED on Silicon），即是所謂的Micro-OLED

售價3,499美元（約新台幣10.7萬元）



SOURCE:https://www.techritual.com/2023/07/23/376546/

- 尺寸為2片約1.4吋Micro OLED，其畫素密度估計約4,000ppi(CMOS背板)
- Vision Pro推估的生產成本約高達1,500美元以上。其中，零件最昂貴就是Micro OLED面板，約佔700美元，這筆大單僅由Sony獨家提供。
- Sony Micro OLED年產能僅約90萬片，雖然蘋果要求Sony擴大產線供應，但Sony卻拒絕大客戶要求(年出貨超過100萬台)

LGD開發車用 pOLED 顯示器

- POLED透過提升有機物材料的發光效率，較先前產品降低約39%功耗，以業界最低水準的功耗和重量，提升了能源使用效率，也被評估為用於電動車，將有利於增加行駛距離。

Source: SID'19

LGD與SDC車用 pOLED 顯示器客戶

- LGD車用OLED面板客戶 : 賓士（Mercedes-Benz）、現代汽車（Hyundai Motor）、通用汽車（GM）及Volvo等9家車廠。
- SDC車用OLED面板客戶 :奧迪（Audi）、現代汽車、BMW、法拉利（Ferrari）等
- 2022年LGD和SDC分別佔據50%和42%車用OLED面板市場，京東方市佔率約7%。

LGD

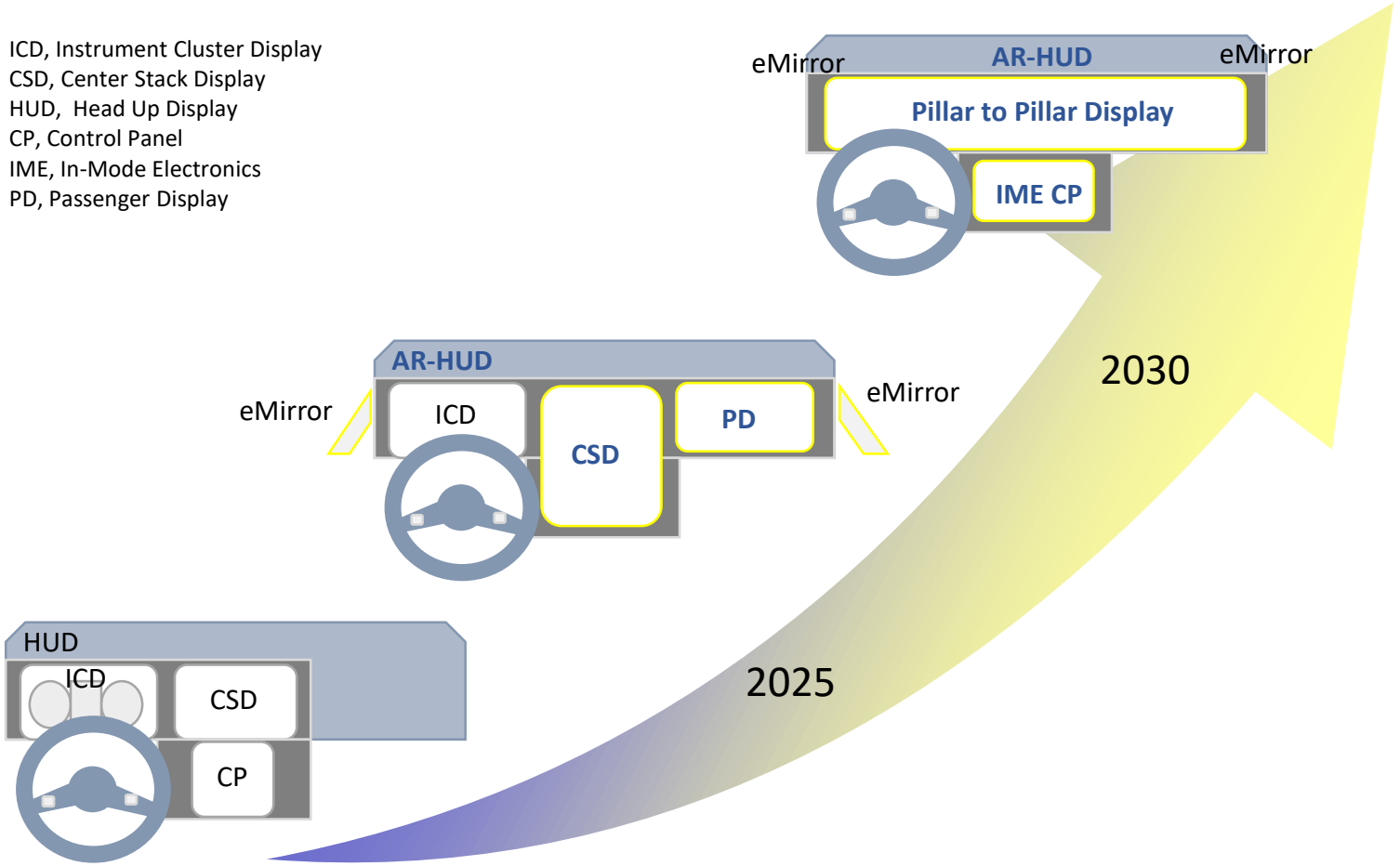
SMD

中國汽車製造商採用柔性OLED屏

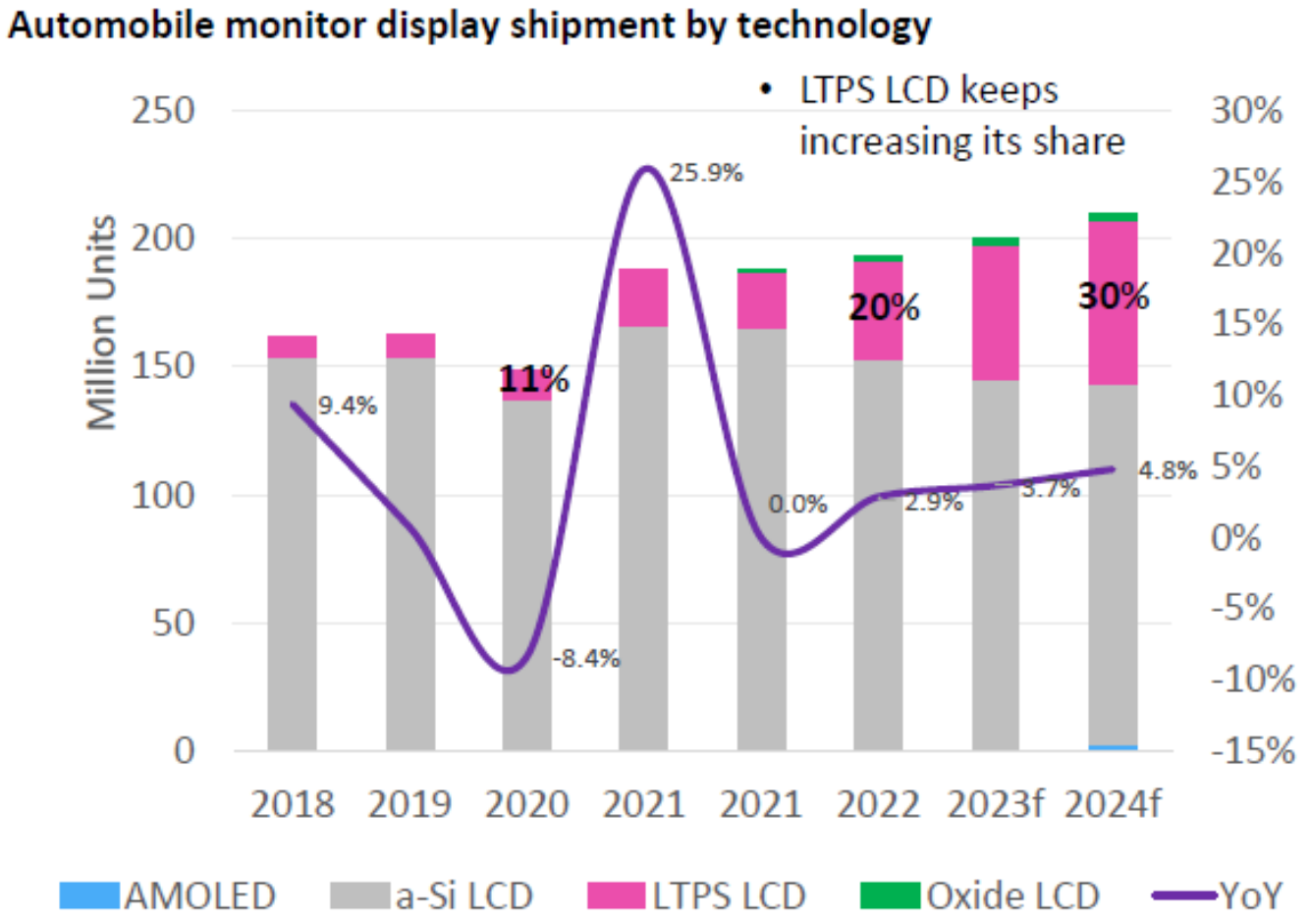
- 中國汽車製造商像是蔚來、理想、吉利、智己、比亞迪等，也紛紛搭載了AMOLED顯示器

智慧座艙顯示器發展

ICD, Instrument Cluster Display
CSD, Center Stack Display
HUD, Head Up Display
CP, Control Panel
IME, In-Mode Electronics
PD, Passenger Display



車用顯示器技術



Note: 2023-2024 is based on 1Q23 prelim numbers; the final numbers will be available in July 2023

Source: Omdia 2023.06

Next Few Decades...

2000 2005 2010 2015 2020 2025

LTPS TFT-LCD

TFT-LCD

Resolution

Lifetime

Thickness

Viewing angle

Outdoor reliability

Response time

AMOLED

- Absolute Black
- Power consumption
- Health
- Full screen
- Cost

Glass AMOLED

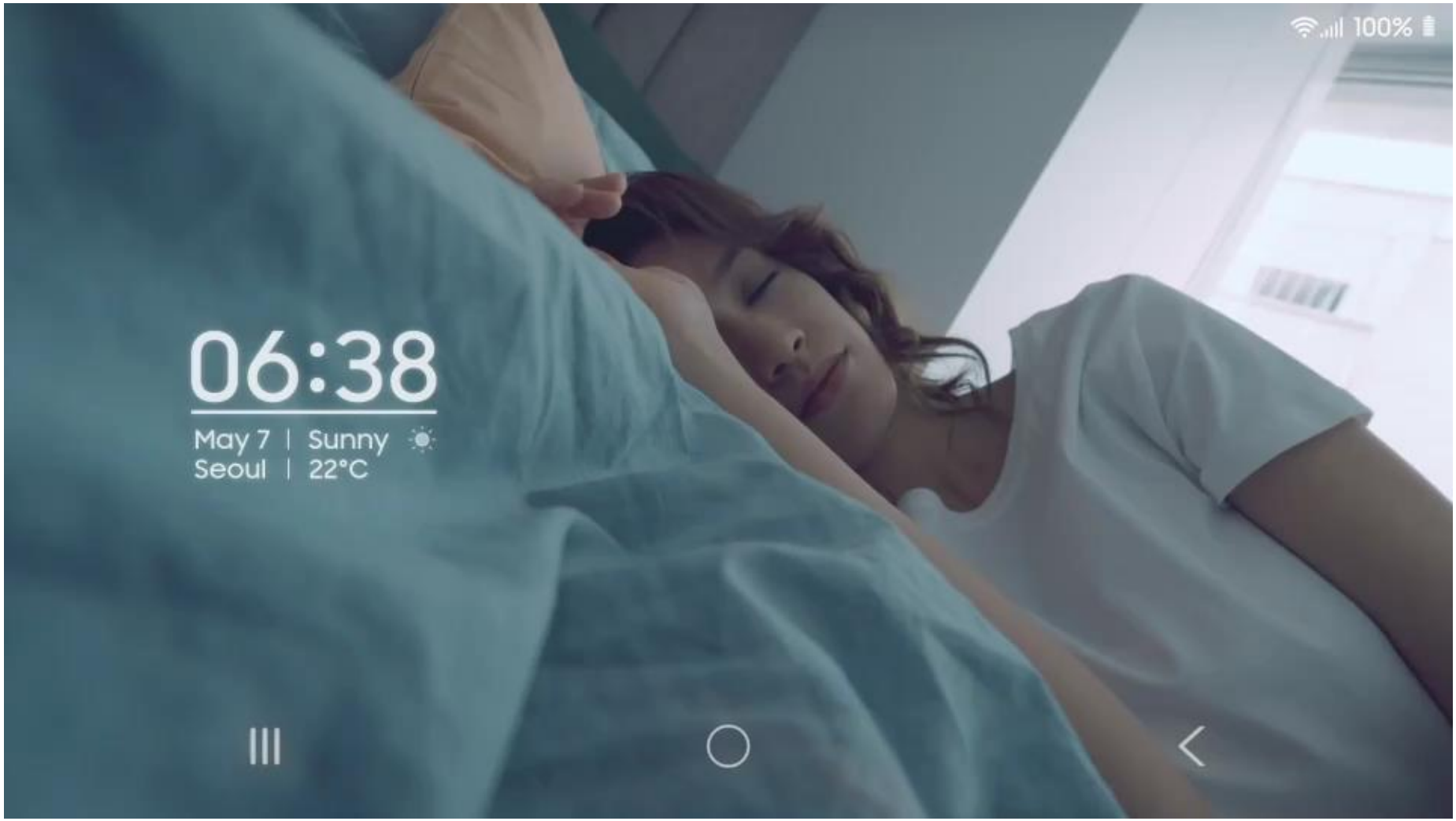
Foldable/Bendable/Rollable AMOLED

Transparent Display

- High brightness

Micro LED

SAMSUNG OLED Future



Source: Display Week 2021


Thank
You