

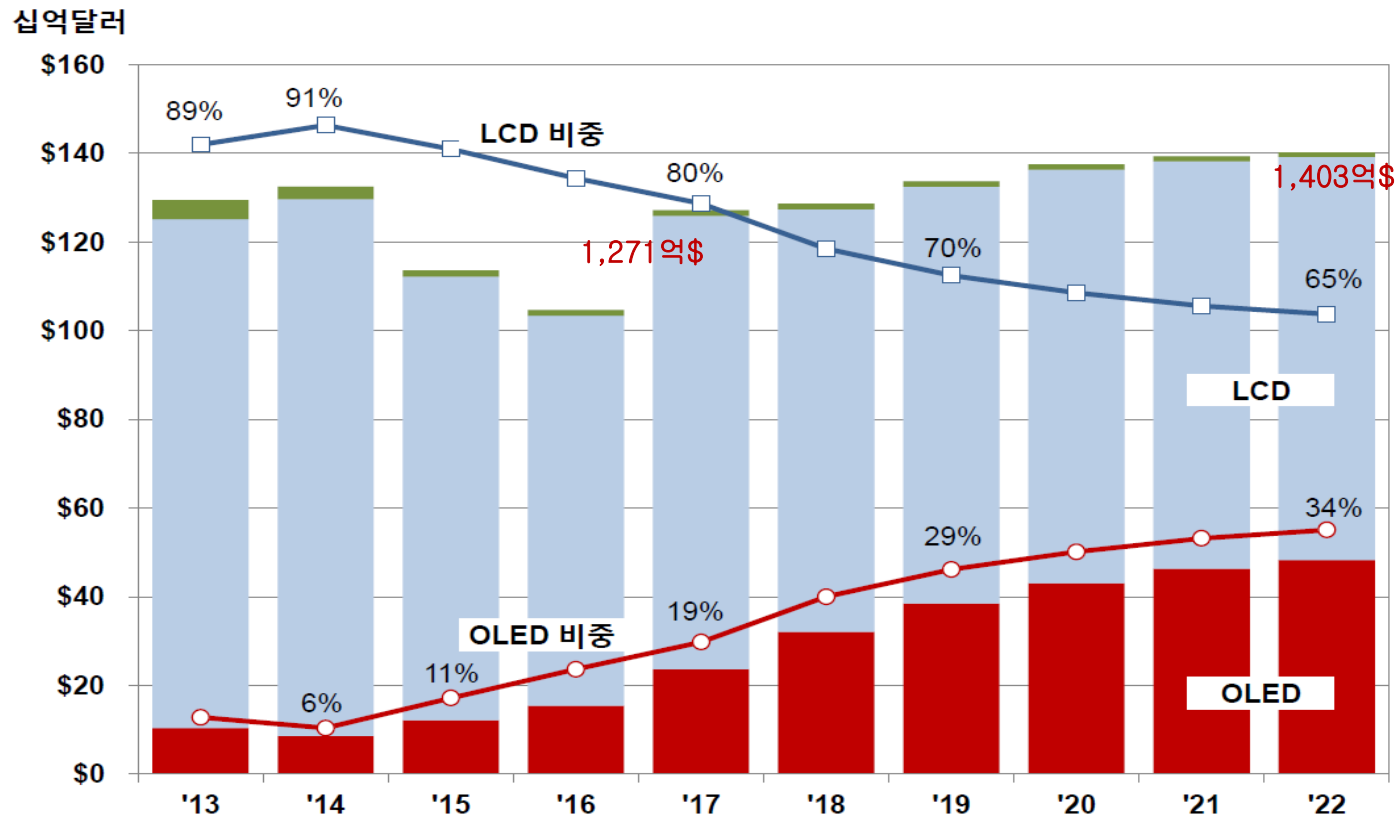
# **플렉시블 디스플레이 기술 동향**

**전자부품연구원**

**디스플레이소재부품연구센터  
곽민기 센터장**

**2018. 06.**

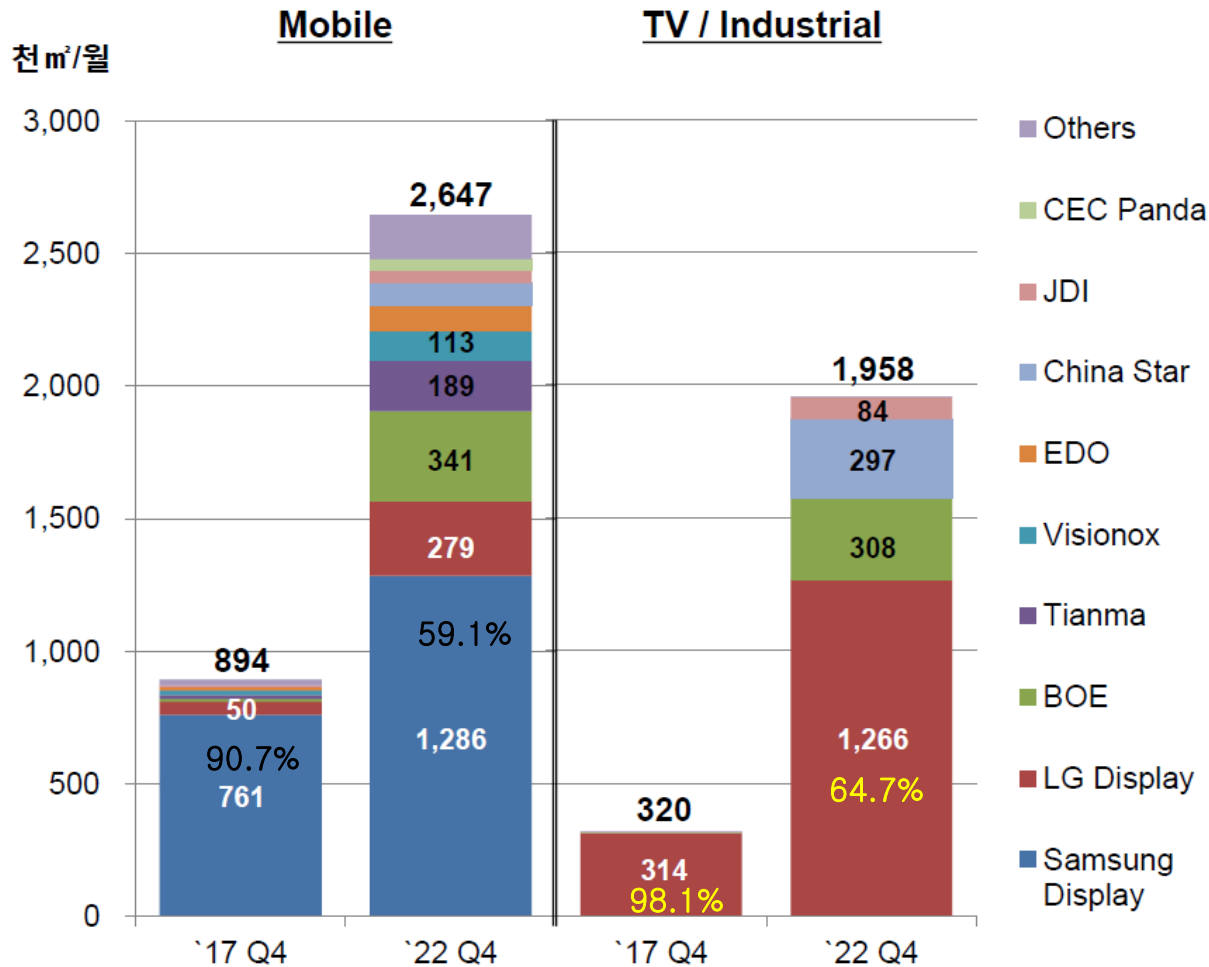
# 평판디스플레이 시장 규모



2017OLED 시장 : 240억\$, 대형은 20억불(8.2%), 소형 220억\$

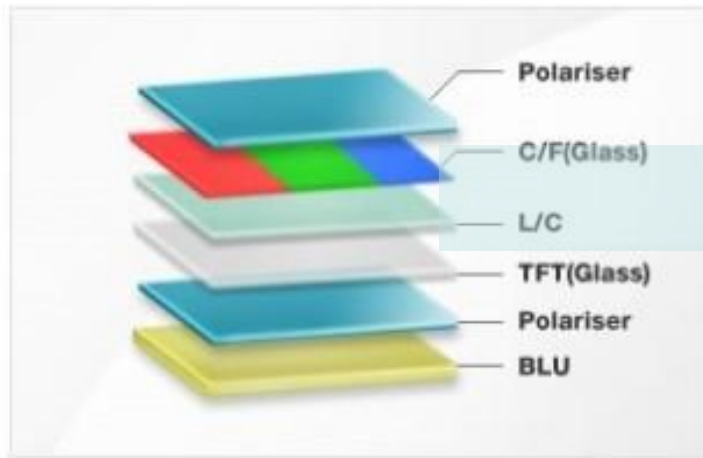
2022OLED 시장 : 485억\$ 대형이 73억불(14.7%), 소형 412억\$

# OLED 생산 Capa ( 면적 )

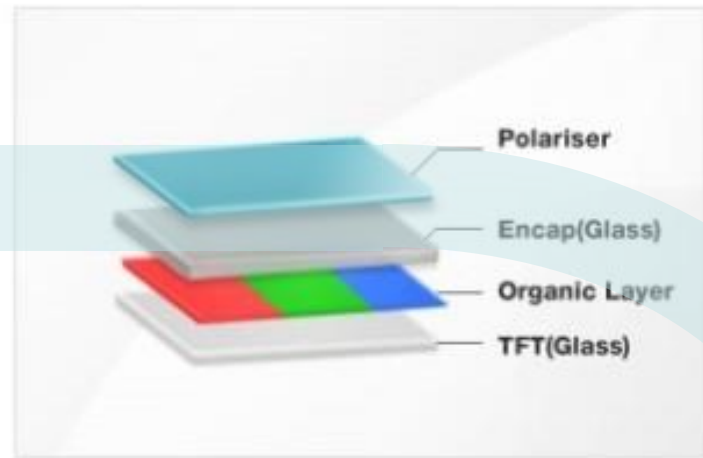


# 디스플레이 종류

## ◆ 대표적인 디스플레이(LCD, OLED)

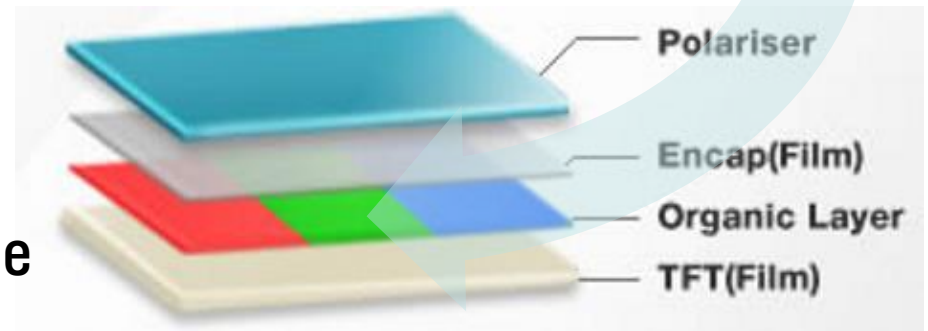


LCD



OLED

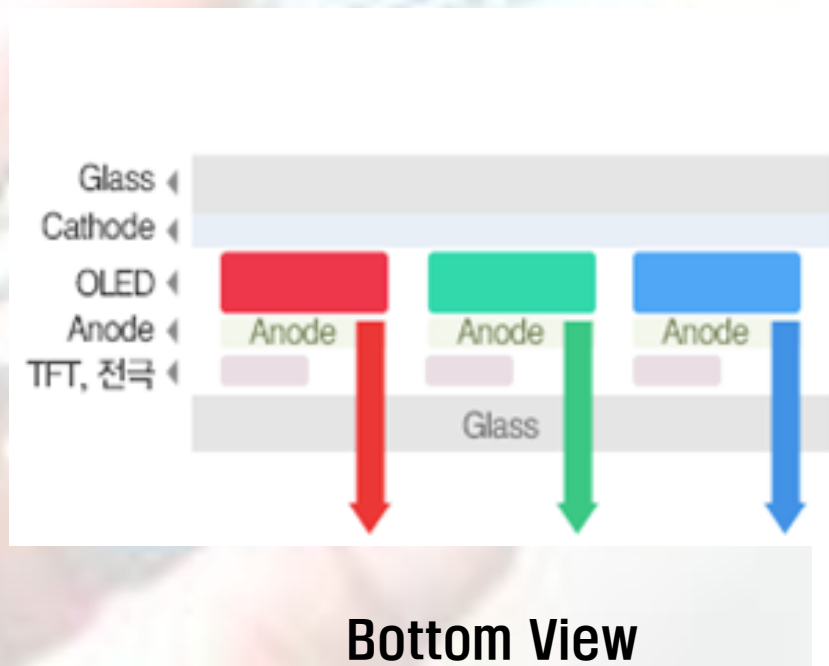
Thinner, lighter, unbreakable



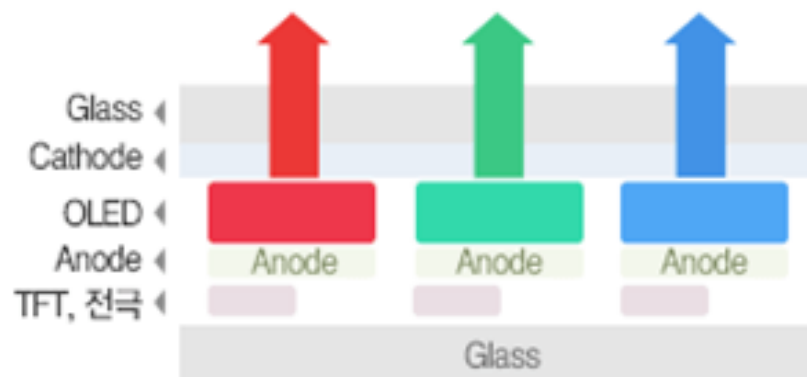
Flexible OLED

# OLED 구조

대형 OLED

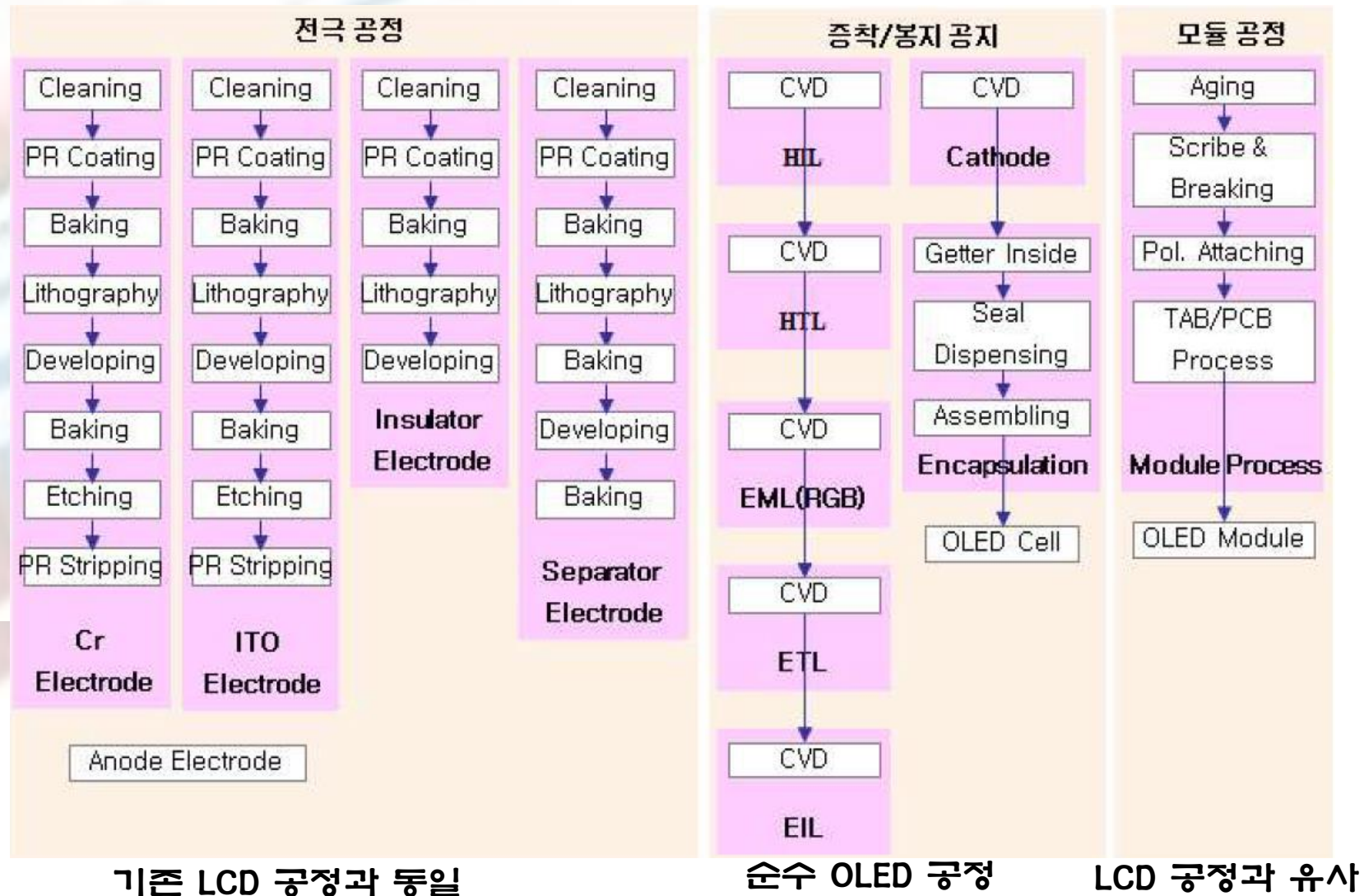


Top View

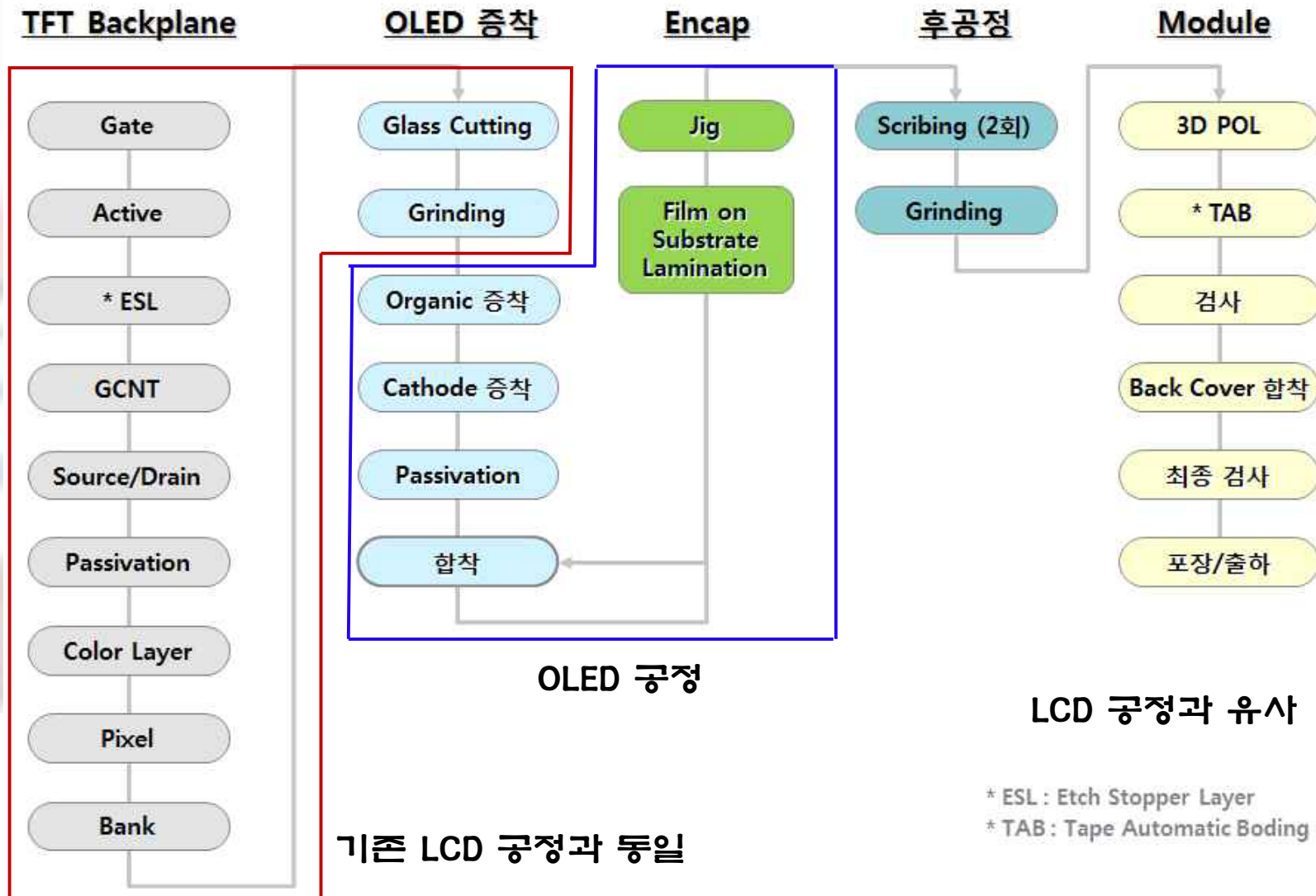


모바일 폰

# RGB-OLED 제조 공정

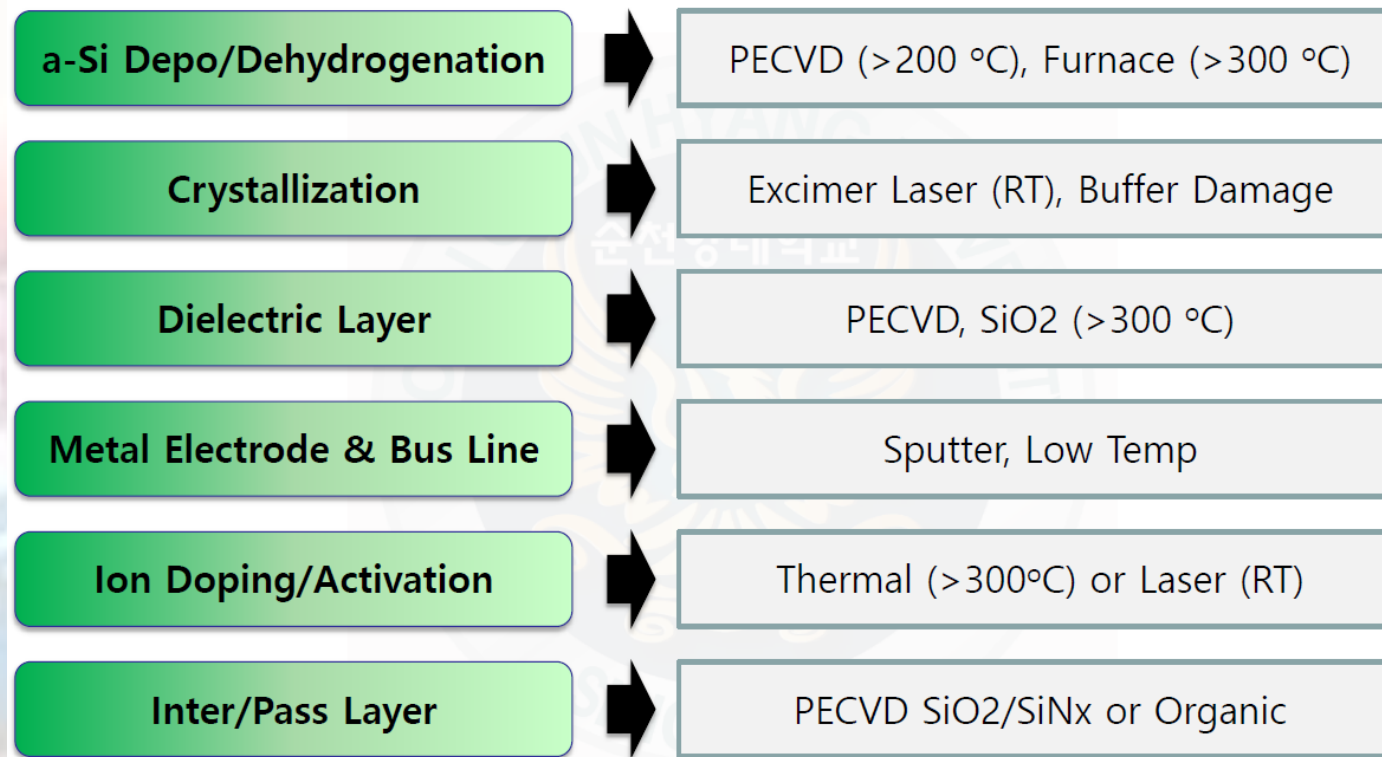


# W-OLED 제조 공정





# LTPS TFT Backplane 공정

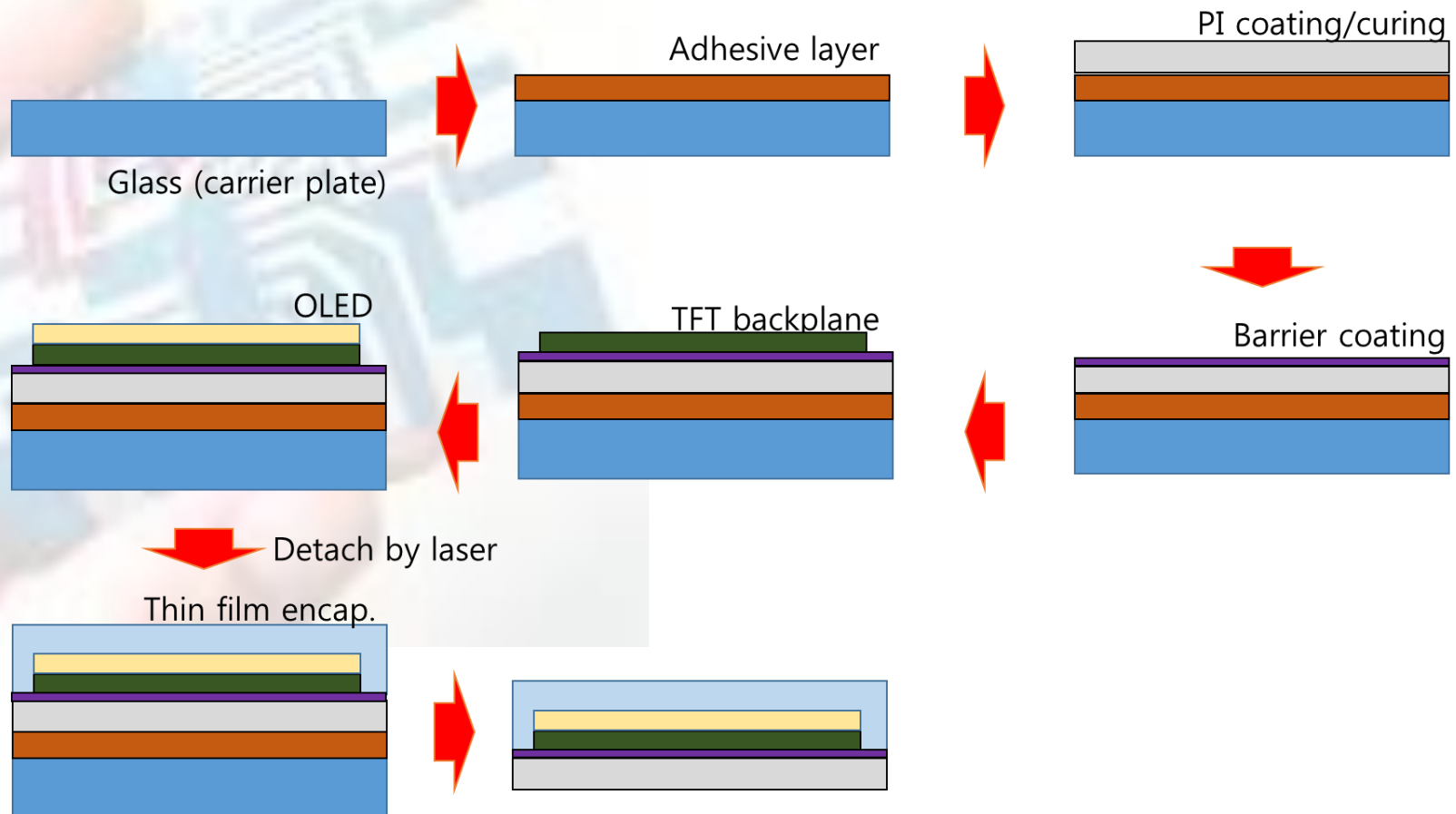


LTPS TFT 공정온도에 견딜 수 있는 기판 필름이 요구됨



# Process for polymer film

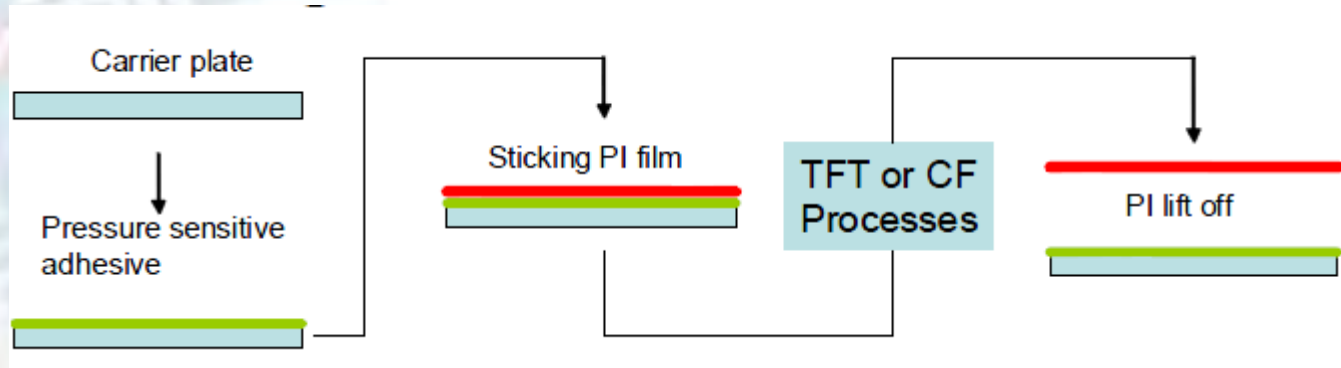
- 유리 기판위에 PI 필름을 형성한 후 디바이스 제작



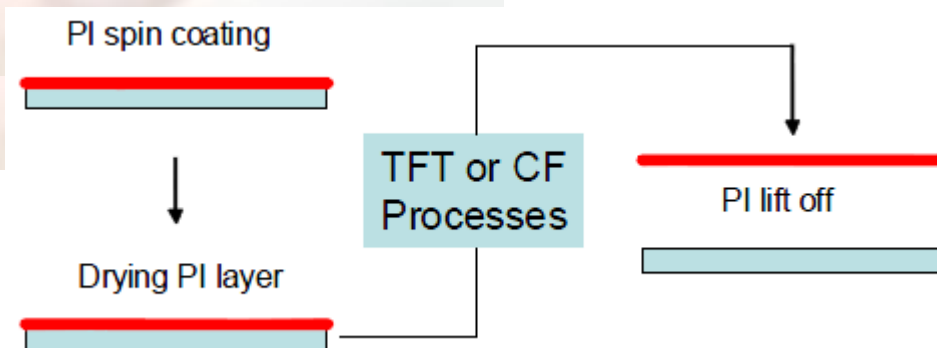
# OLED 기판 형성 기술

❖ 플렉시블 OLED용 기판으로는 PI 필름이 사용되는데 형성 기술로는 2가지가 있음

➤ PI 필름을 직접 carrier 기판에 부착하여 사용하는 기술

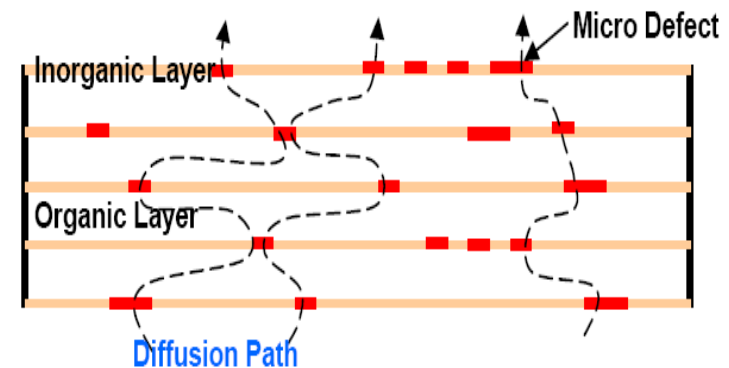


➤ PI varnish를 사용하는 기술



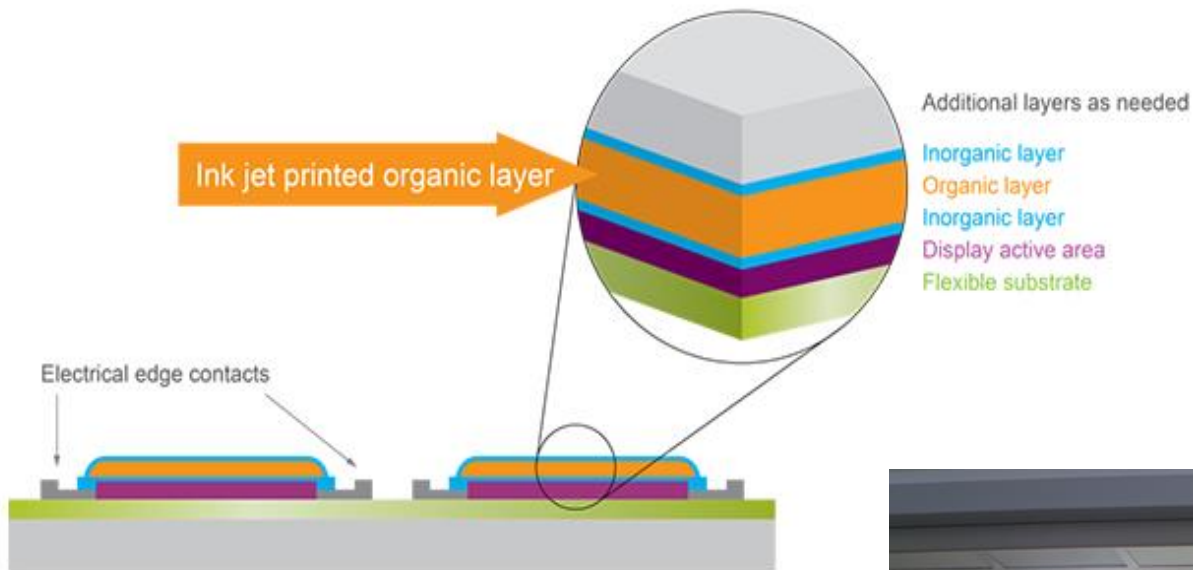
# Barrier coating

- Polymer 기판의 양면에 유기 or 무기막을 단일 또는 다층으로 형성
  - Inorganic layer :  $H_2O$ , oxygen 차단
  - Organic layer : diffusion path 증가
- 공정시 온도 변화에 따른 수축 팽창 제어 효과



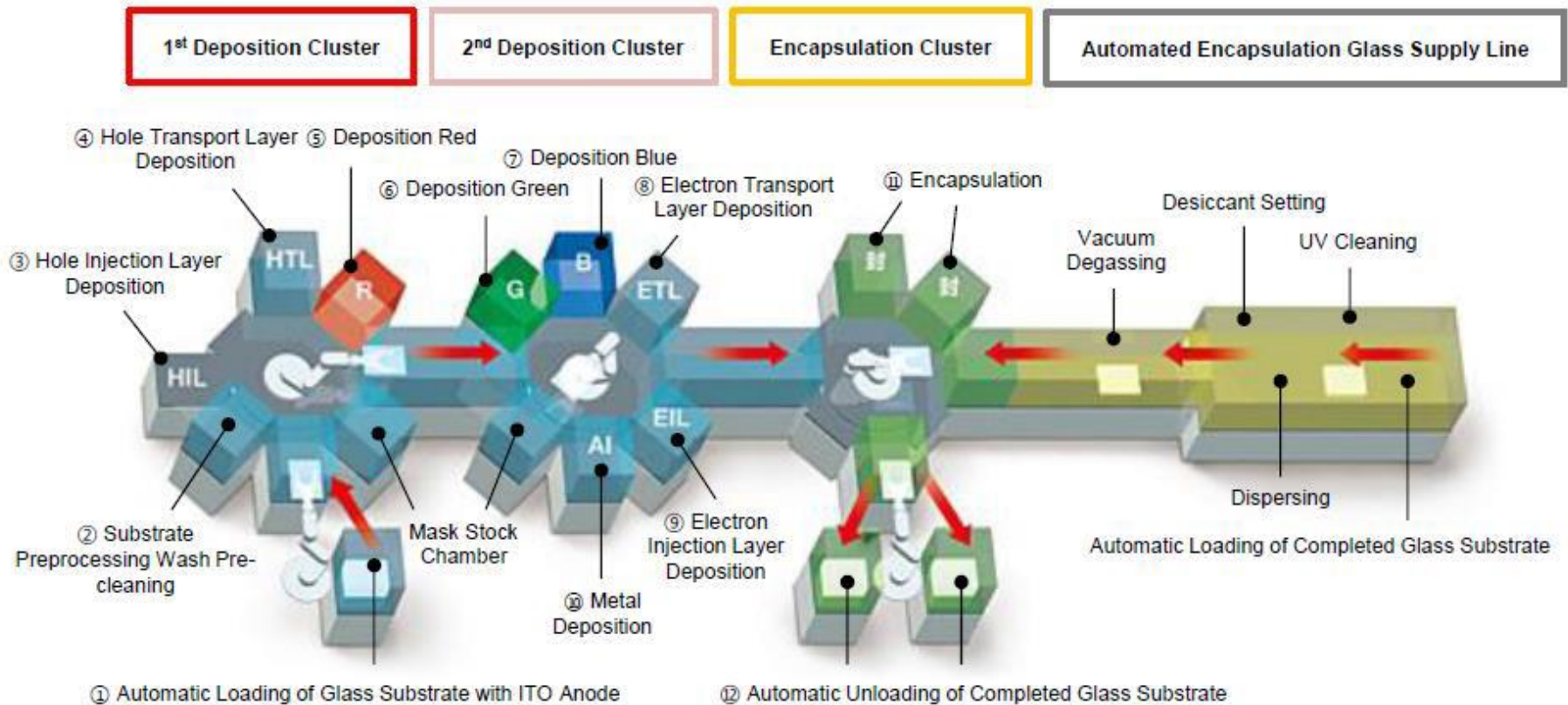
Barrier type	WVTR	OTR	Strengths	Weaknesses
Polymer (no barrier)	$10^2$ to $10^{-1}$	$10^{-1}$ to $10^1$	Excellent clarity Excellent Flexible and tough	Low performance
Inorganic	$10^0$ to $10^{-2}$	$10^{-1}$ to $10^0$	Good clarity Good flexible	Brittle in tension
Multilayer of inorganic & organic	$10^{-3}$ to $10^{-6}$	$10^{-1}$ to $10^{-4}$	Good clarity Good flexible	Somewhat brittle High cost

# TFE 공정



출처 : <http://ko.kateeva.com>

# OLED 증착 시스템



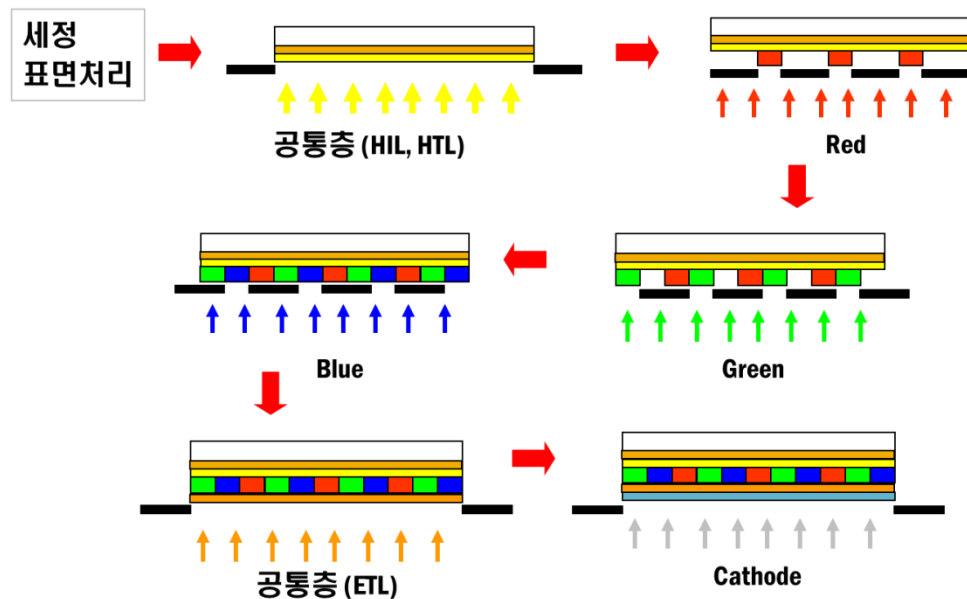
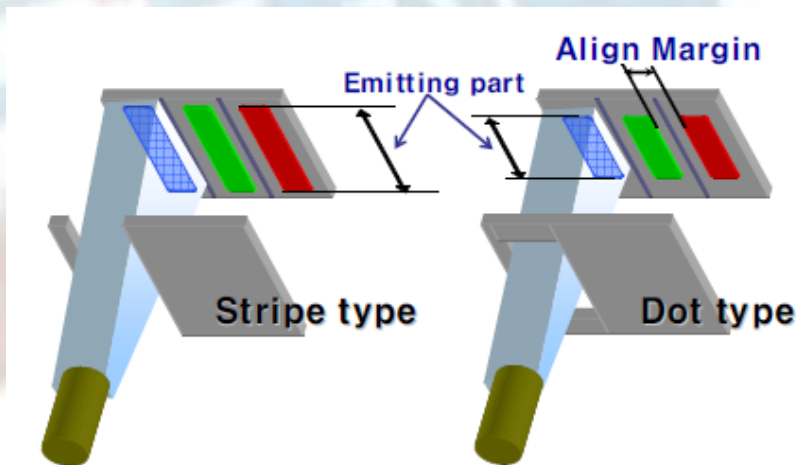
# FMM

## FMM : Fine metal mask

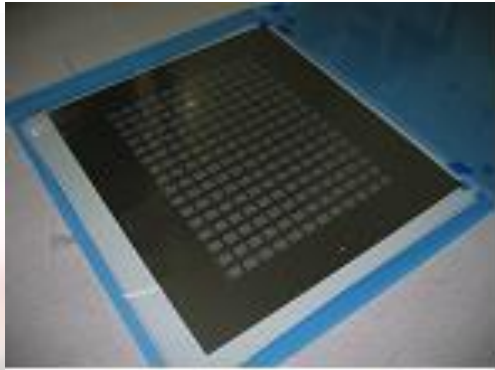
Fine shadow mask is fabricated by electroforming or laser.

Stripe type : Low aperture ratio, sagging problem

Dot type : Inner shadow → Lower aperture ratio



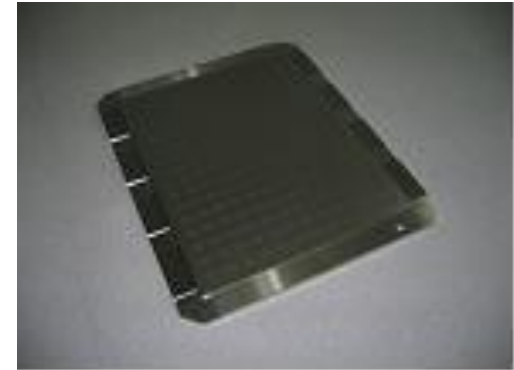
# Shadow mask 구성 및 제작 방법



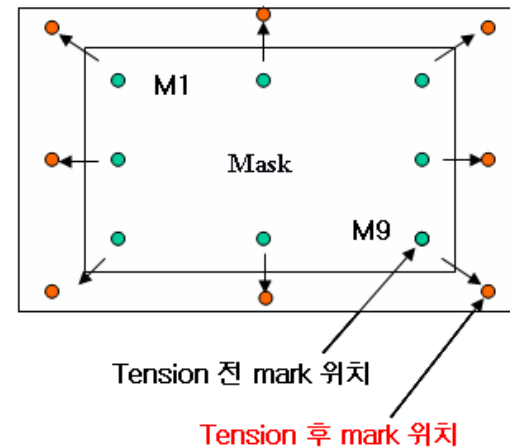
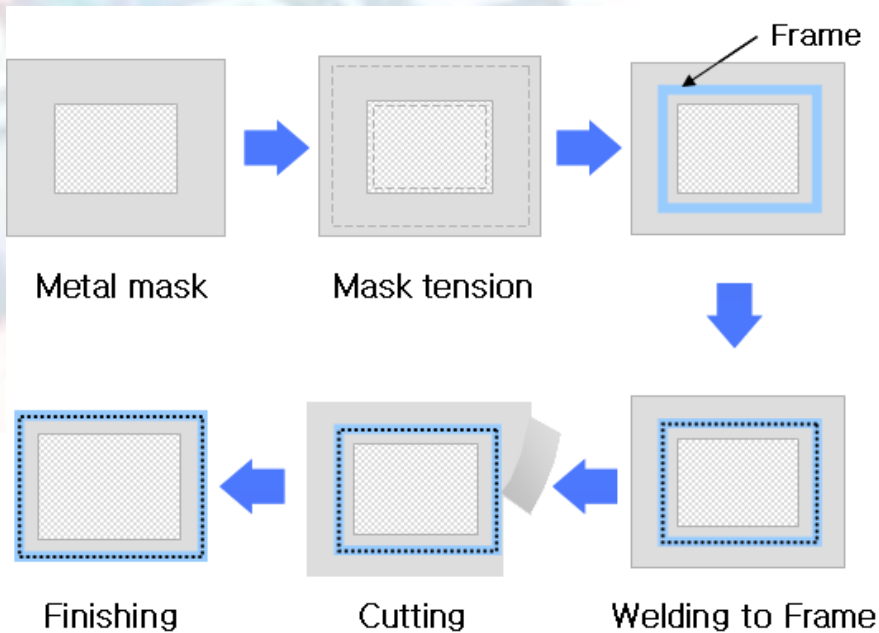
Metal shadow mask



Frame



Mask ass'y

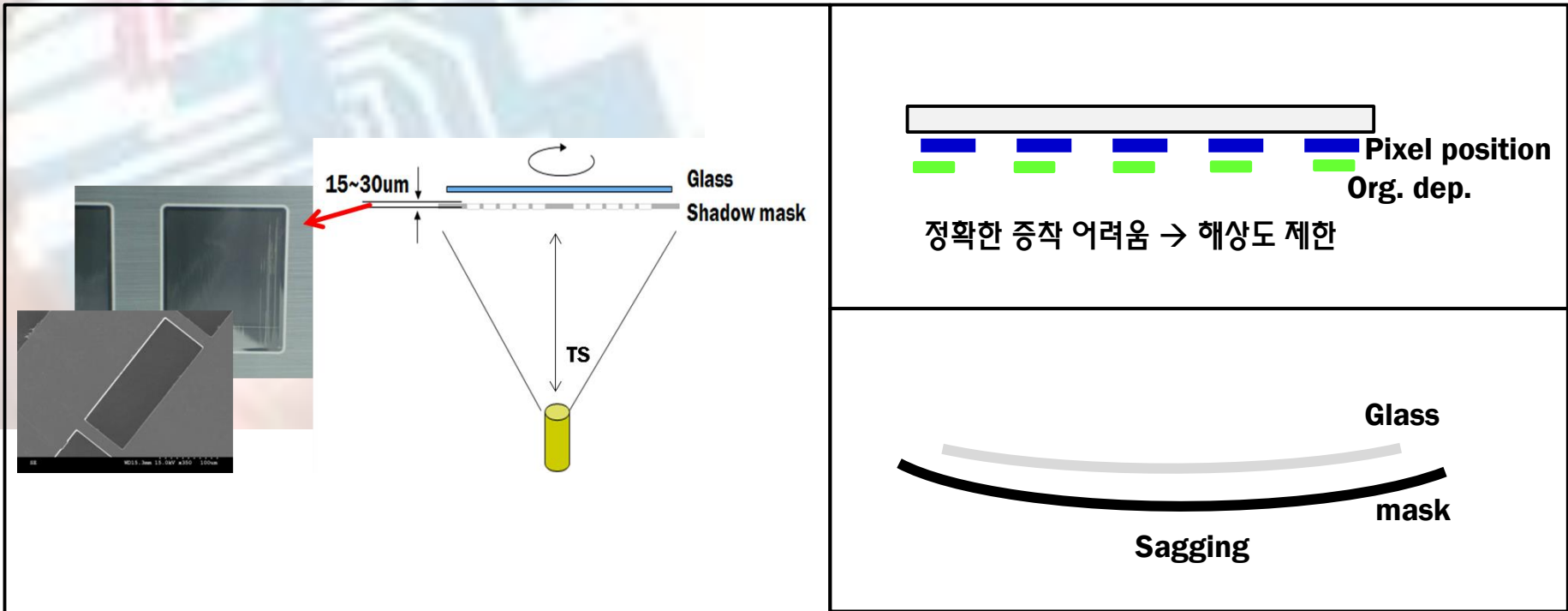




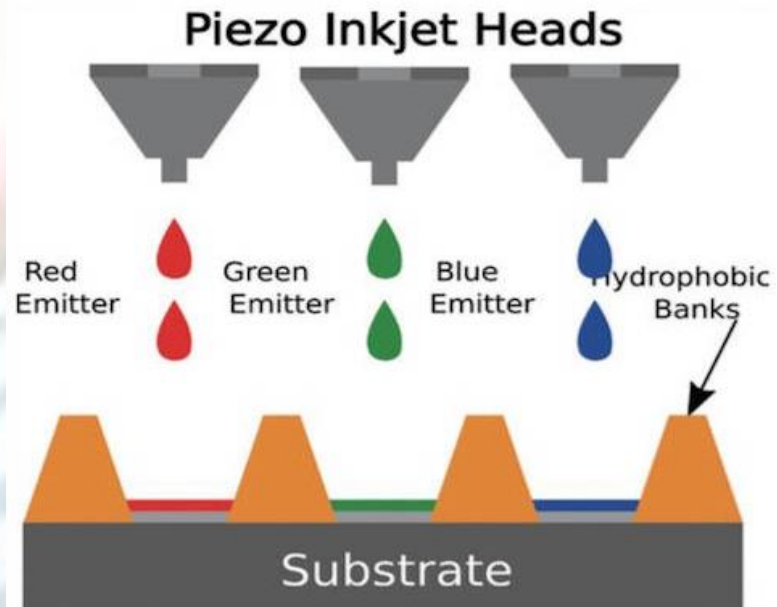
# Issue of FMM

- Issue

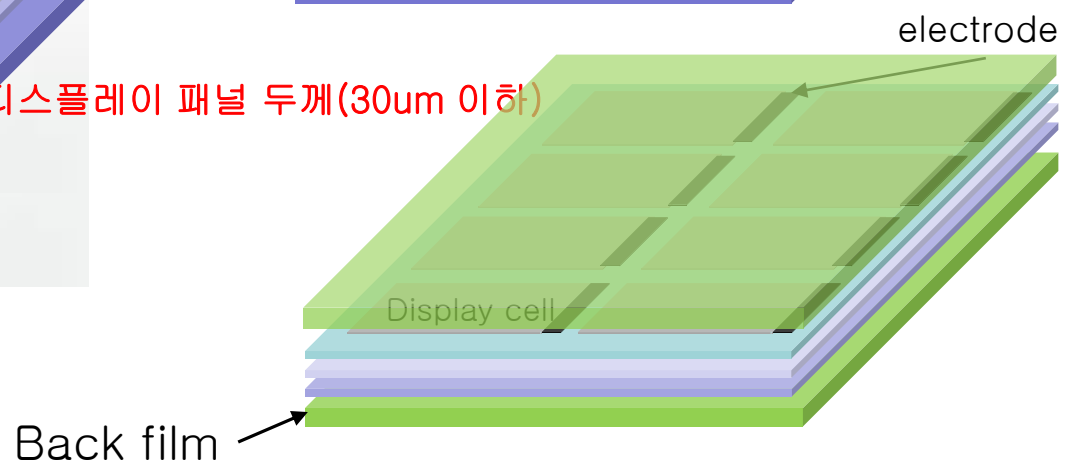
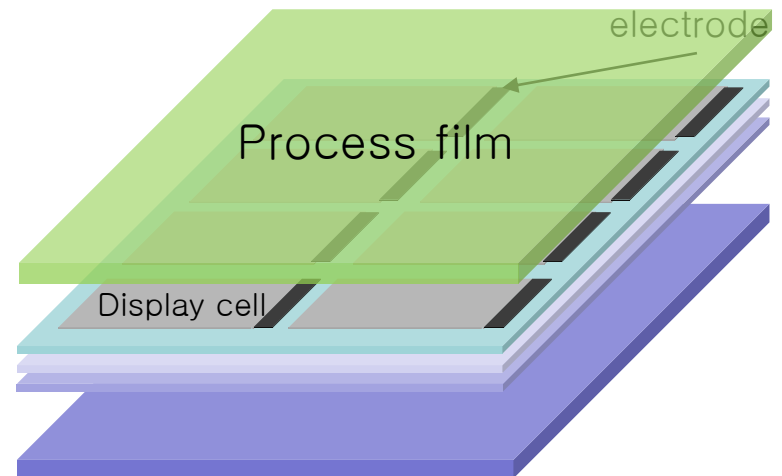
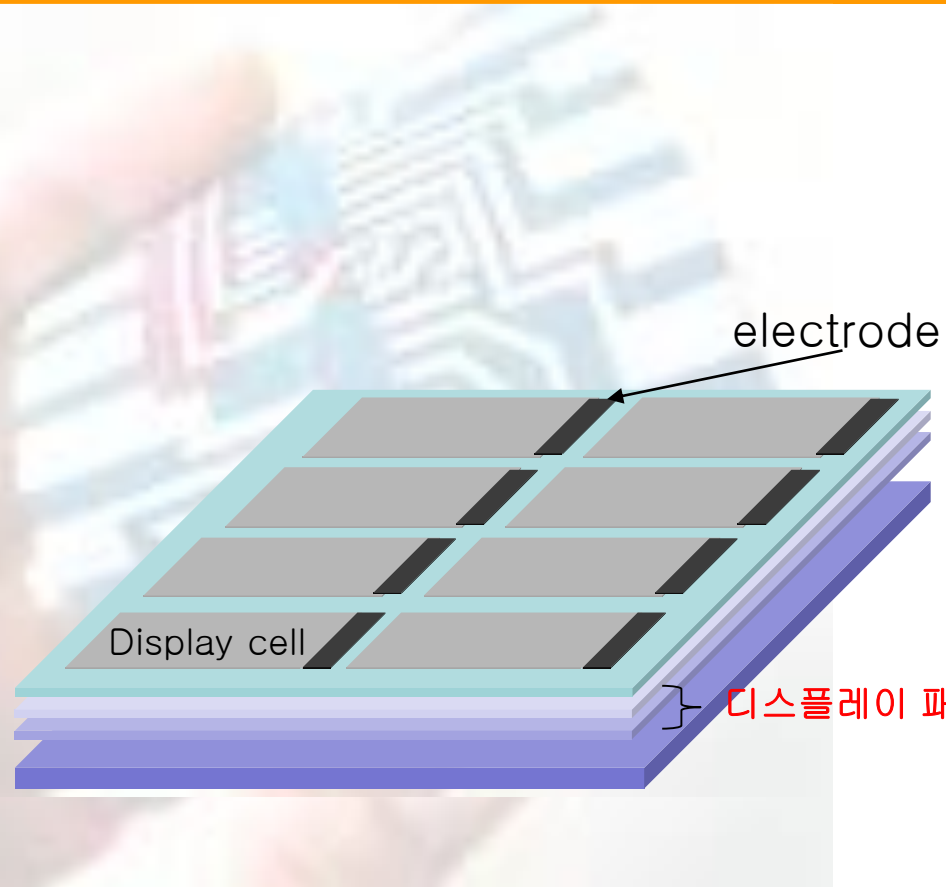
- Mask : fabrication, sagging, cleaning
- Equipment : Scalability, alignment, mask expansion
- Device : high resolution, particle



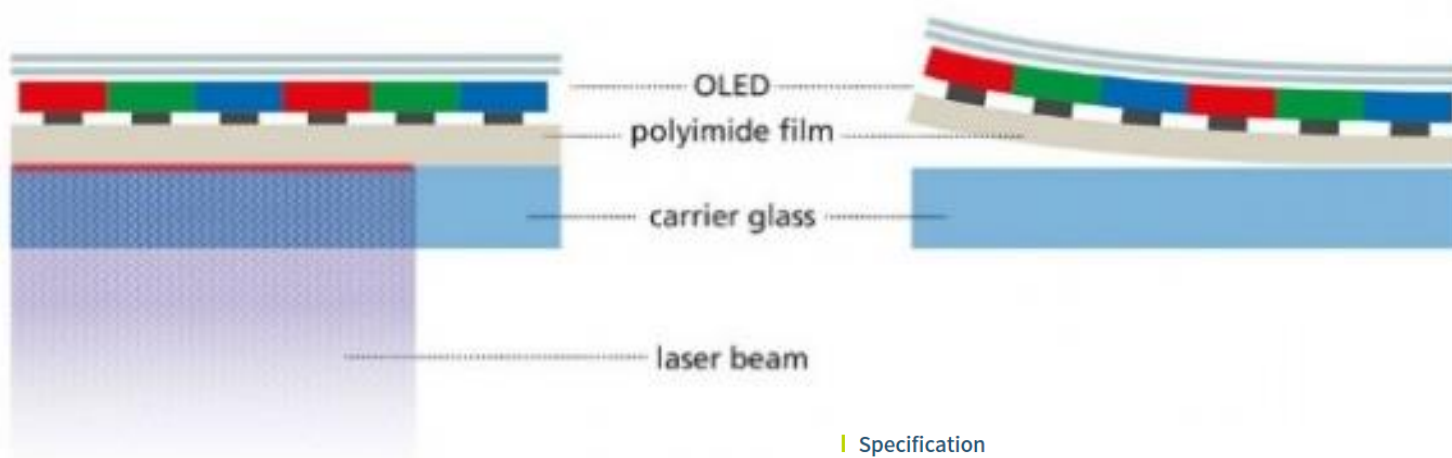
# Ink jet 공정



# OLED 제조 공정(1)



# LLO 장비



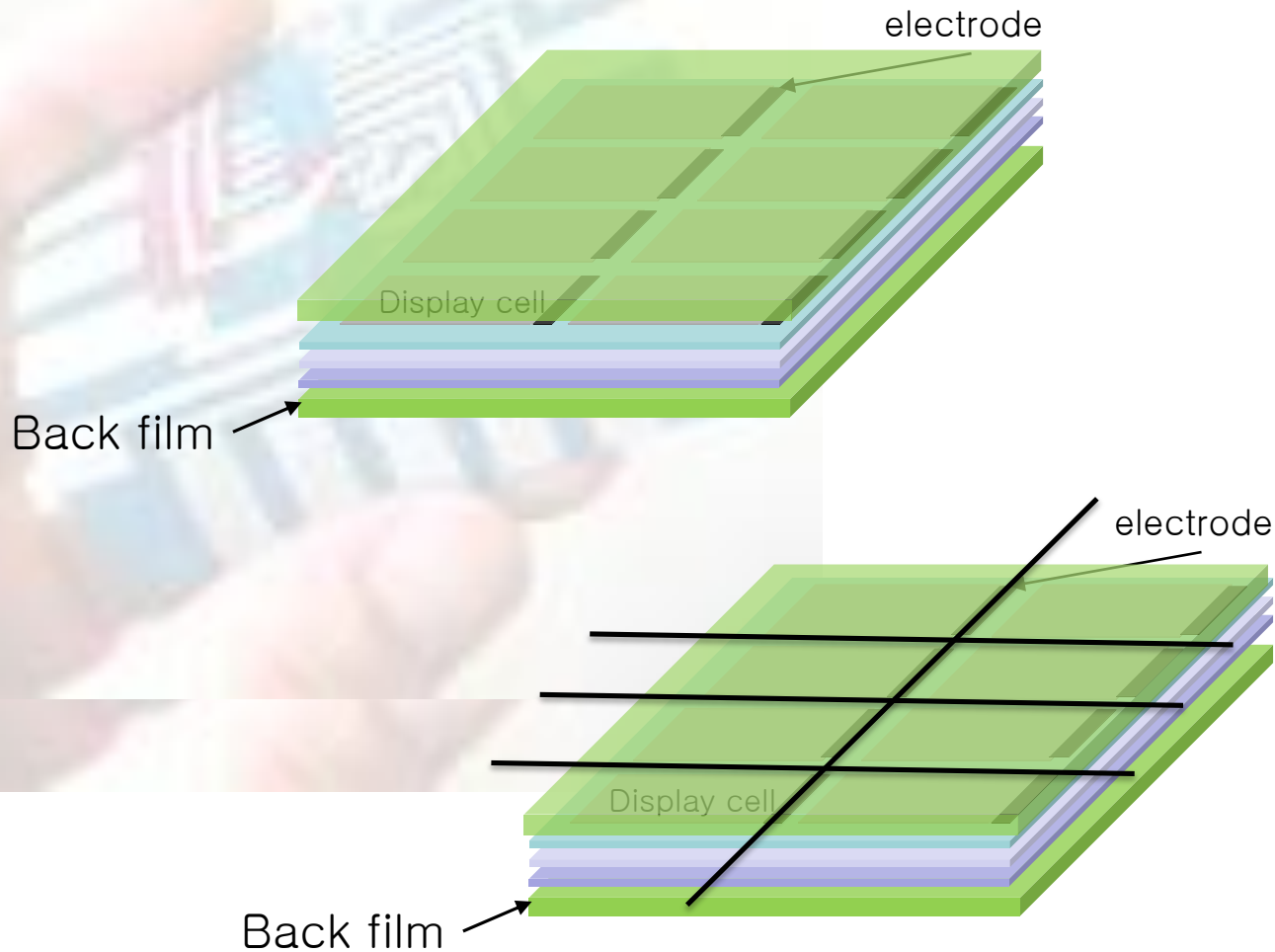
LLO System

AP시스템이 개발한 LLO. (사진=AP시스템)

## Specification

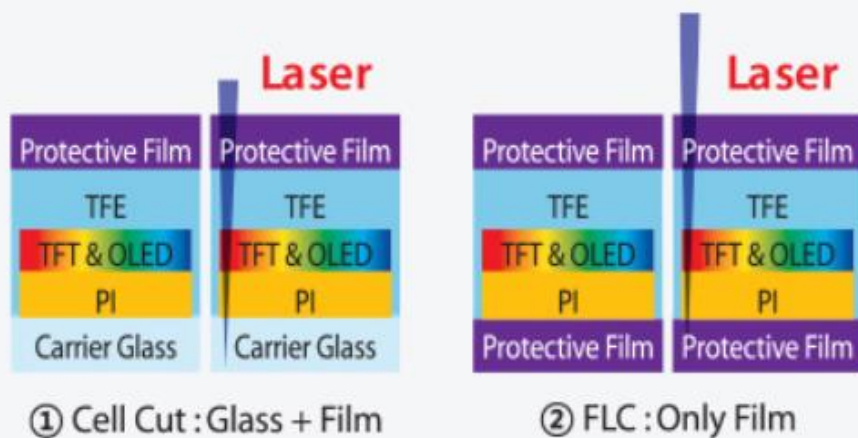
Laser Type	Excimer Laser
Laser Wavelength	308nm (XeCl)
Laser Repetition Rate	600Hz
Laser Pulse Energy	1J, 2J
Laser Uniformity	Long Axis ( $2\sigma$ ): $\leq 1.8\%$ (@96%), Short axis ( $2\sigma$ ): $\leq 3.0\%$ (@96%)
Stage Type	Single Plane or Stack Plane
Stage Position accuracy	X1, X2 axis: $\leq \pm 4\mu\text{m}$ , Y1, y2 axis: $\leq \pm 4\mu\text{m}$
Process Environment	ATM

# OLED 제조 공정(2)



레이저 cutting

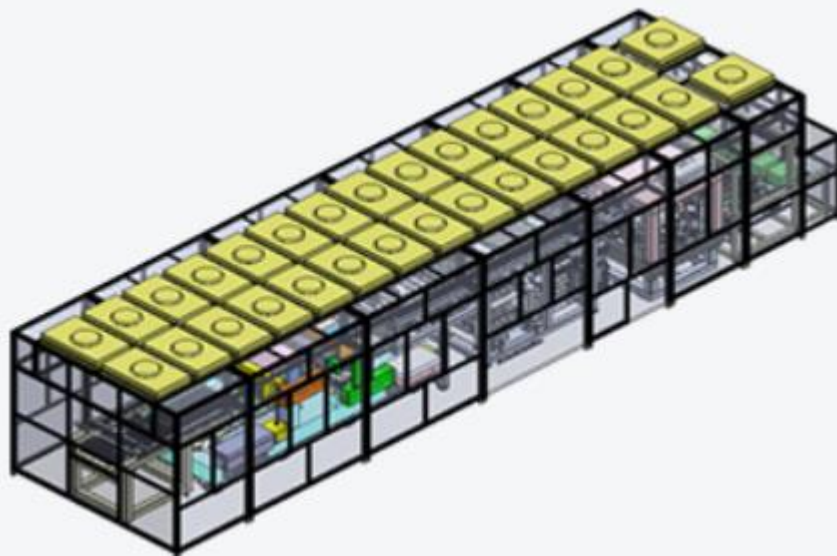
# OLED cutting



\* Diode-pumped solid-state laser

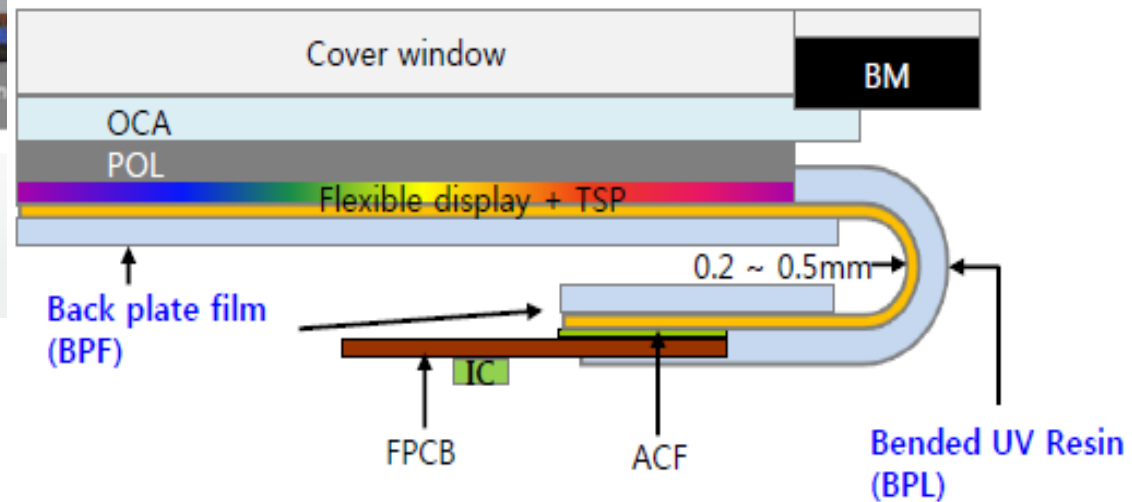
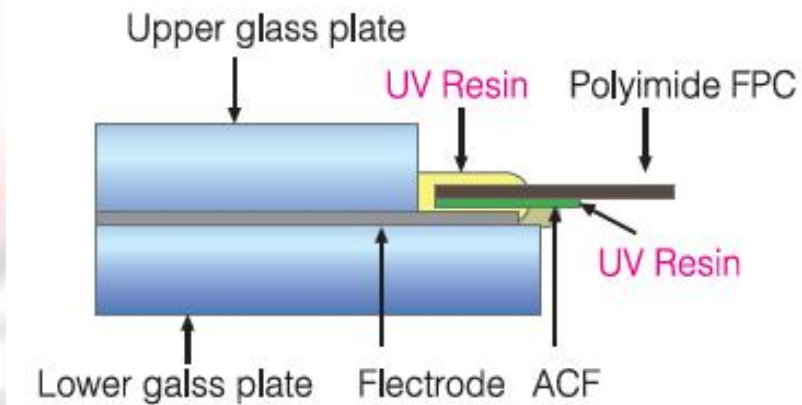
## Specification

Laser Type	DPSSL / CO <sub>2</sub>
Laser Wavelength	355nm(UV), 532nm(Green), 1064nm(IR), 9.6um
Cutting Accuracy	≤ ±50um
Model change	Working table(Auto change ≤ 1hour)
Stage Type	Single Plane or Stack Plane
Process Environment	ATM
Software	Easy Cluster™
Safety Certification	CE, SEMI, S-Mark



출처: <http://www.apsystems.co.kr>

# OLED 모듈 제조 공정





# OLED 장비 공급업체[삼성]

삼성디스플레이의 OLED 장비 밸류 체인

공정		장비	장비 공급업체
Flexible		PI Coating	에스에프에이
		PI Curing	테라세미콘
TFT	Cleaning	Cleaner	(日)Shibaura, (日)DNS, 케이씨텍, 세메스, 디엠에스, STI
	Deposition	PECVD	(美)AMAT, (日)Ulvac, SFA
		Sputter	(日)Ulvac, 이루자
	Annealing	Dopant Activation	(日)MES, 테라세미콘, 비아트론
	Doping	Ion-implanter	(日)Nissin
	Crystallization	ELA	AP시스템
		Non-Laser	테라세미콘, 비아트론
	Lithography	Dry Etcher	(日)YAC, (日)TEL, 아이씨디, 원익IPS
		Wet Etcher	세메스, 케이씨텍, 디엠에스
		Stripper	세메스, 케이씨텍, 디엠에스
		Exposurer	(日)Canon, (日)Nikon

# OLED 장비 공급 업체(삼성)

공정	장비	장비 공급업체
RGB patterning	Evaporator	(日)Tokki, (日)Hitachi, (日)Ulvac, SNU, SFA
	Inkjet Printing	(美)Kateeva
Encapsulation	Glass	AP시스템, 엘아이에스, 테라세미콘
	Thin Film	(日)Ulvac, SNU, (美)Kateeva, (美)AMAT, 원익IPS, 세메스, (美)Veeco
	Hybrid	SFA
Cell	LLO	AP시스템
	Cutting	로체시스템즈
Other	FA	(日)Daifuku, SFA, 톱텍
	Inspection	HB테크놀러지, 케이맥, 엔비전
	Repair	참엔지니어링

# LGD 장비 공급업체



공정		장비	장비 공급업체
Flexible		PI Coating	New long, Seria, 나레나노텍
		PI Curing	비아트론
TFT	Cleaning	Cleaner	(日)Shibaura, (日)DNS, 케이씨텍, LIG인베니아, 디엠에스
	Deposition	PECVD	(美)AMAT, 주성Eng
		Sputter	(日)Ulvac, 이루자
	Annealing	Dopant Activation	테라세미콘, 비아트론
	Doping	Ion-implanter	(日)Nissin
	Crystallization	ELA	(日)JSW
		Non-Laser	비아트론
	Lithography	Dry Etcher	(日)YAC, (日)TEL, LIG인베니아
		Wet Etcher	케이씨텍, 디엠에스
		Stripper	케이씨텍, 디엠에스
		Exposurer	(日)Canon, (日)Nikon
RGB patterning		Evaporator	(日)Tokki, (日)Hitachi, 야스, 주성Eng, LIG인베니아, (日)Ulvac
		Inkjet Printing	(日)TEL
Encapsulation		Glass	아바코, 탑Eng, 주성Eng
		Thin Film	아바코, 주성Eng
		Hybrid	주성Eng, LIG인베니아, 아바코, Seria
Cell		LLO	이오테크닉스
		Cutting	(日)MDI, 탑Eng
Other		FA	신성FA, 아바코
		Inspection	탑Eng, 참Eng
		Repair	참Eng

# 장비 수출비중

국가별 디스플레이 장비 수출 비중(단위: 백만\$)

	전체	중국	대만	일본	베트남	홍콩
2017.9 누적	2,878	1,345 46.7%	85 3.0%	198 6.9%	1,190 41.3%	36 1.3%
2016	1,731	1,282 74.1%	145 8.4%	126 7.3%	125 7.2%	25 1.4%
2015	1,647	1,308 79.4%	99 6.0%	41 2.5%	127 7.7%	42 2.6%
2014	1,209	1,020 84.4%	77 6.4%	35 2.9%	9 0.7%	39 3.2%
2013	1,127	953 84.6%	66 5.9%	49 4.3%	13 1.2%	30 2.7%
2012	376	225 59.8%	45 12.0%	58 15.4%	2 0.5%	12 3.2%
2011	843	531 63.0%	132 15.7%	102 12.1%	1 0.1%	6 0.7%
2010						3%
2009						3%
2008						2%
2007	322	108 33.5%	90 28.0%	36 11.2%	0 0.0%	22 6.8%

- 삼성디스플레이 하노이 모바일 용 OLED 모듈 장비
- LGD 하이퐁에 OLED TV, 모바일 모듈 장비

\* 출처 : 한국무역협회(KITA)

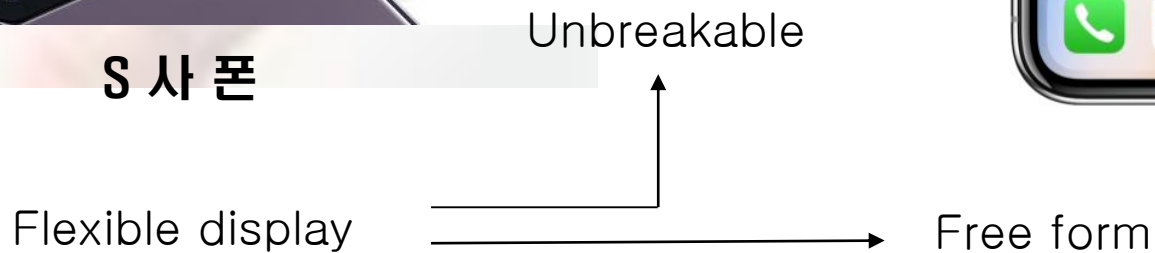
# OLED 모바일 폰



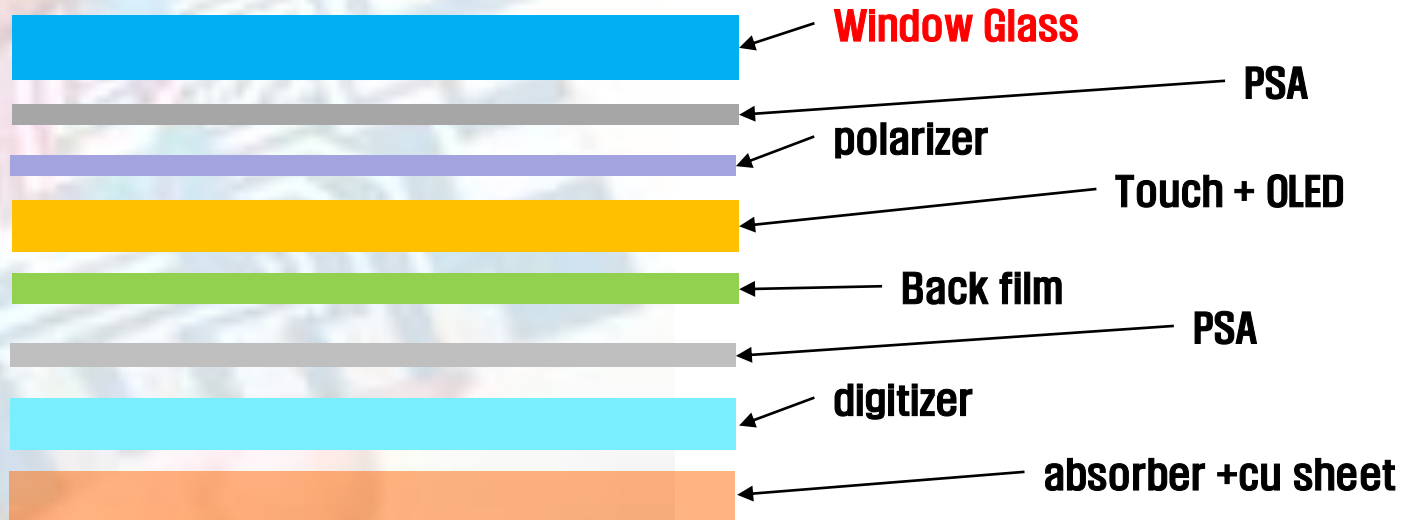
S 사 폰



A 사 폰

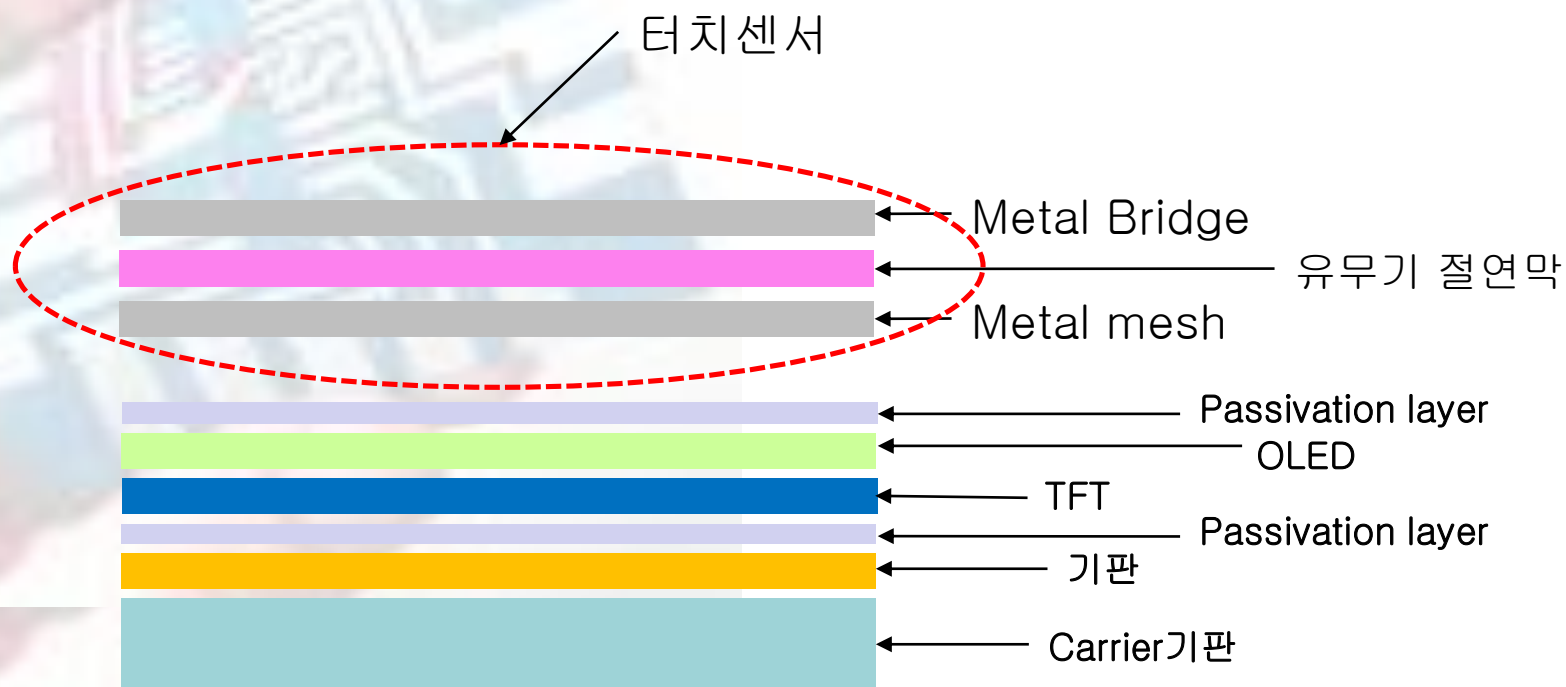


# Smart phone display



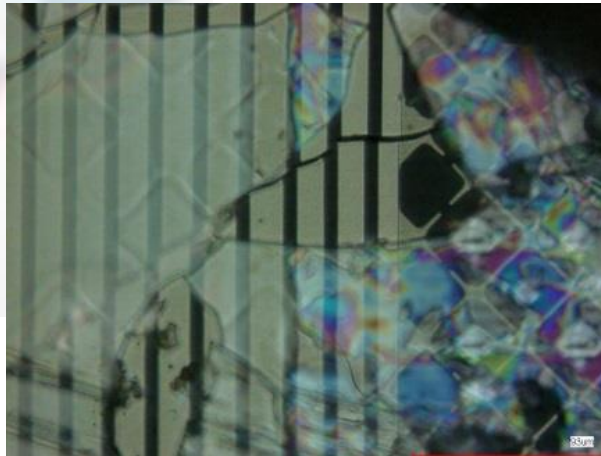
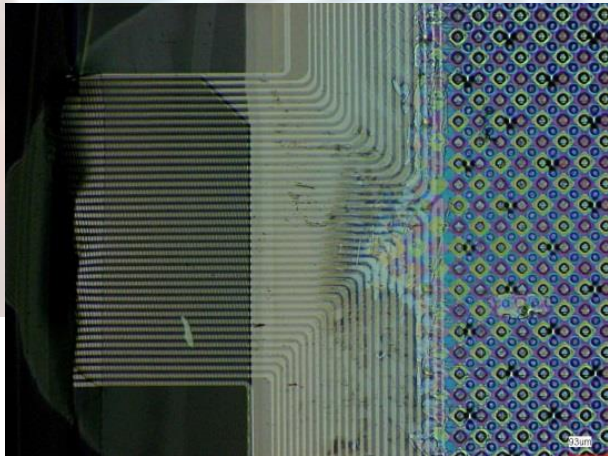
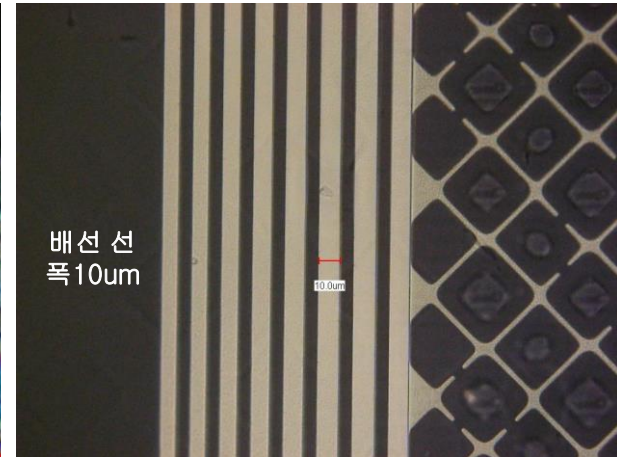
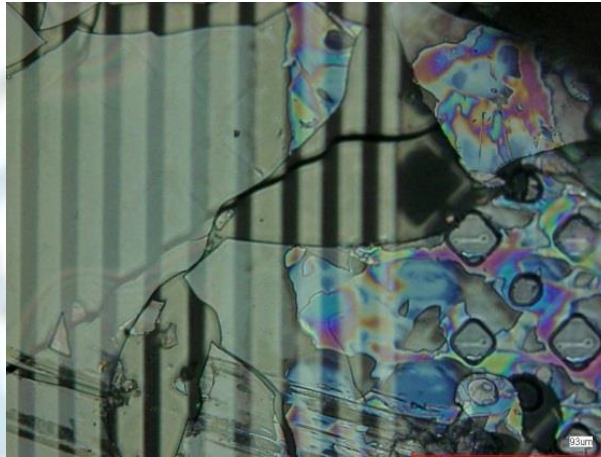
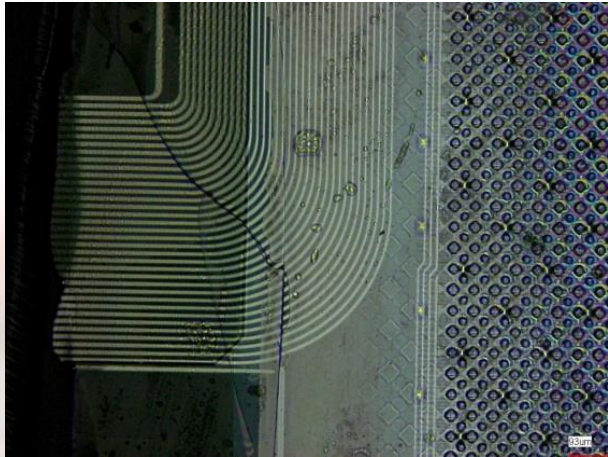
# 일체형 터치센서 구조

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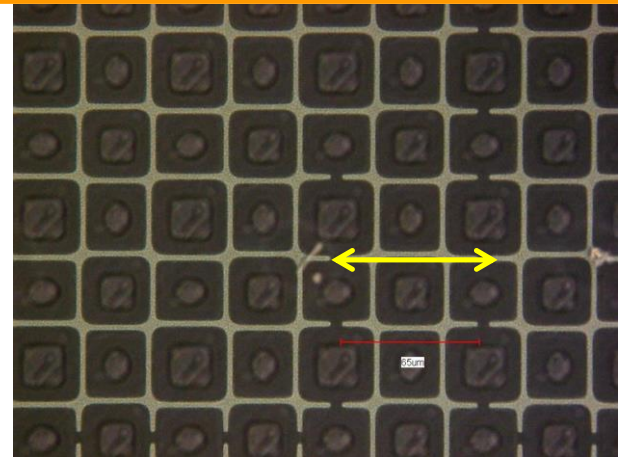
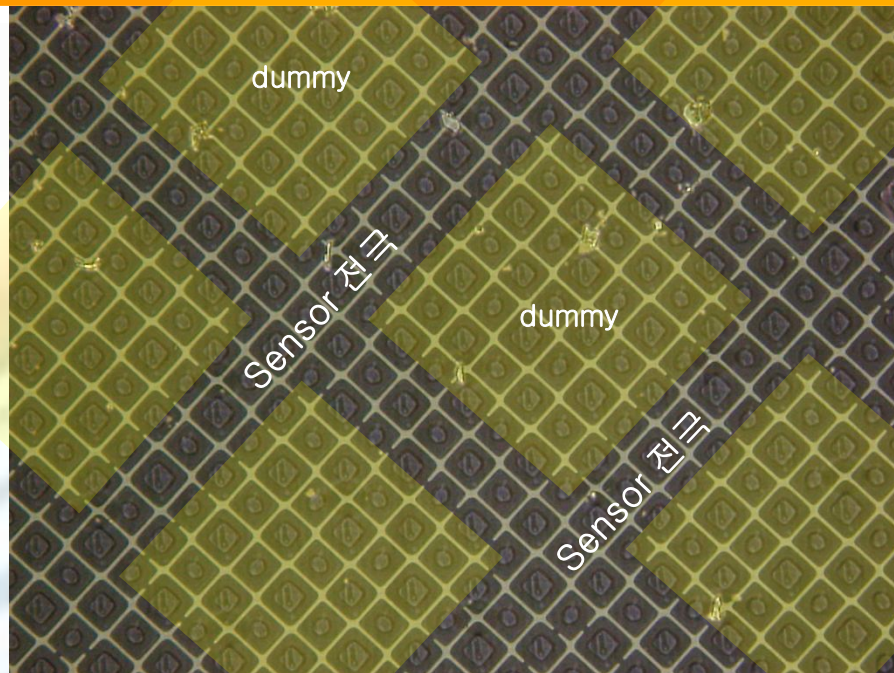


# 일체형 터치센서 1

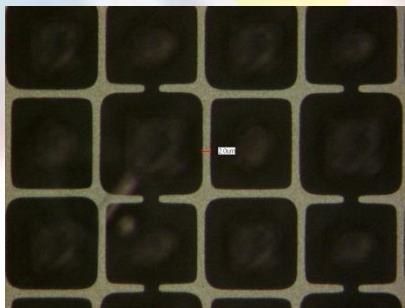




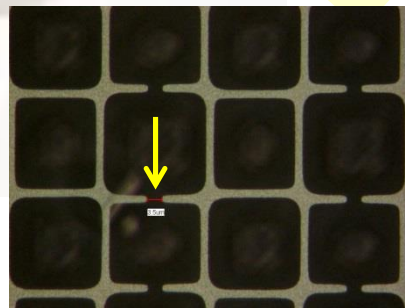
# 일체형 터치센서 2



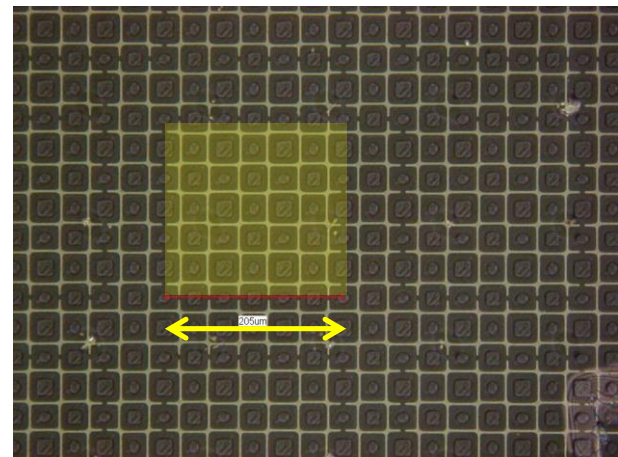
Sensor 전극 치수 : 65um



Mesh 선 폭: 2um



Dummy와 전극 사이 거리 : 3.5um

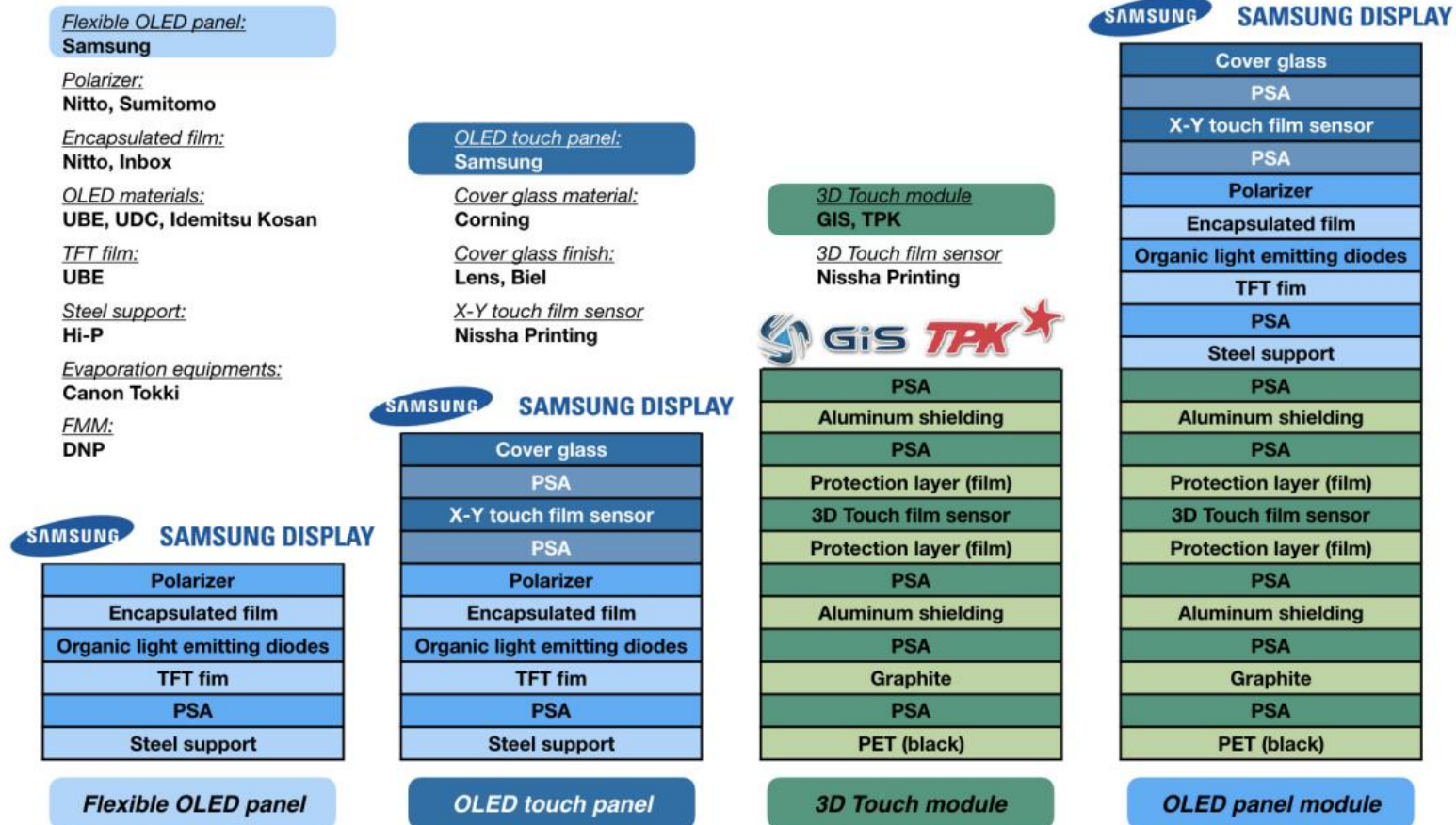


Dummy 치수 (가로, 세로) : 205um

# i-phone x OLED 모듈 구조

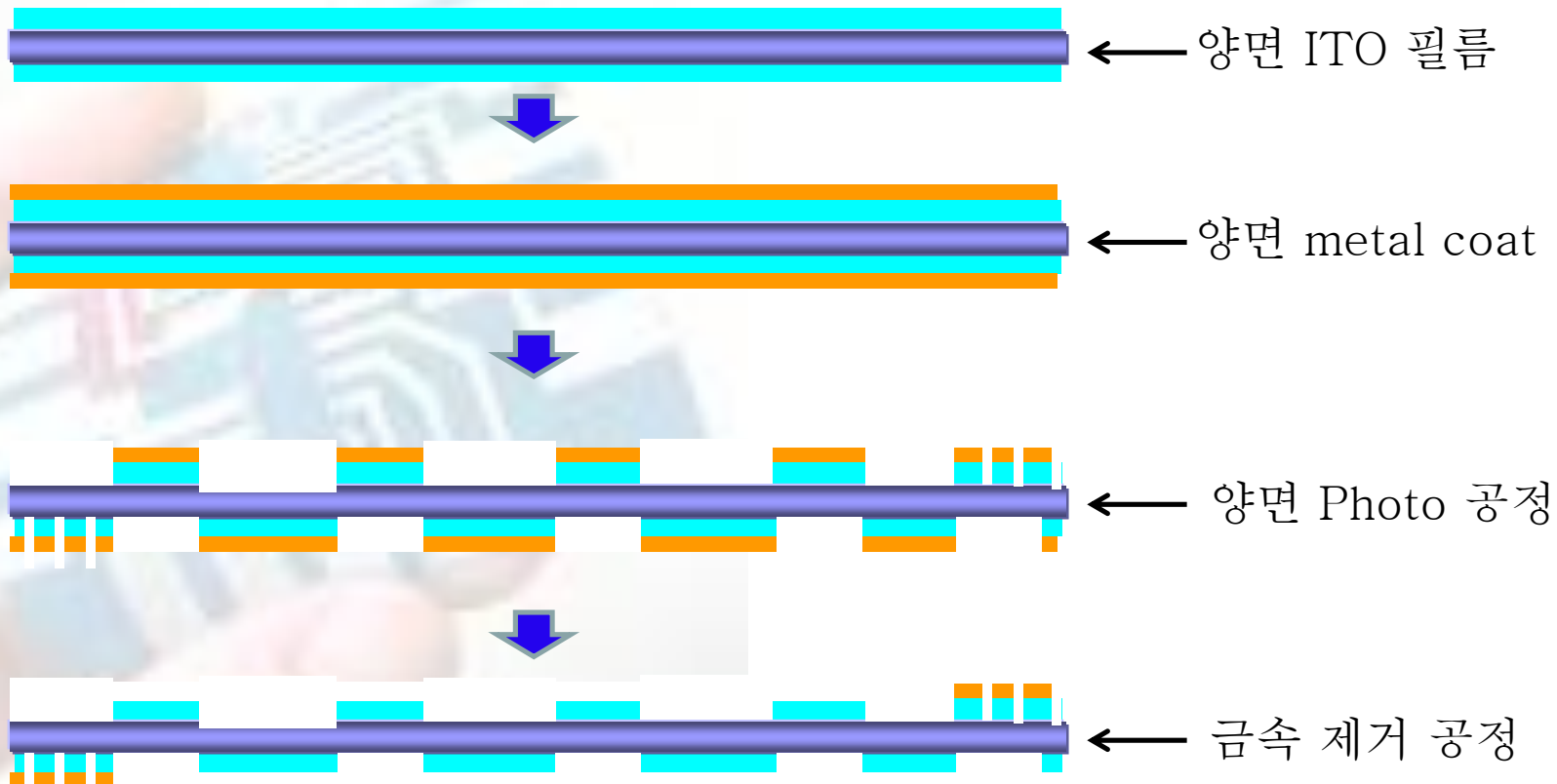
32

Figure 1: Our predictions on structure & supply chain members of OLED iPhone panel



# A사 터치 센서 공정

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# I-phone x 구성

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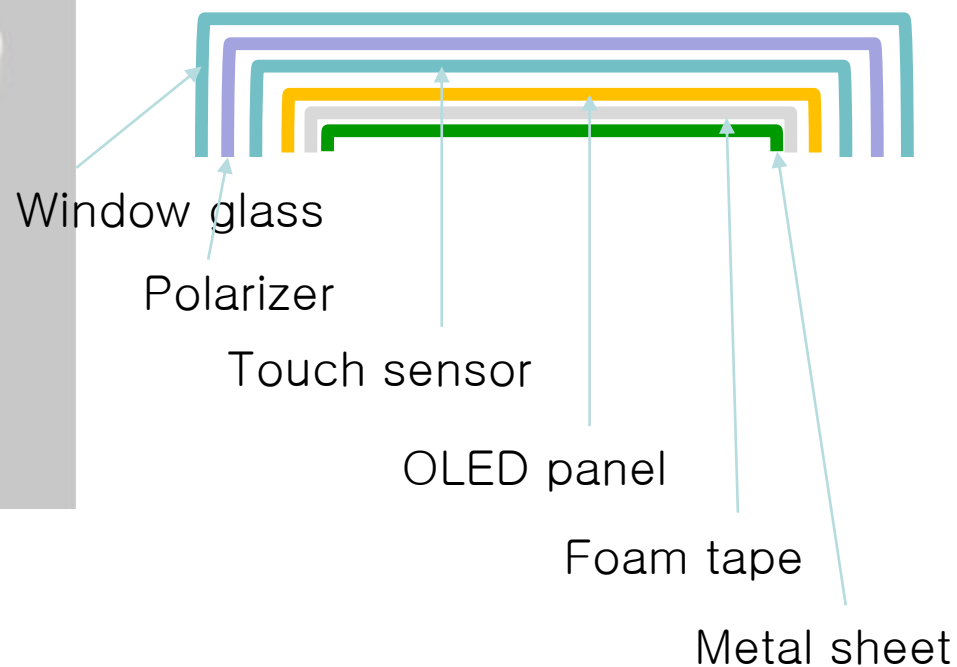
# Foldable smartphone ( Samsung )

35



# 차세대 폰 구조

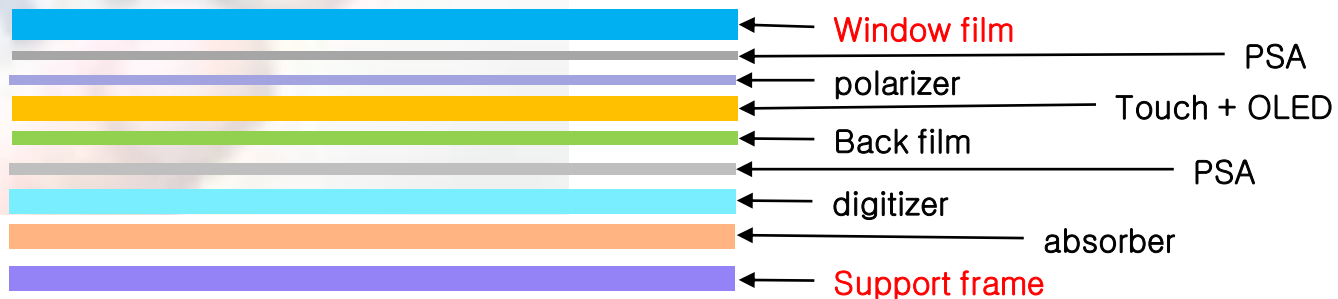
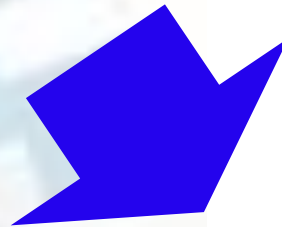
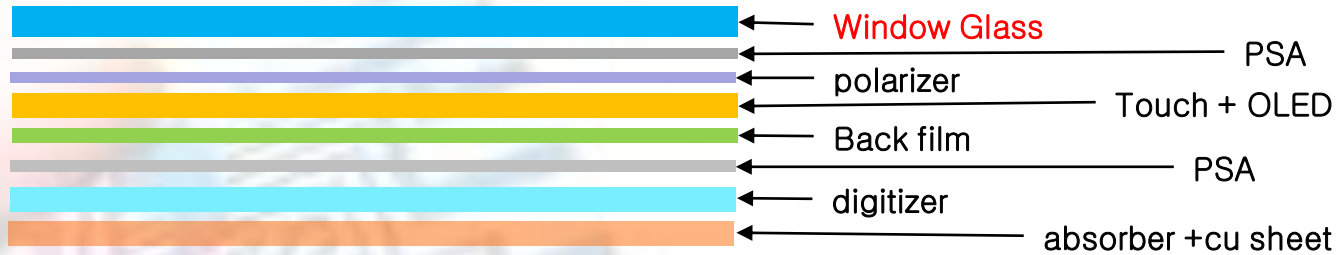
36





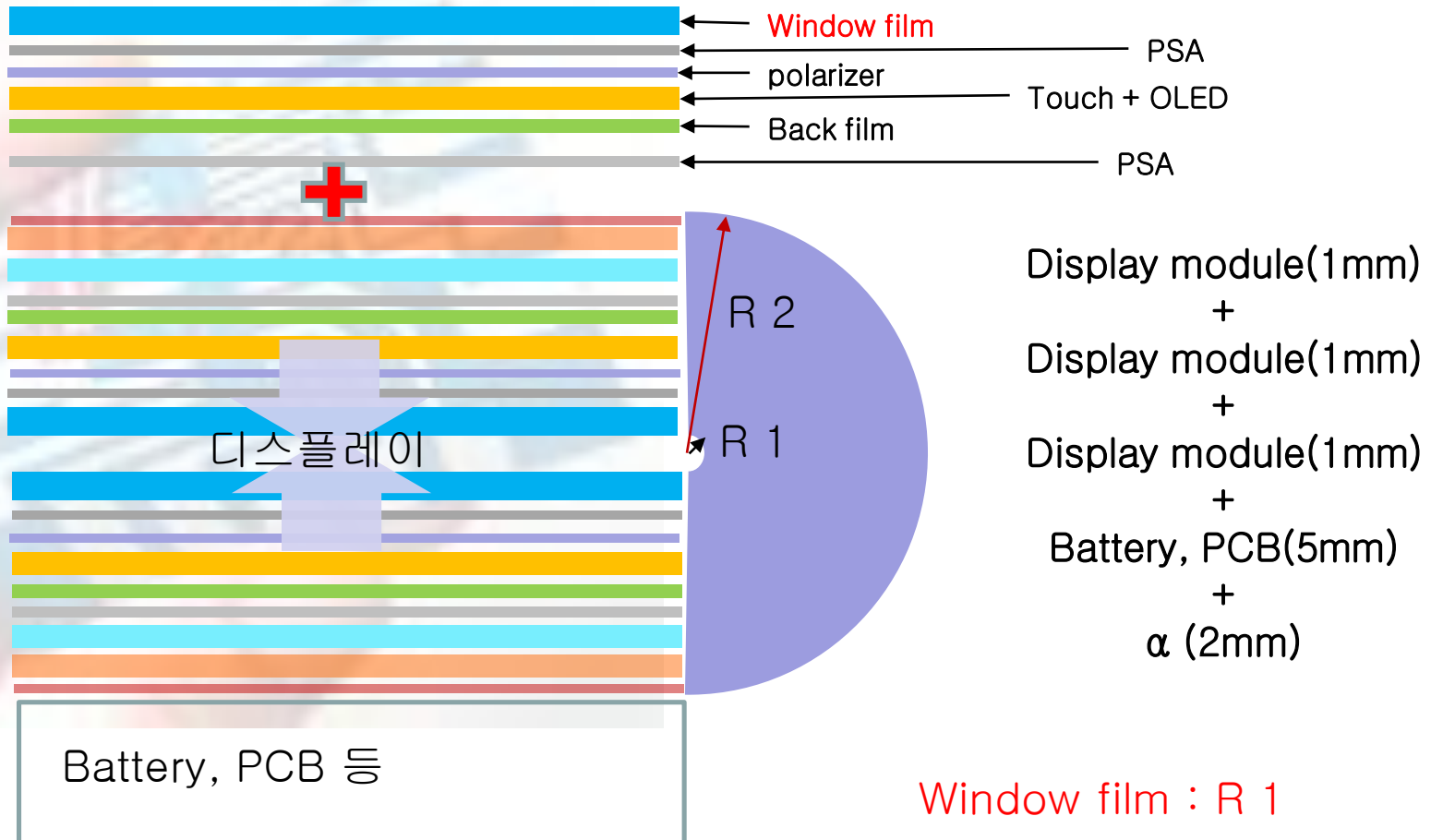
# Foldable display

37



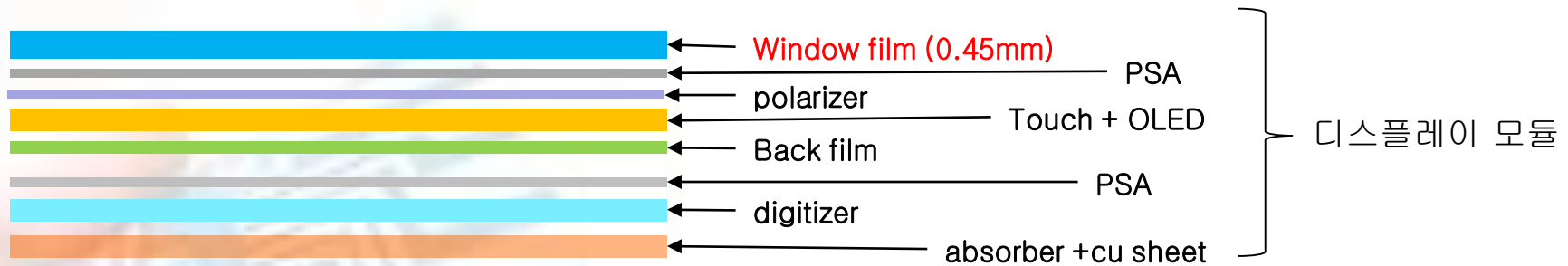
# Foldable display ( in fold )

38

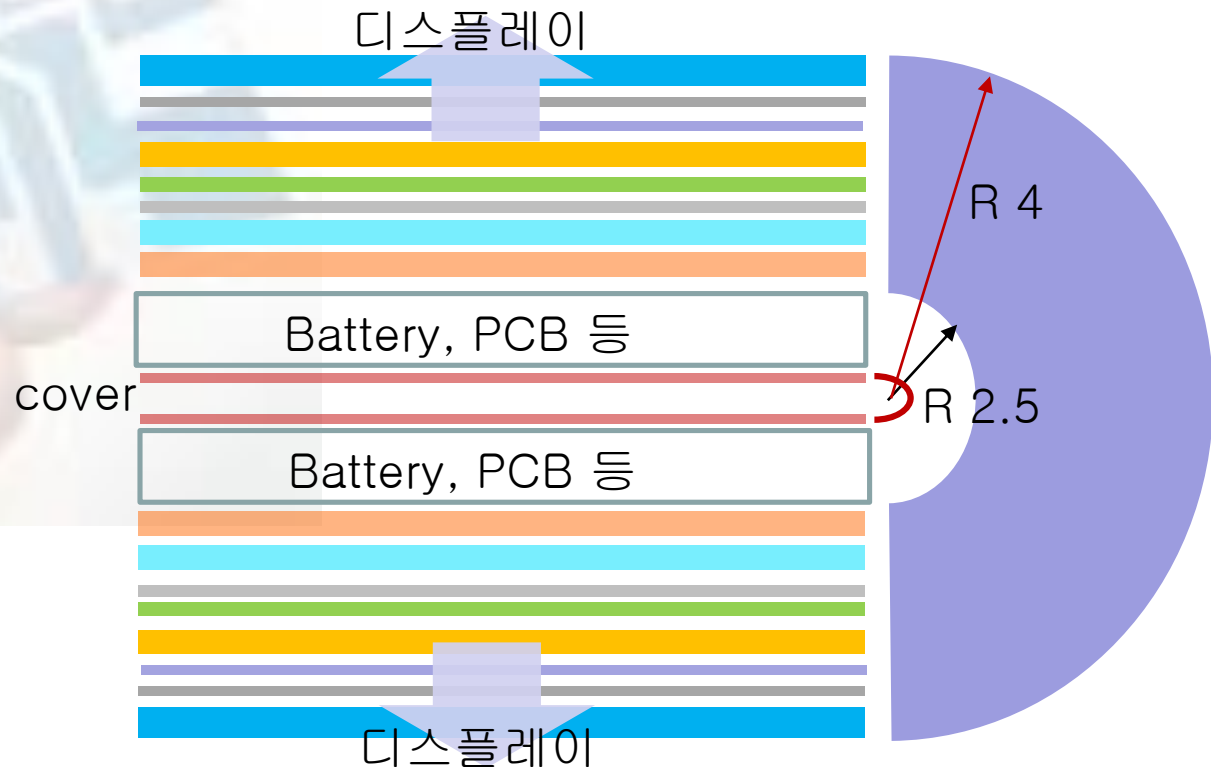


# Foldable display (out fold )

39

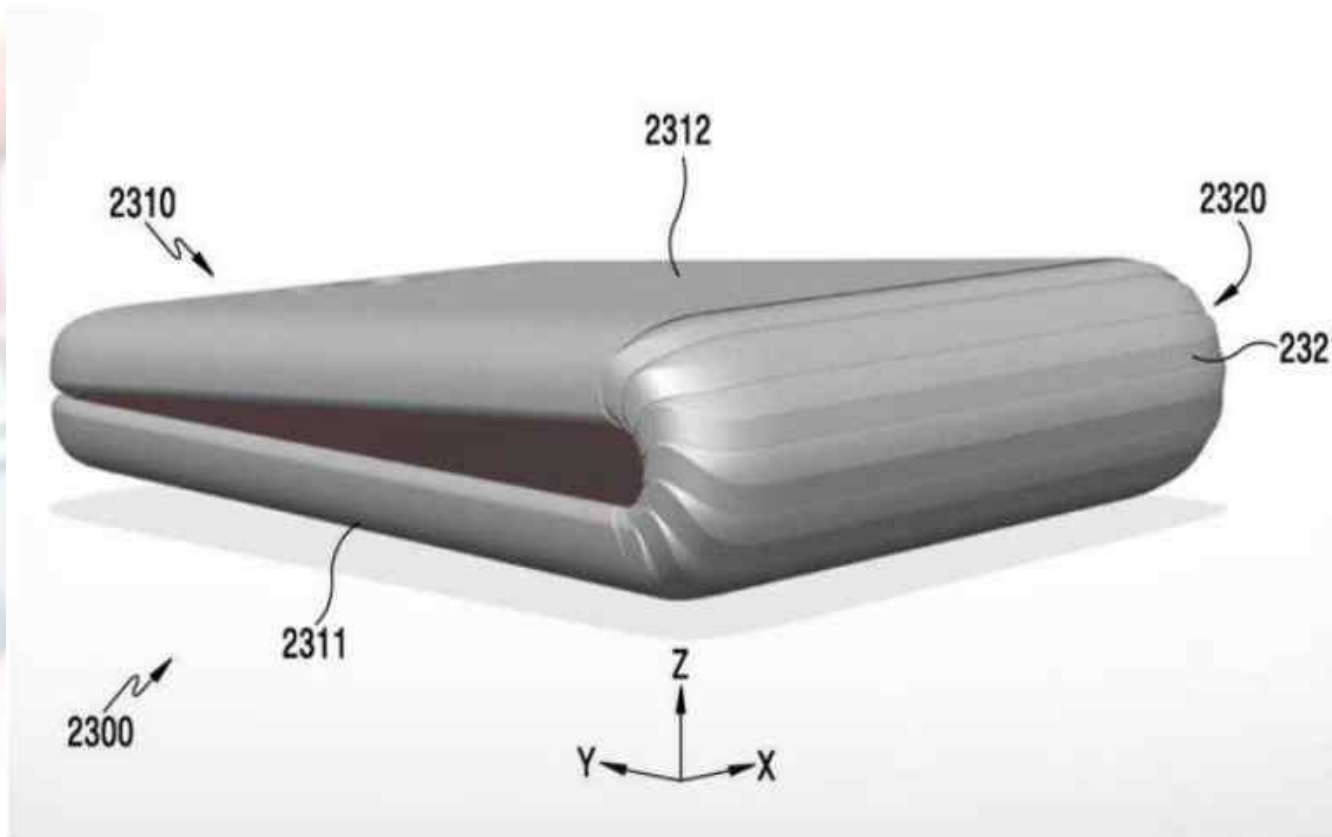


Display module(1mm)  
+  
Display module(1mm)  
+  
Battery, PCB(5mm)  
+  
 $\alpha$  (2mm)

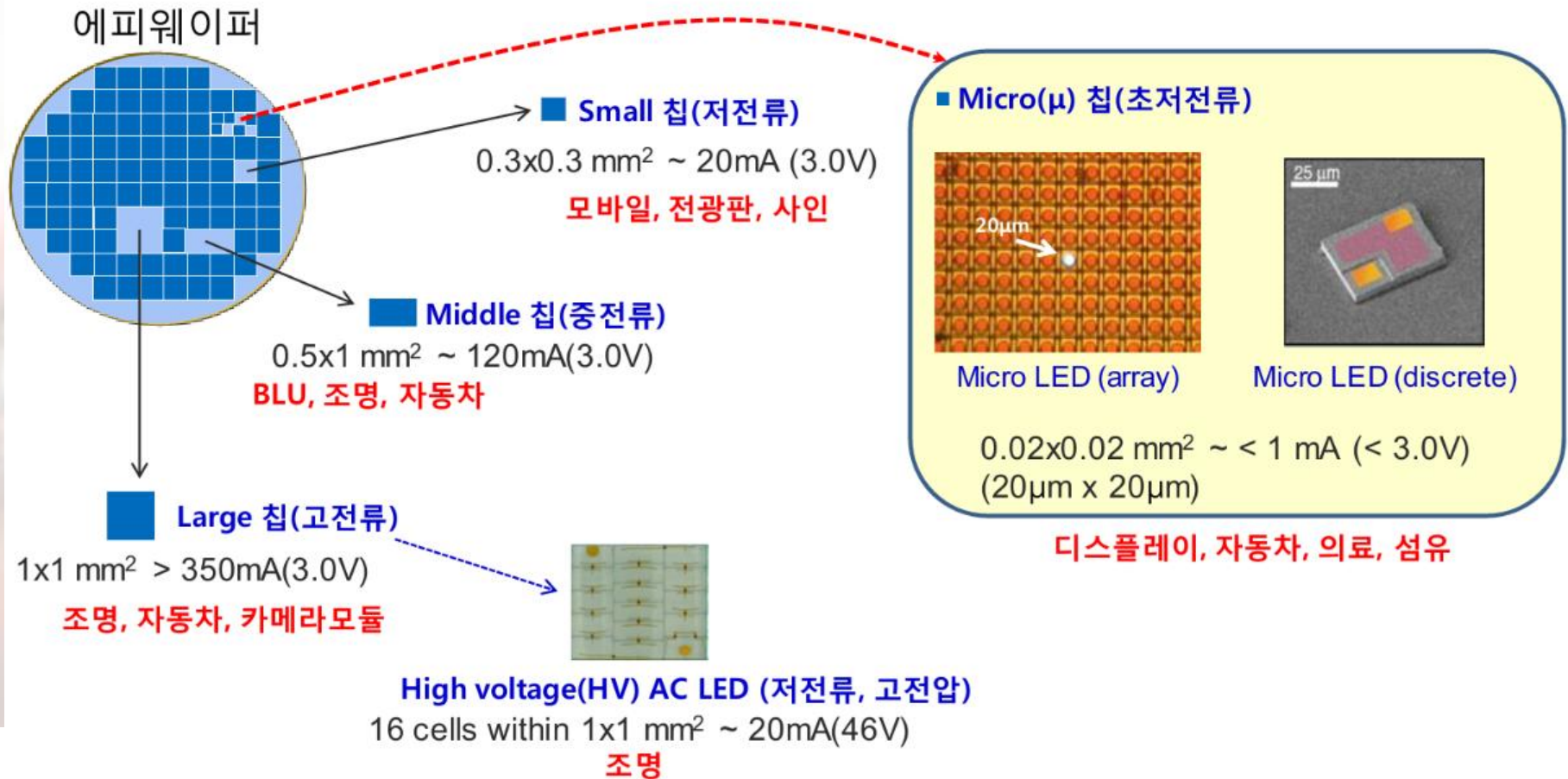


# Foldable phone( Samsung patent )

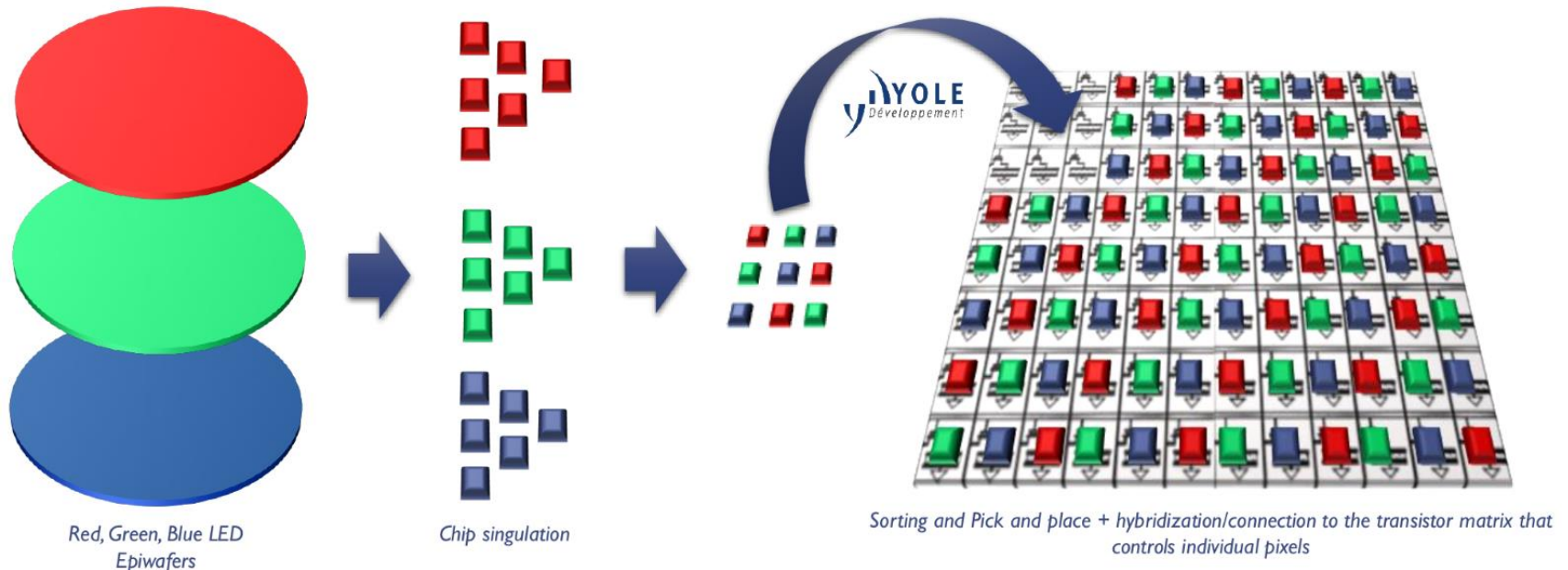
40



# LED 크기에 따른 칩의 용도



# 마이크로 LED 디스플레이란 ?



- mLED는 5~10um 단위의 LED 칩 자체를 발광재료로 사용.
- 플렉서블 구현 가능.
- 4K 디스플레이(TV, 스마트폰 등.) 구현을 위해 약 24,900,000개의 mLED 칩이 필요한데 개별 pick & place 방식으로는 약 41일이 소요

# 마이크로 LED 디스플레이 장단점

mLED는 기존 LED 광원에 비해 빠른 반응속도,  
저전력, 경량, 초박형, 고효율이 가능하며 디스플레이에  
적용시 저전력, 슬림화, 고신뢰성, 야외 시인성 및  
flexible에 용이

→ Power saving 측면에서 OLED에 비해 10배  
이상이 개선되지만 cost가 관건!!

	LCD	OLED	Micro_LED
메카니즘	Backlight/LED	자체발광	자체발광
시감도	보통	낮음	높음
휘도 (cd/m <sup>2</sup> )	3000 (full color) ~ 104 (green)	1500 (full color) ~ 103 (yellow)	~105 (full color) ~107 (blue/green)
명암비	200:1	매우높음>10,000:1	매우높음>10,000:1
응답시간	milisecond (ms)	microsecond (μs)	nanosecond (ns)
관리온도	0~60℃ , 히터필요	_50~70℃	_100~120℃
내충격성	보통	높음	보통
수명	보통	보통	깊
비용	낮음	낮음	높음



# 마이크로 LED 디스플레이 응용분야

Smartwatches  
and wearables



Apple

Virtual reality

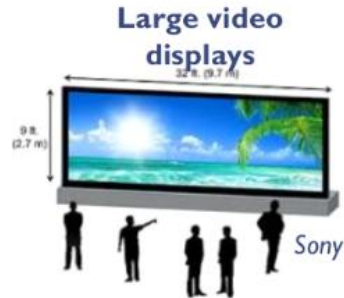


Oculus

Augmented/Mixed  
Reality



Microsoft



Sony

TV



LG

Smartphones



Samsung

Laptops and  
convertibles



HP



MicroLED TV prototype (Sony, CES 2012)

Automotive  
HUD



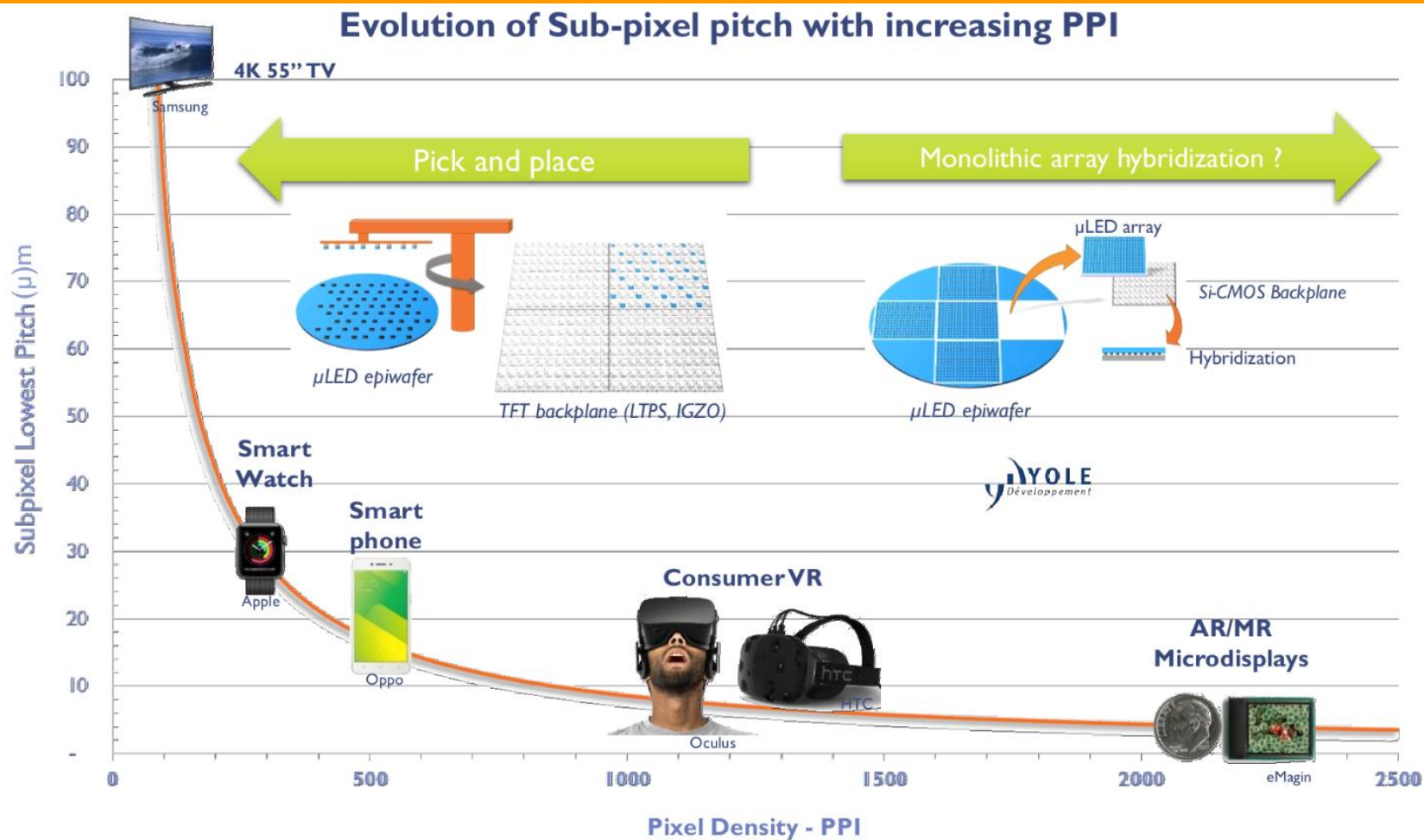
BMW

Tablets



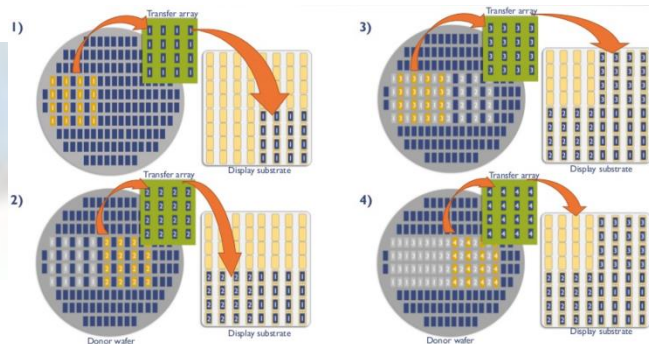
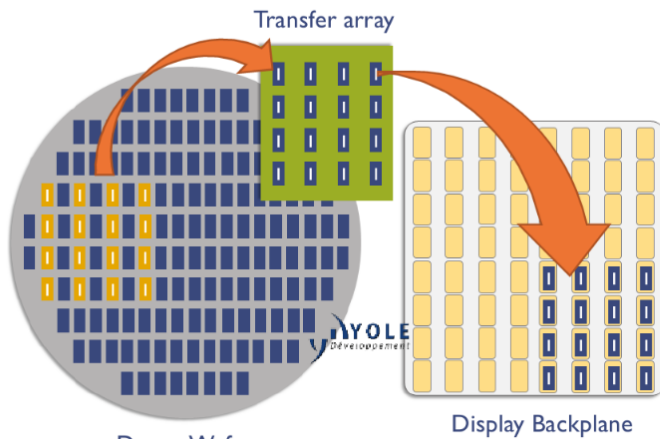
Acer

# 마이크로 LED 디스플레이 pitch



# 마이크로 LED 디스플레이 모듈 제조 공정

## Concept

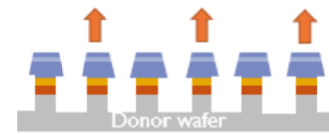


## Challenges

### Die Stabilization and release



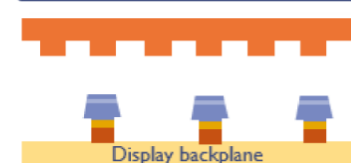
### Selectivity



### Pick Up



### Place





# Thank you !

곽민기 센터장

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