最新ディスプレイの現状と課題および材料開発について

第230回　フォトポリマー懇話会　光機能性材料の最新の進捗
2019/1/25

メルクパフォーマンスマテリアルズ株式会社
野中　敏章

Outlines

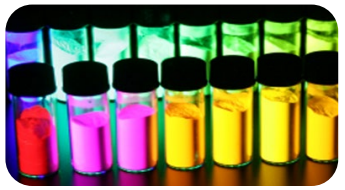
Merck Broadest portfolio for the display market

LC materials

Innovation for the next technology generation

Reactive Mesogens

Improving image quality in energy-saving displays

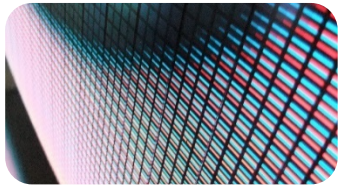


LED Materials

For bright, energy-efficient and vivid color B/L

Organic TFTs

For flexible and robust displays

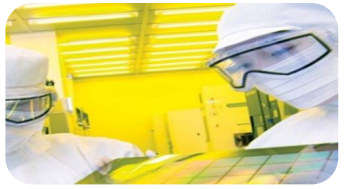


OLED materials

Revolutionizing display and lighting production

Quantum Materials

Major leap in color and peak brightness



Photoresists

Creating more pixels with wider process margins

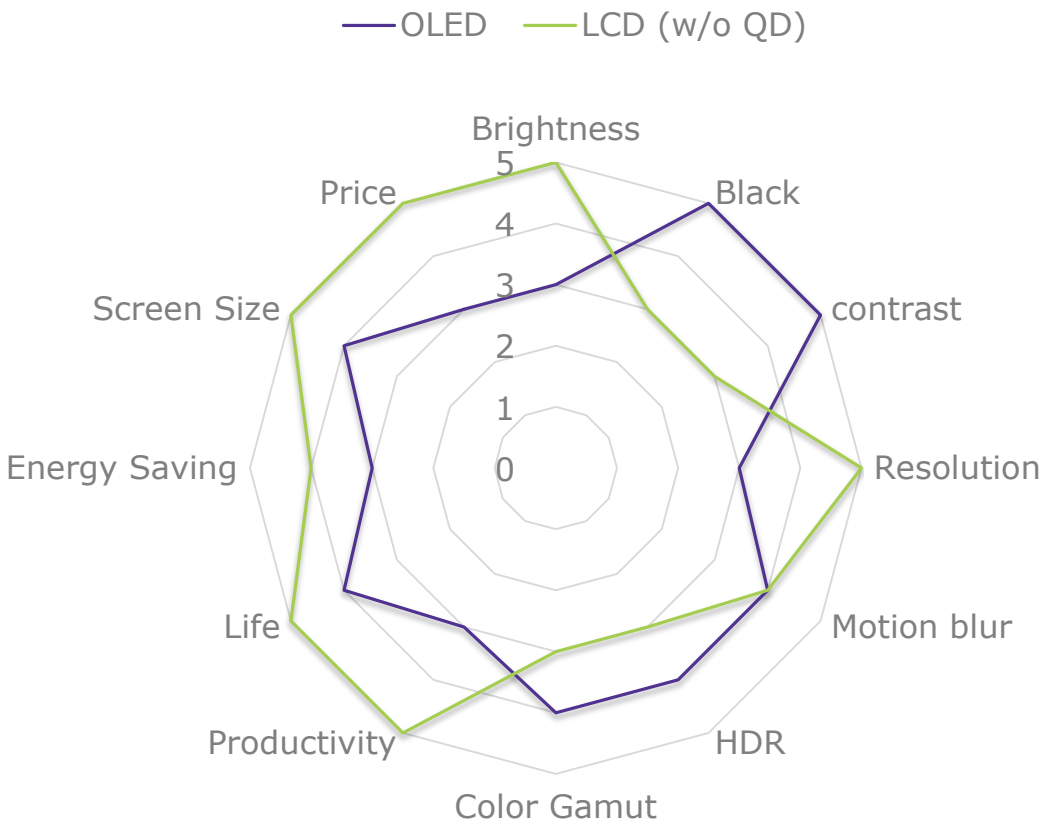
Siloxanes/Silazanes

For low-k dielectrics & ultra-thin barrier coating

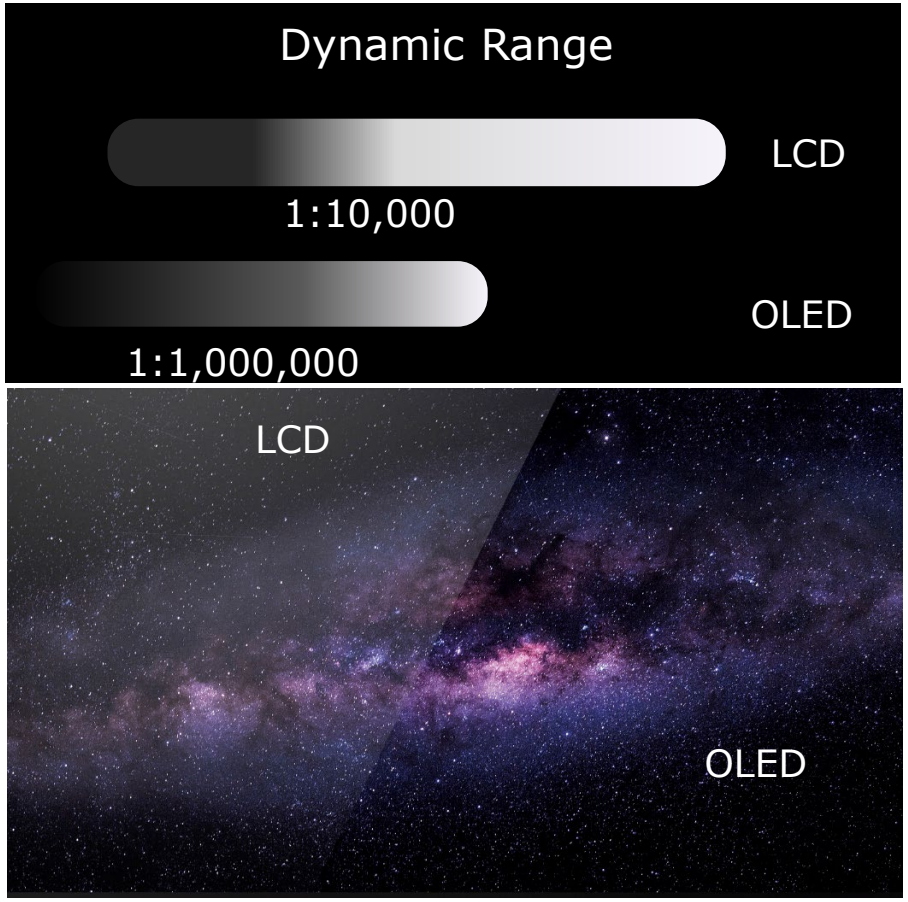
Trends drive display development

- LCD vs OLED
- Quantum dot
- High Resolution Patterning
- Light Management

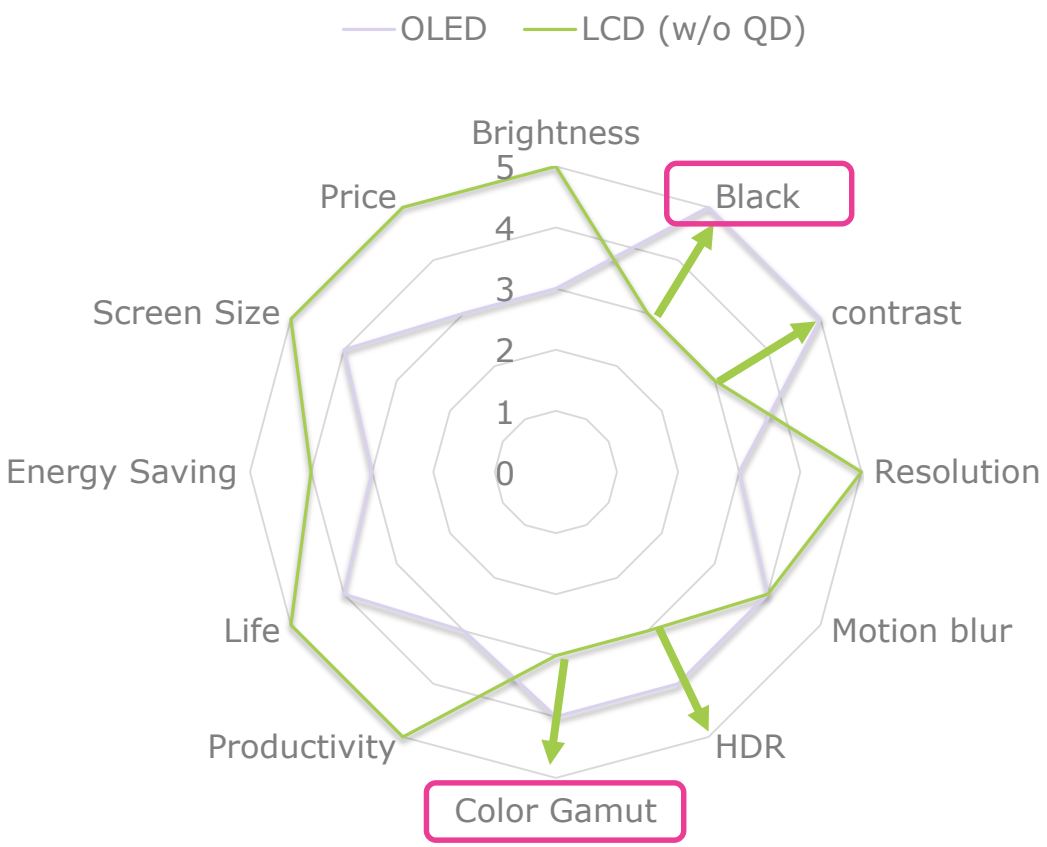
液晶テレビとOLEDテレビの比較



Source : CNet by Geoffrey Morrison (April 12, 2017)

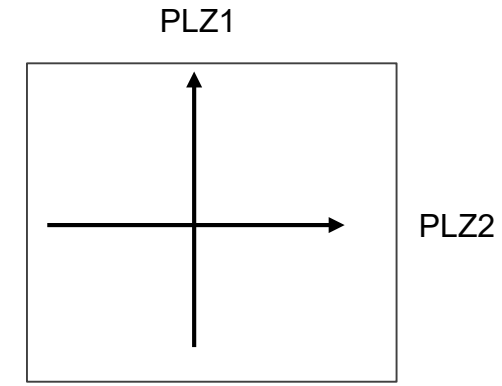


液晶パネルの課題

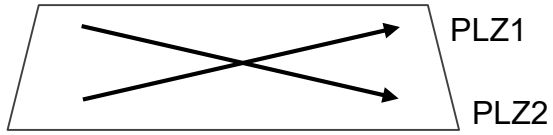


Source : CNet by Geoffrey Morrison (April 12, 2017)

LCD (light leakage at black state)

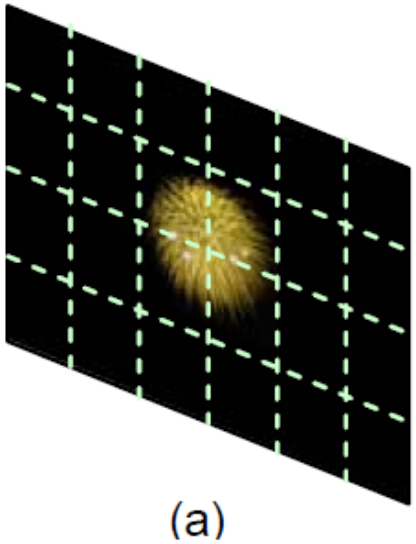


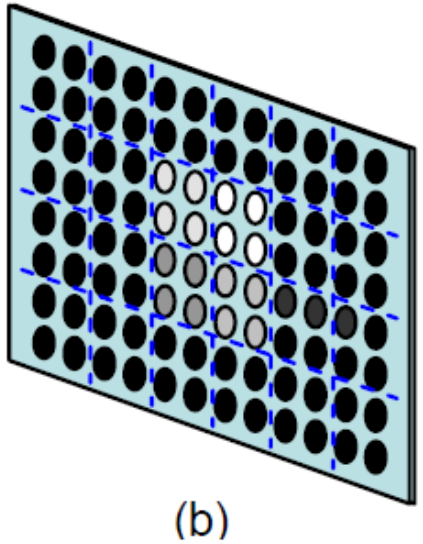
Polarization rate



Viewing angle and light leakage

2D local dimming for LED B/L



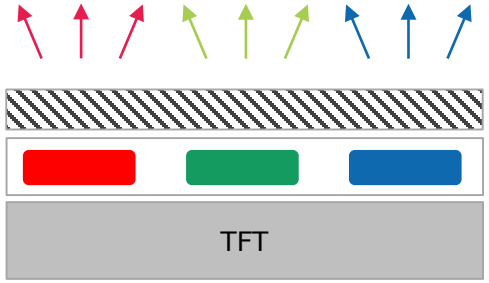


LCD image **B/L input**

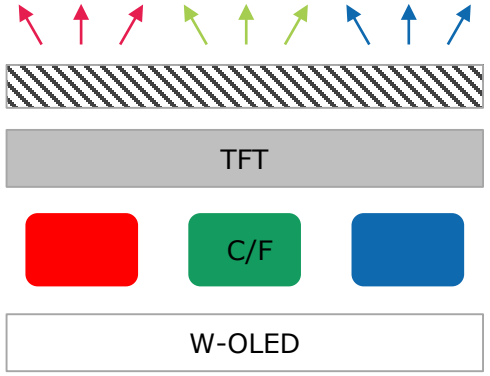
LCD local dimming driving **OLED**

OLEDの課題

Small OLED
(Top Emission)



Large OLED
(Bottom Emission)



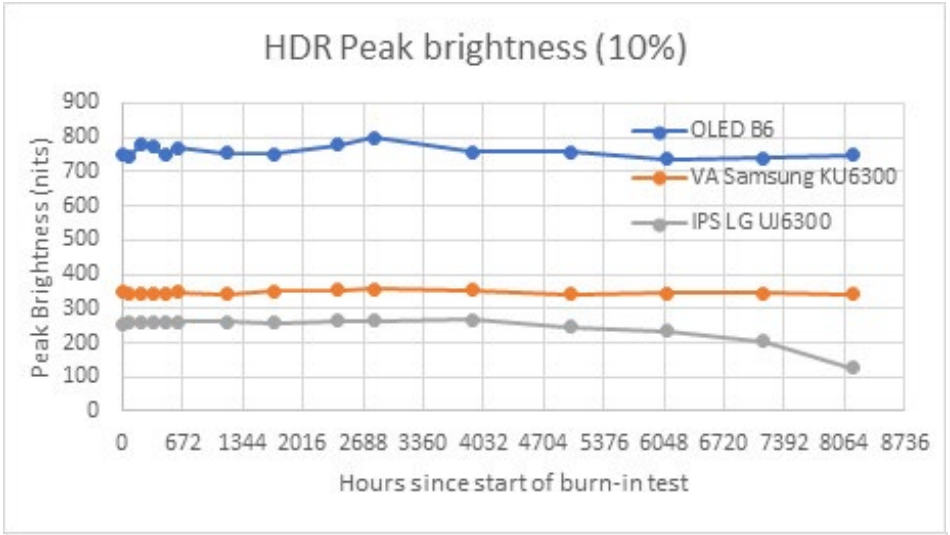
焼き付きと信頼性

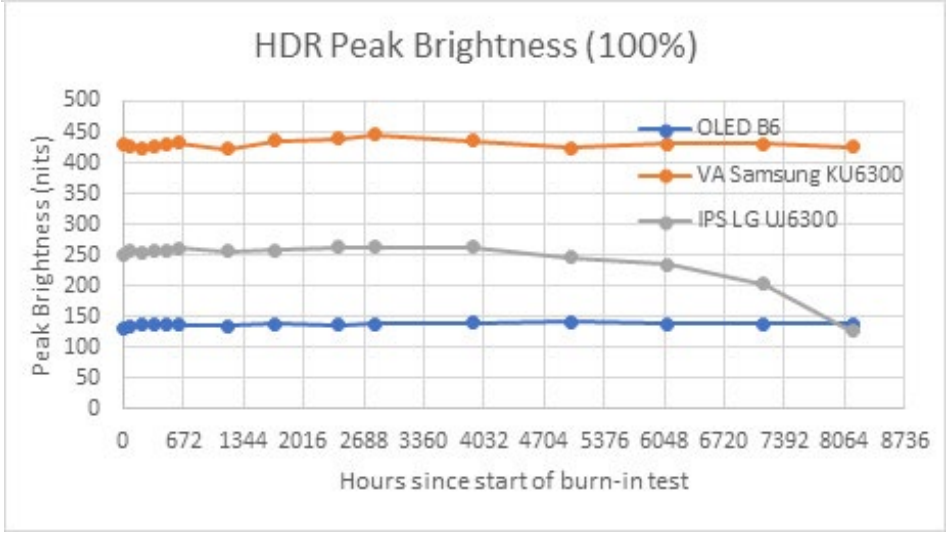
- 輝度と寿命
- 光取り出し効率（約25%）の向上　→　屈折率制御
- 画素構成（開口率）（ボトムエミッションからトップエミッションへ）
- 円偏光板（偏光板＋位相差板）
- カラーフィルターの有無　(RGB塗分け、量子ドットによる色変換)

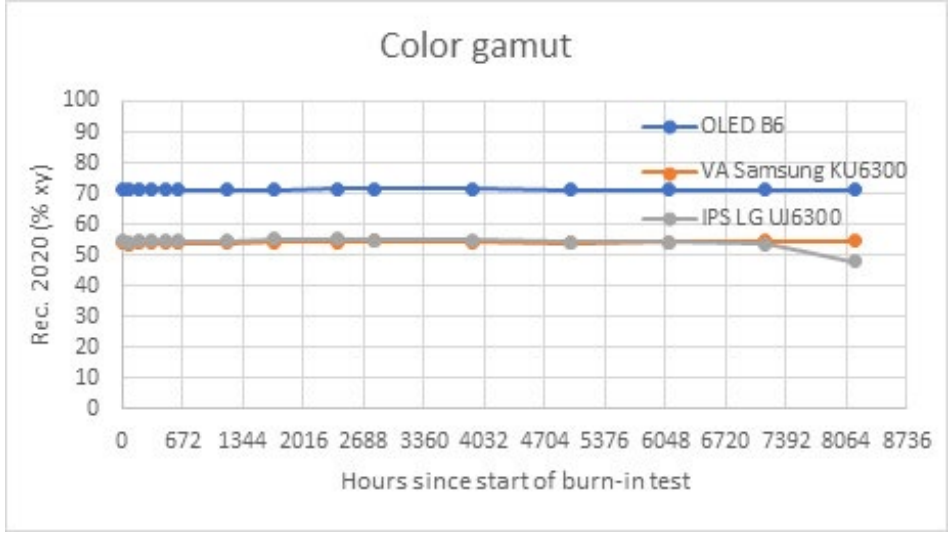
駆動と大画面化

- LTP・酸化物半導体TFTの大型化
- FMM蒸着に代わるパターン形成技術

OLED vs LCD VA vs LCD IPS

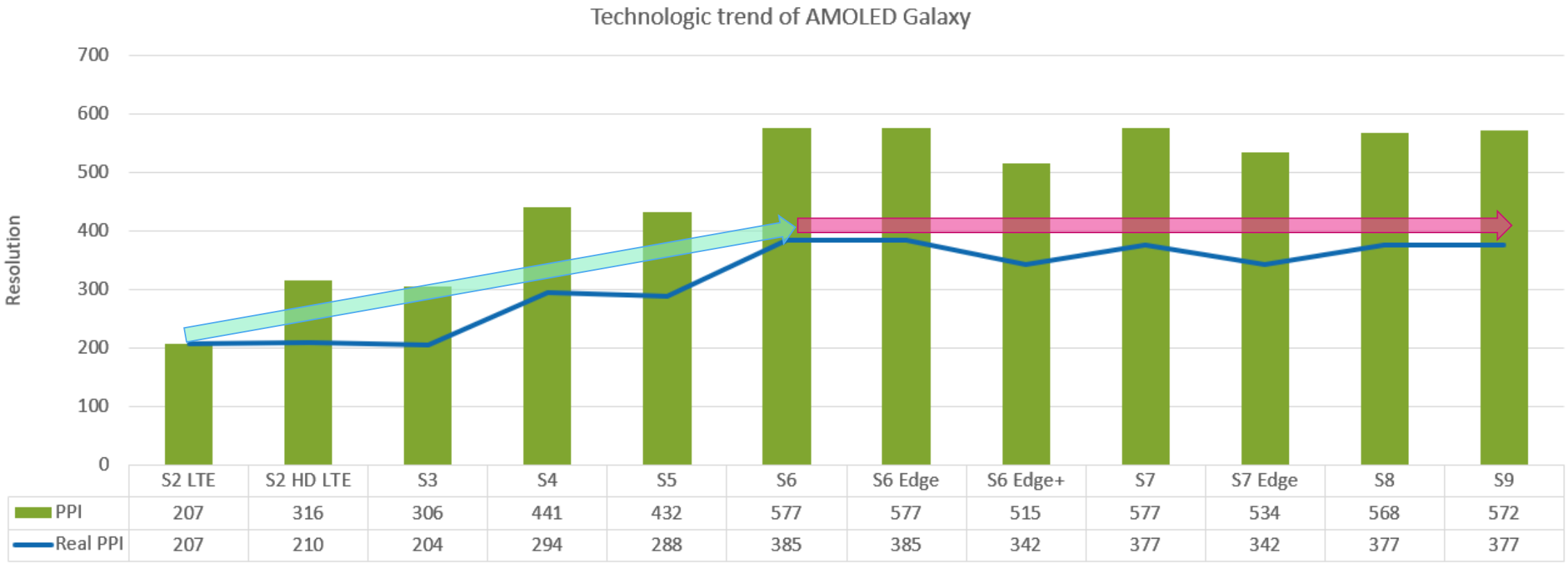






https://www.rtings.com/tv/learn/permanent-image-retention-burn-in-lcd-oled

Samsung Galaxy OLED resolution trend

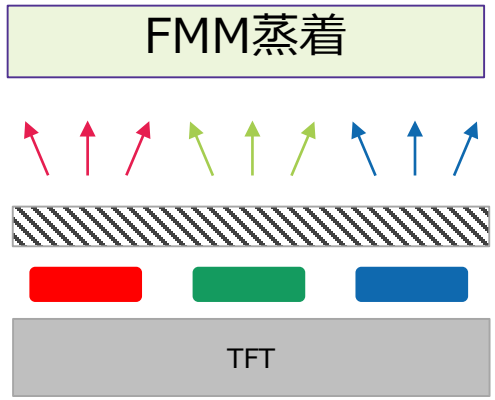


	S2 LTE	S2 HD LTE	S3	S4	S5	S6	S6 Edge	S6 Edge+	S7	S7 Edge	S8	S9
PPI	207	316	306	441	432	577	577	515	577	534	568	572
Real PPI	207	210	204	294	288	385	385	342	377	342	377	377

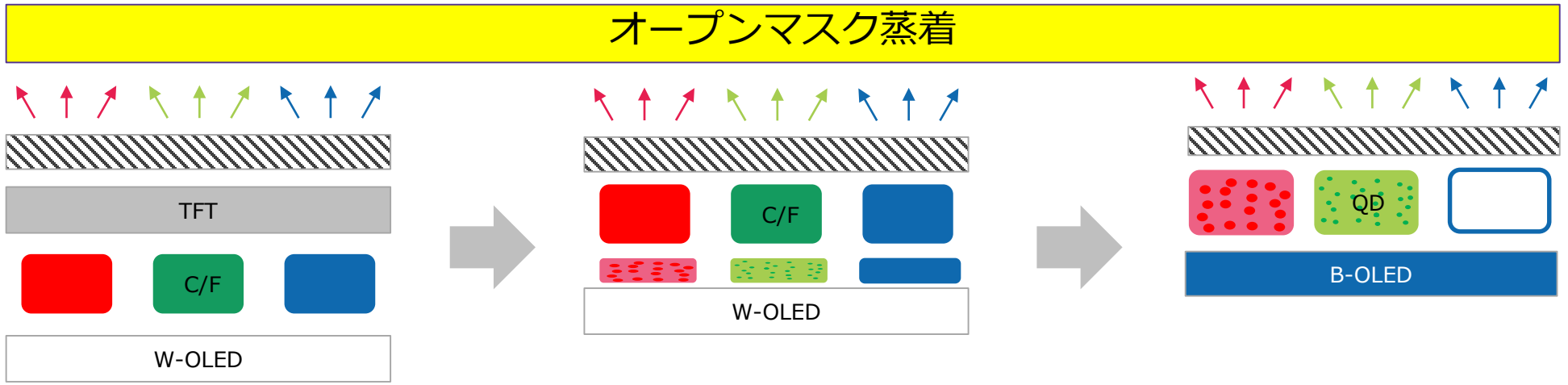
Source : SID2018, Session 75-2 and 75-4

OLEDのトレンド

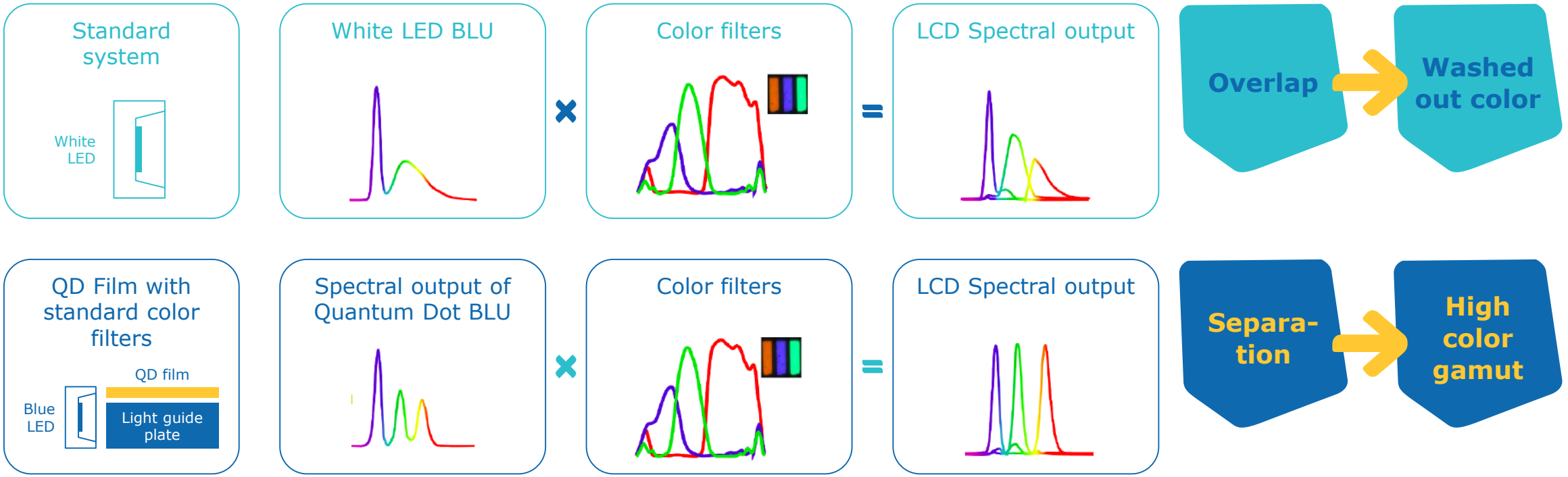
RGB塗分け



W-OLED
＋
色変換



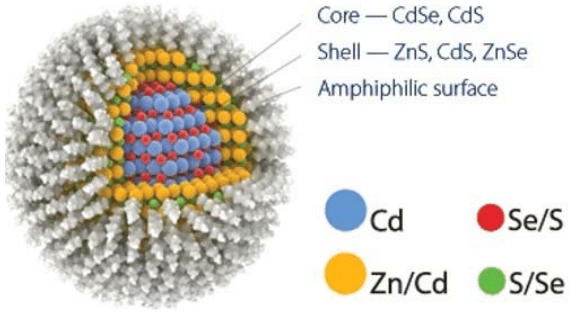
Why better color gamut with QMs

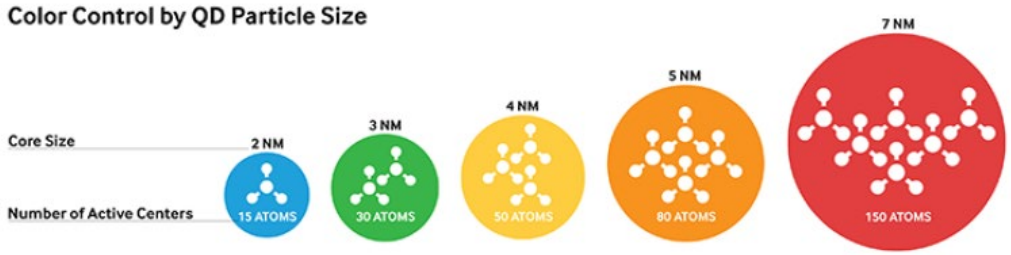


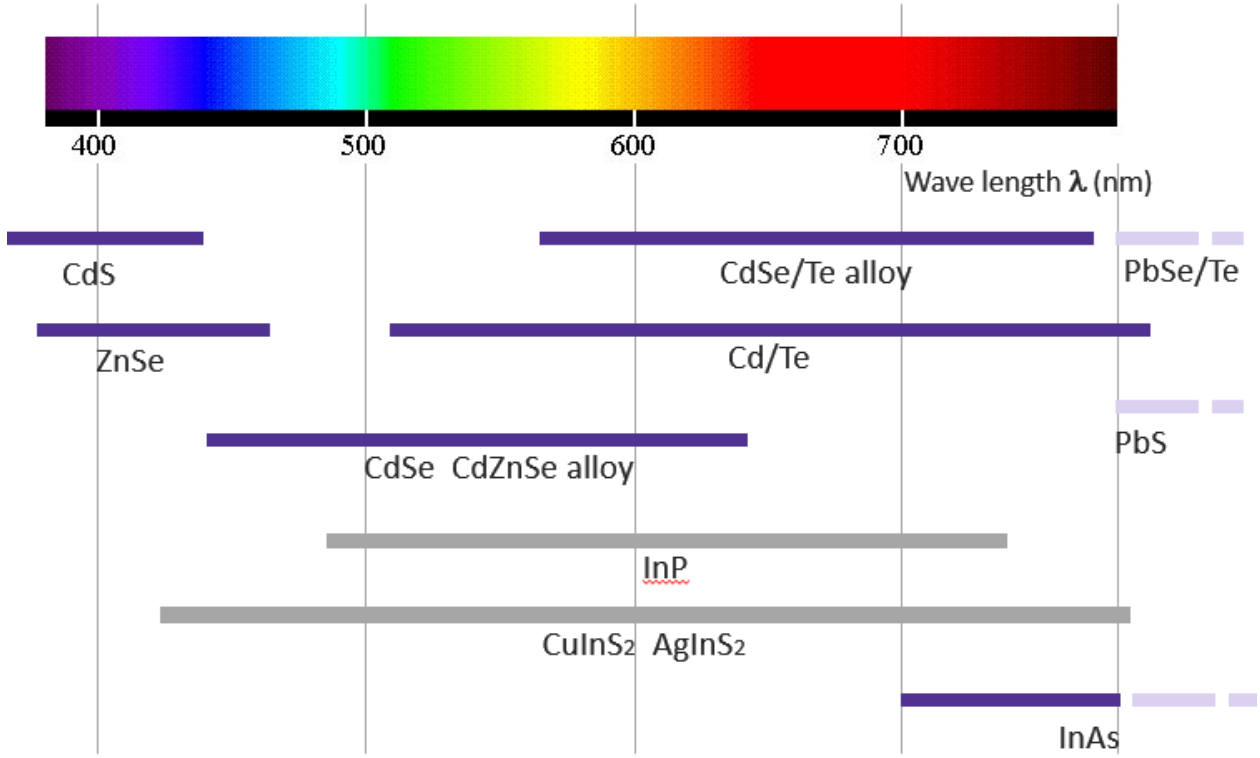
1 With traditional white LEDs, the light source doesn't exhibit separate peaks for each primary color. The color performance of the display therefore relies on the color filters and a lot of light is left out.

2 Quantum dots are well suited to enable narrow sub-pixel output spectral distributions: they produce narrow output spectral distributions that are easily tunable in peak wavelength to match LCD color filters.

Quantum dot







Cd system : QD Vision

Cd/Cd Free hybrid (RoHS<100ppm)

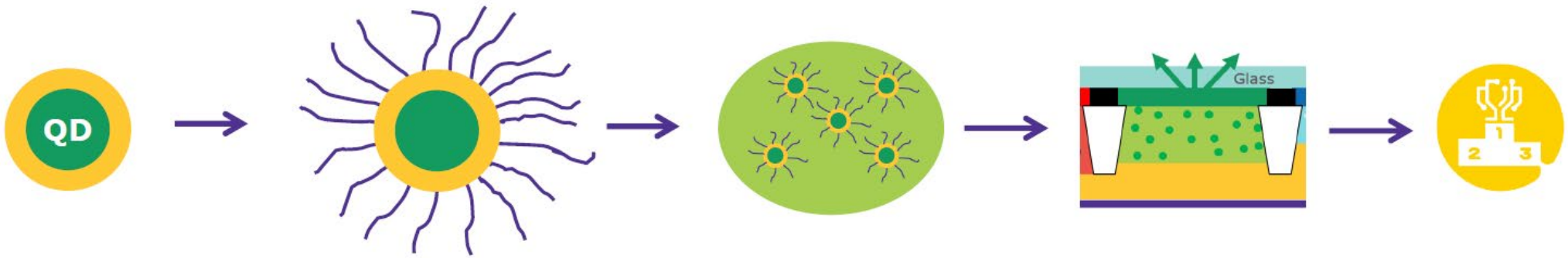
- Nanosys

Cd Free (quantum efficiency < Cd system)

- Nanoco Technologies
- Quantum Materials

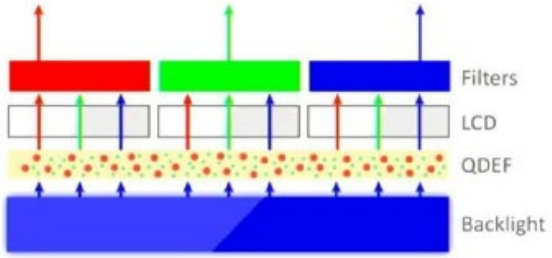
量子ドットのデバイスへの応用

Quantum Dot x **Ligands** x **Formulation** (ink, PR) x **Device Design** = **Performance**

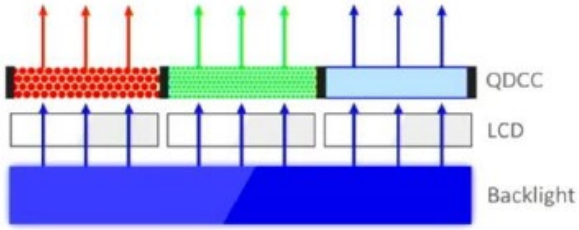


- QDフィルム
- QD カラー変換
  - LCD (B—LED)
  - OLED (W-LED+C/F)
  - OLED (B-OLED)
  - µLED (B-µLED)
- 太陽電池
- センサー等

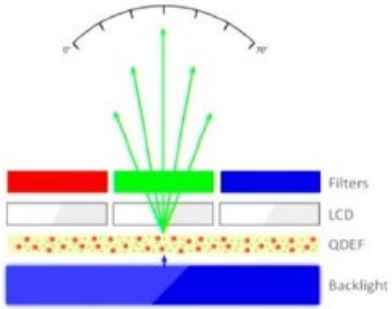
量子ドットの色変換のメリットと課題

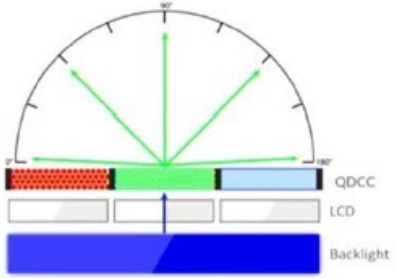


~2/3rds of light lost in color filters



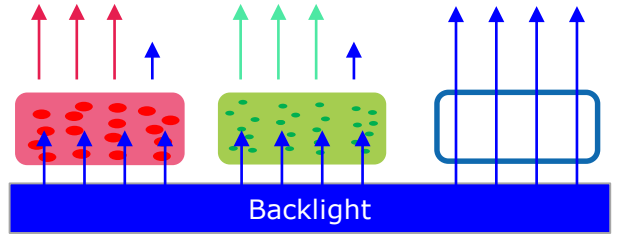
Significant luminance boost compared to QDEF



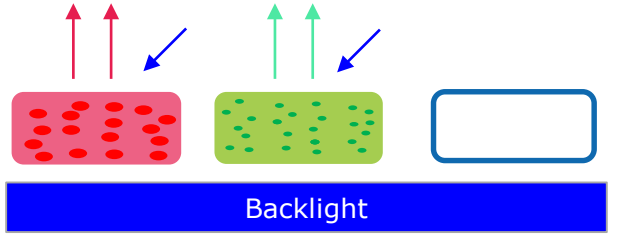


Much greater viewing angle compared with traditional LCD

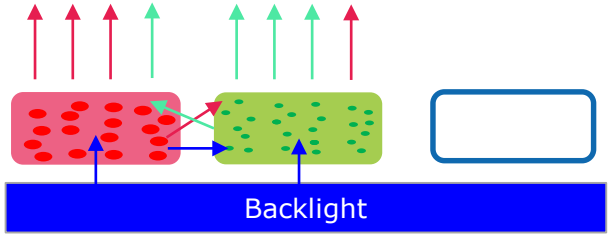
Source; SID2018, Session 41-5 nanosys



量子ドットの変換効率

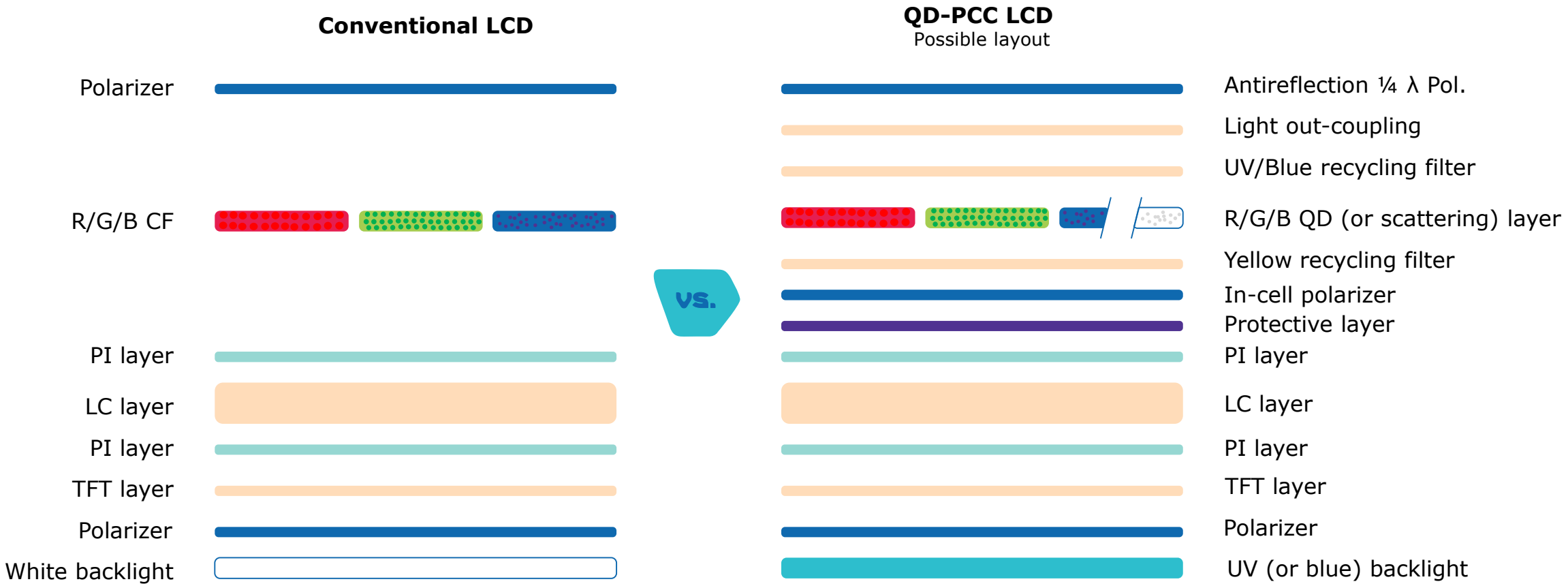


外光による発色

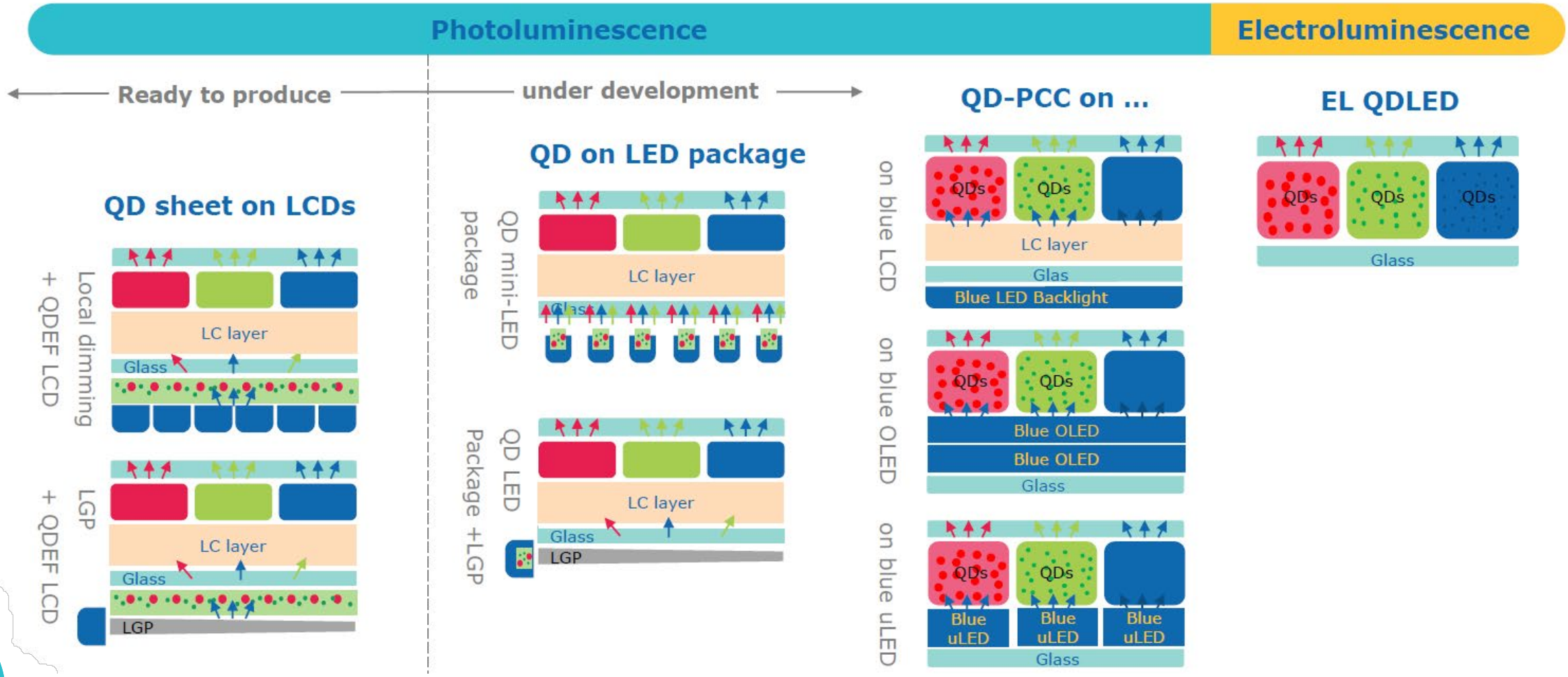


カラーミキシング

Conventional vs. Quantum Dot – Pixel Color Converter (QD-PCC) LCD

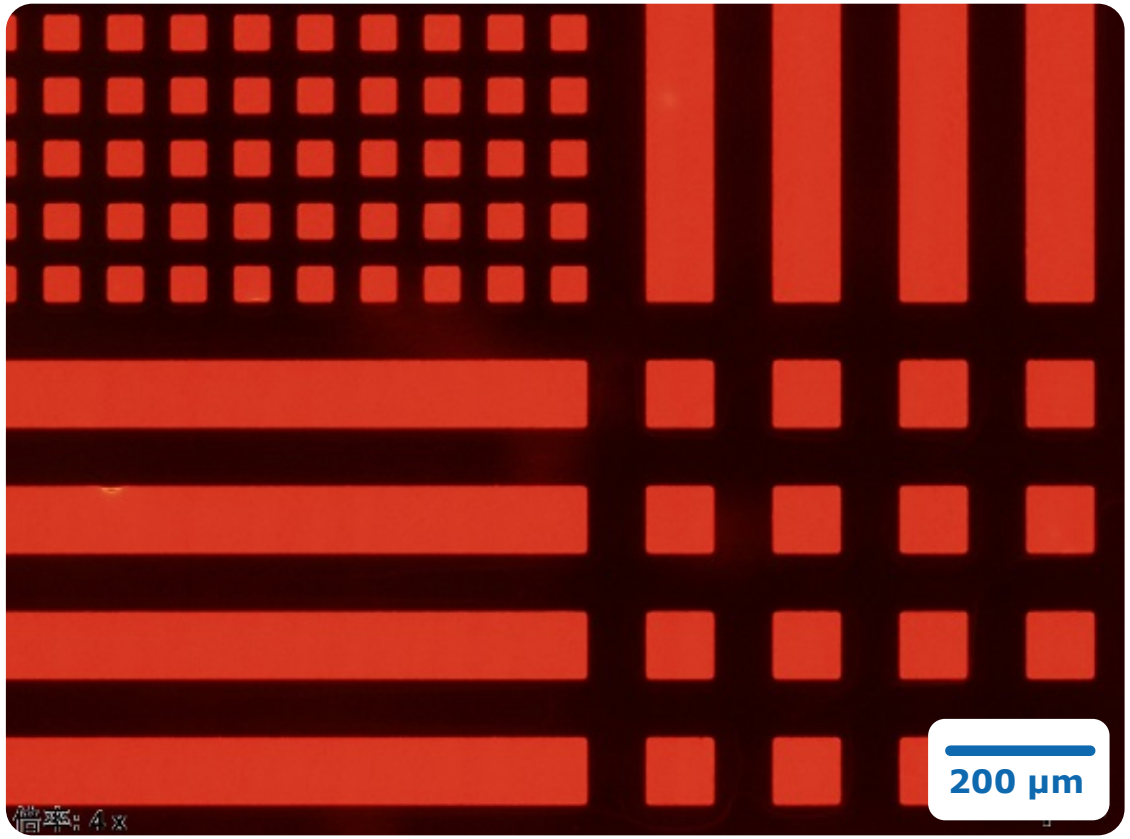


量子ドットのディプレイへの応用



Quantum Dot – Photoresist

Merck Patternable QD Photoresist solutions



Benefits

Green

Environment friendly:
Cadmium-free, higher energy efficiency

Process

Photo-patternable with standard color filter technology but high material loading required to achieve high optical density

Cost reduction

Use of existing equipment

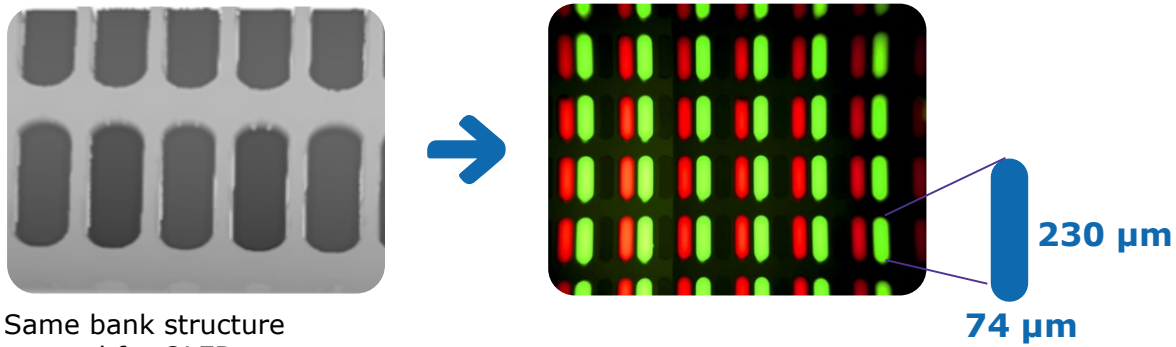
Innovation

Appearance like an emissive display, high brightness

Quantum Dot – Photoresist

Ink-jet printing of Merck Quantum Materials

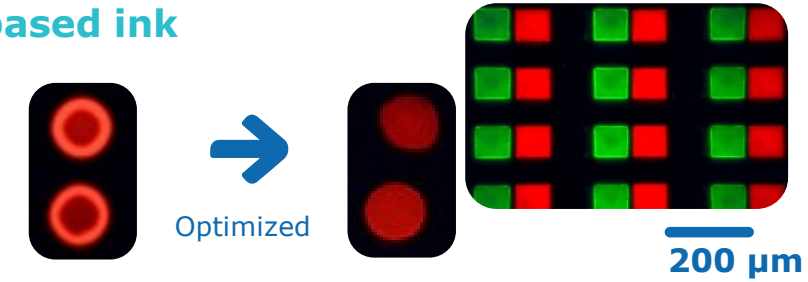
Water-based ink



Same bank structure
as used for OLED

Solvent-based ink

Coffee ring
effect



Benefits

Green

Environment friendly:
Cadmium-free, higher energy efficiency, less waste

Process

Patterning by Ink-jet technology in principle possible, “coffee ring” effect occurring for organic solvents could be solved

Cost reduction

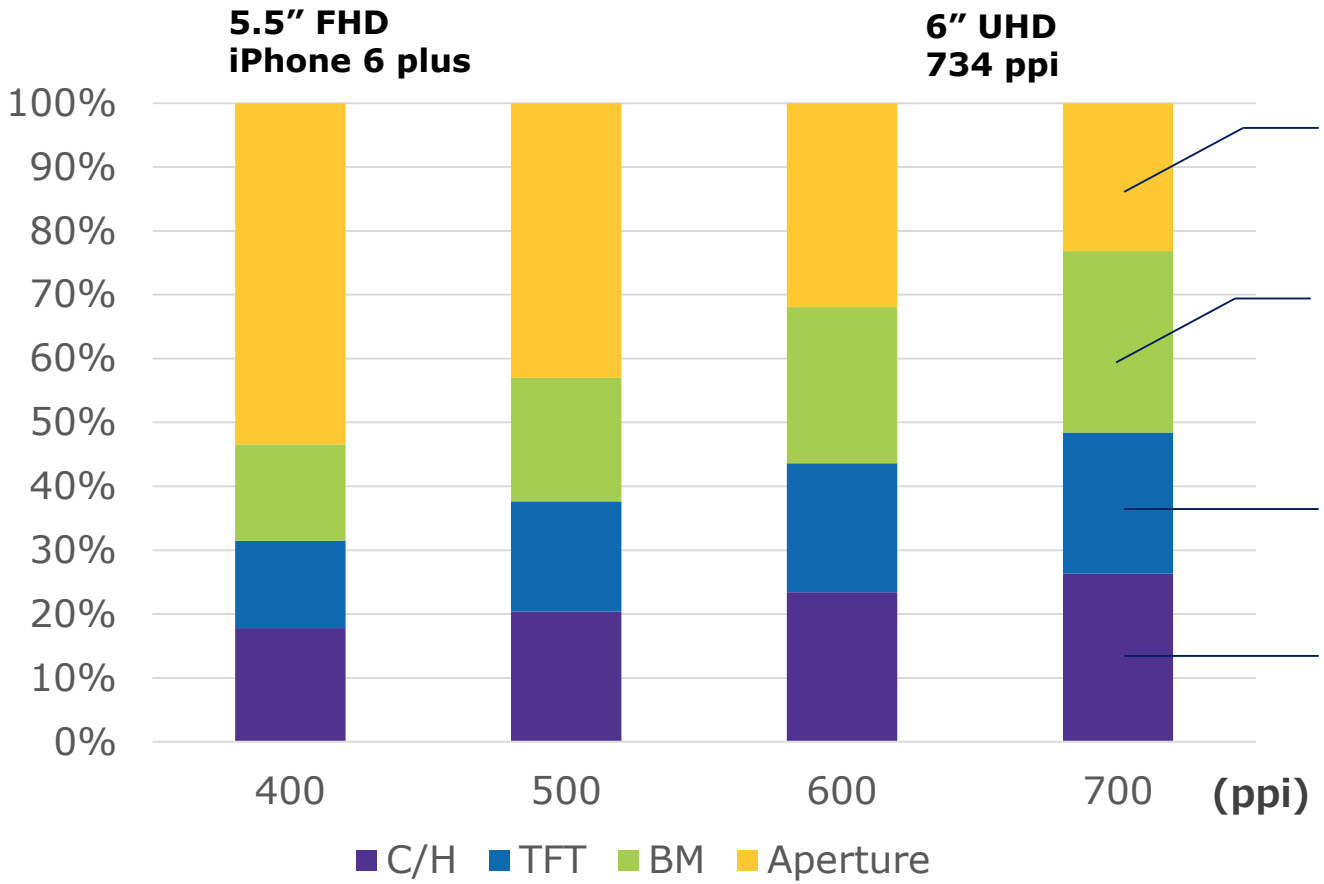
Use of printing technology, less waste

Innovation

Appearance like an emissive display, high brightness

Outlines

Non-Transparent Factors in high resolution trend (smart phone)

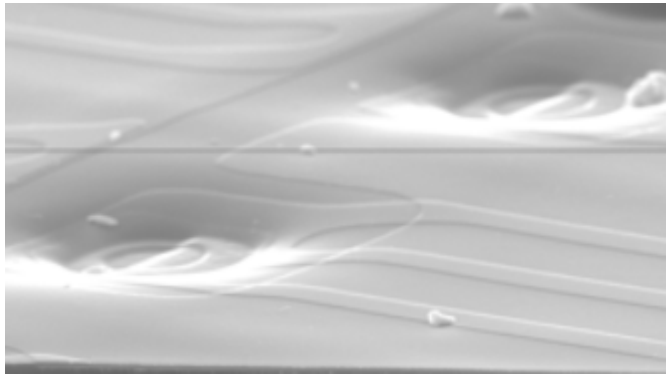


光の透過エリア

BM (ブラックマトリックス)
- 配線
- アライメントマージン

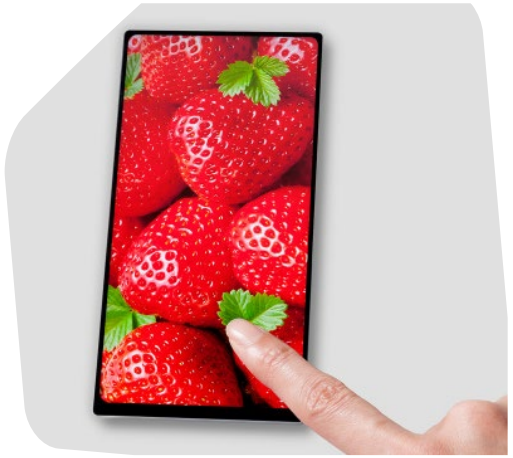
TFT (LTPS)

BM (コンタクトホール)

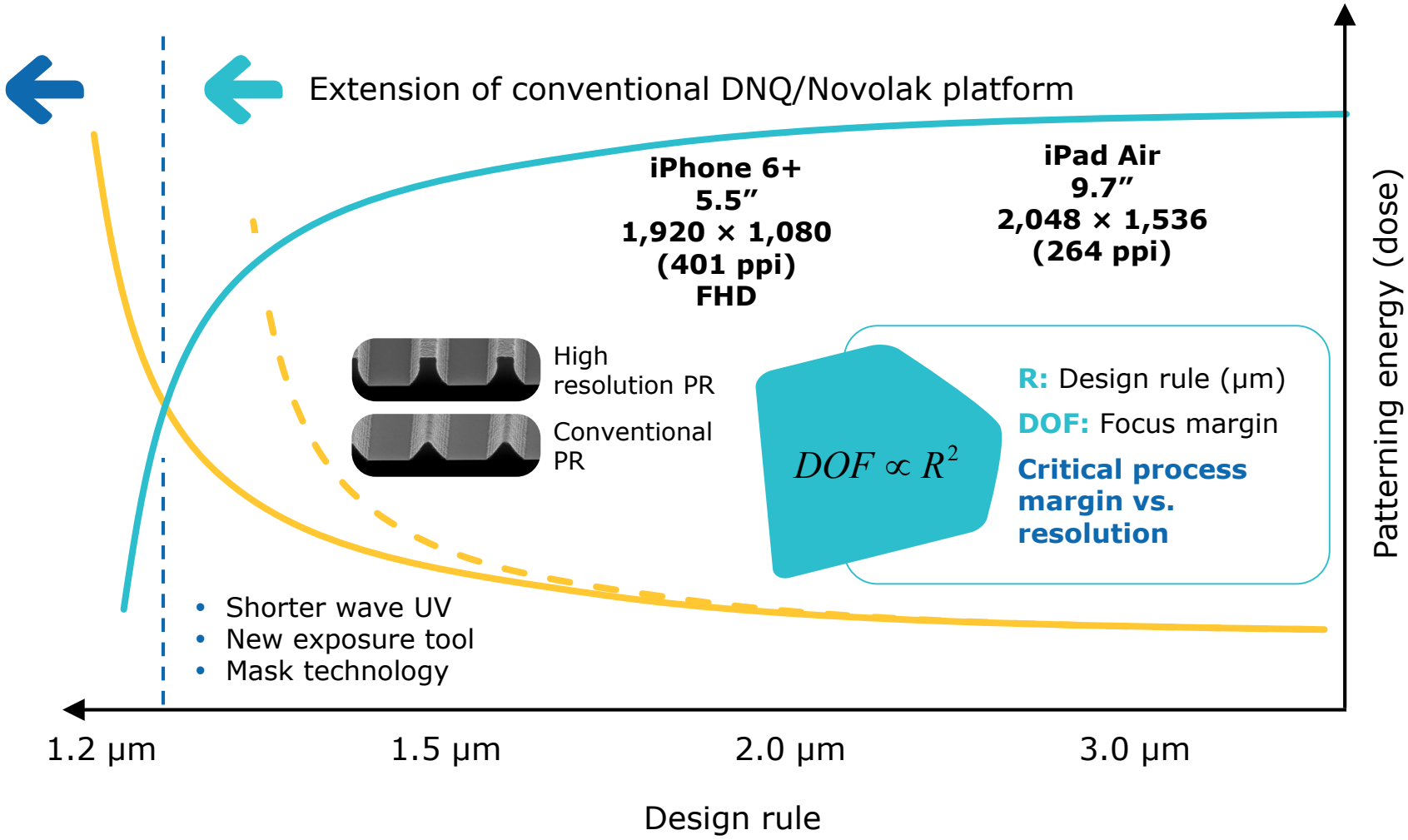


Source : SID2015, 63.1 An Ultra High Density 736-ppi LCD using IGZO platform, Sharp

フラットディスプレイとフォトリソグラフィ技術

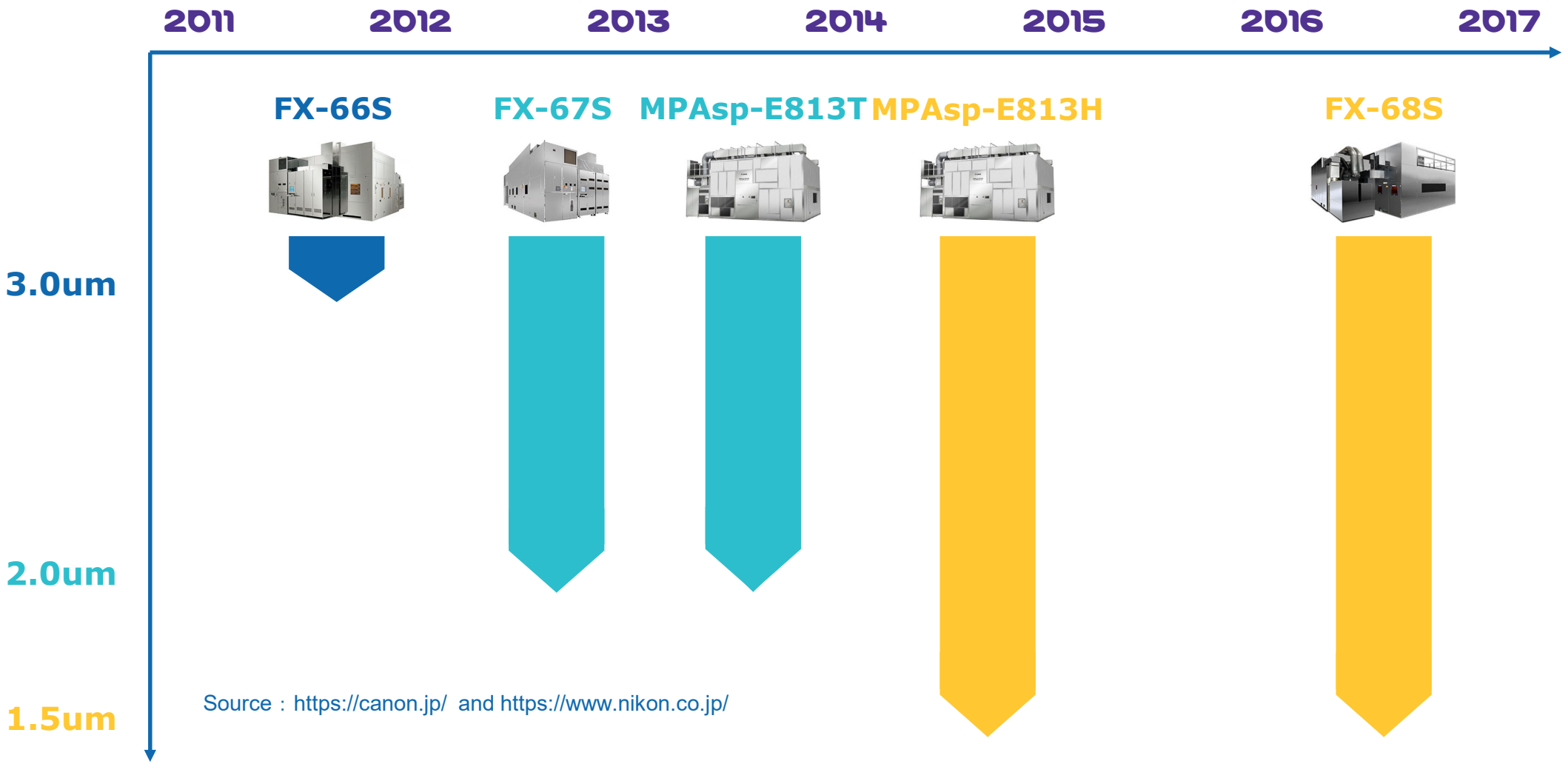


狭額物デザイン



Novel High Resolution Photolithography Process

Exposure tool for display fabrication



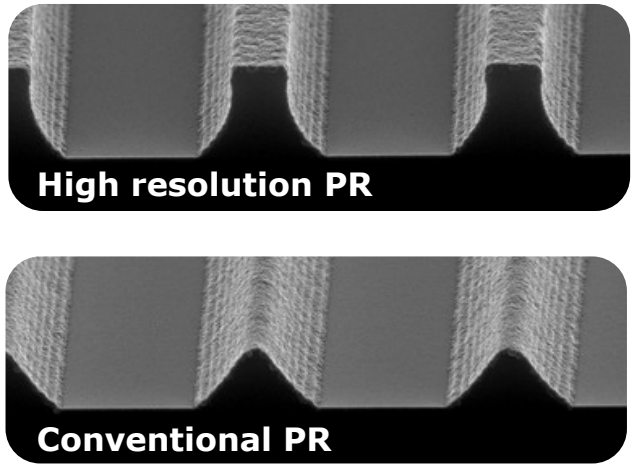
Source：https://canon.jp/ and https://www.nikon.co.jp/

Merck の高精細フォトリソグラフィへの取り組み

DNQ/ノボラック系の高精細化

- 高感度化
- プロファイル（ドライエッチ）

1.75um L&S
(Conventional equipment)



新材料と新プロセス

- 化学増幅型　(*FPD-CAR)
- 高解像度化プロセス
- その他

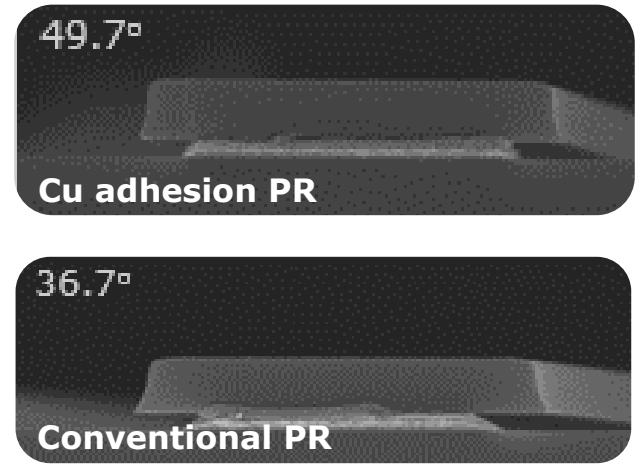
*CAR: Chemically amplified resit

solutions for future new devices

高機能化

- Cu配線への密着性（ウエットエッチ）
- ハーフトーンプロセス

After wet-etching

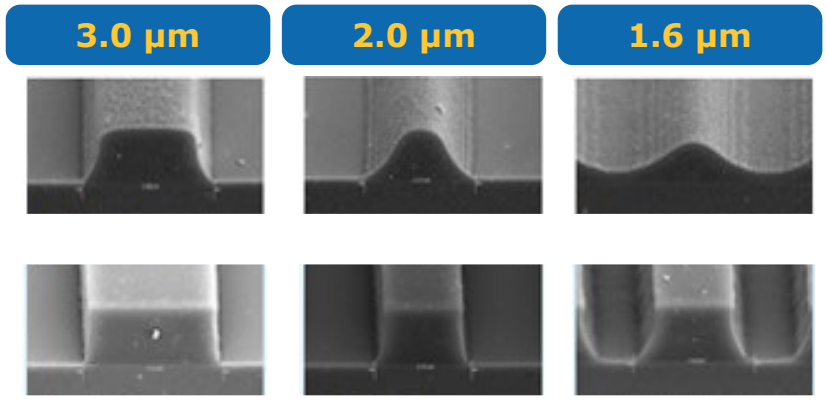


化学増幅型レジスト(CAR)のフラットディスプレイ製造への応用

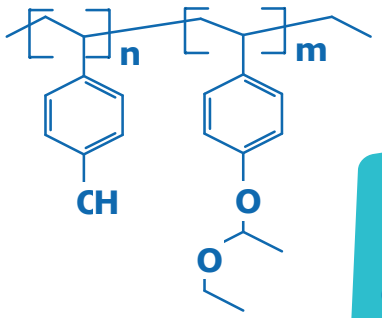
Feature size (µm)

DNQ-ノボラック

CAR

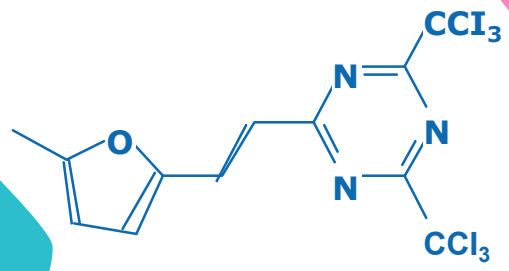


Example CAR system



Acetal protected PHS

Photo-acid generator



FPD-CAR導入への障害

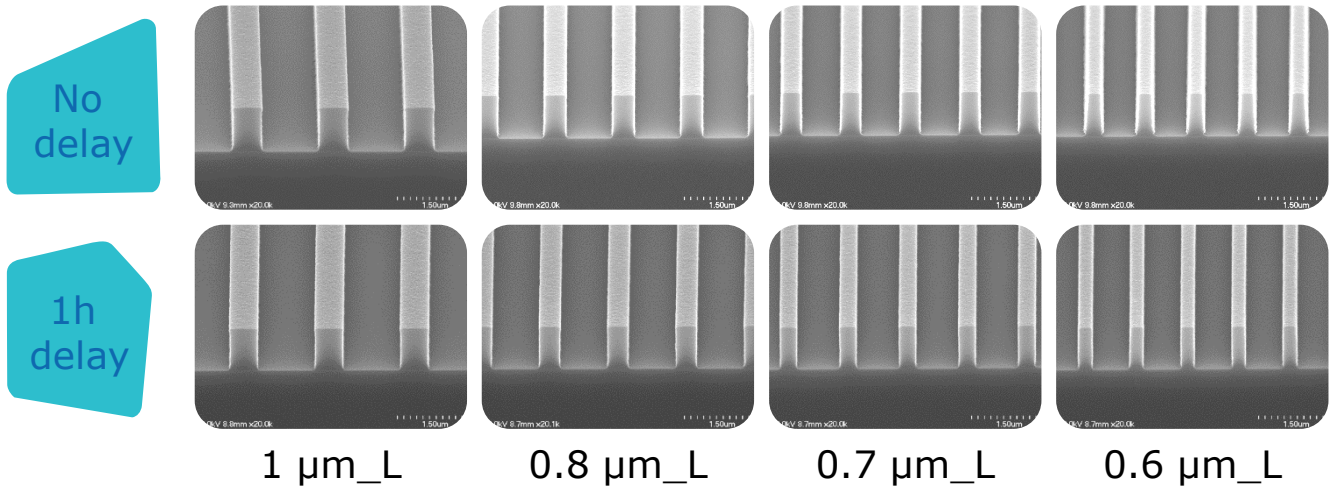
- PEBプロセス
- 雰囲気による影響
- 酸性脱ガスによるレンズ、装置の腐食
- ウエットエッチレジスト
- 剥離性
- コスト

PEB-free Chemically Amplified Resists for FPD production

CAR Coat → Exposure → **Delay** → Development

- Merck is developing PEB-free chemically amplified resists for next generation FPD production.
- **Developed PEB-free CAR system with good post exposure delay stability.**

PEB-free CAR (sample) – Post exposure delay stability



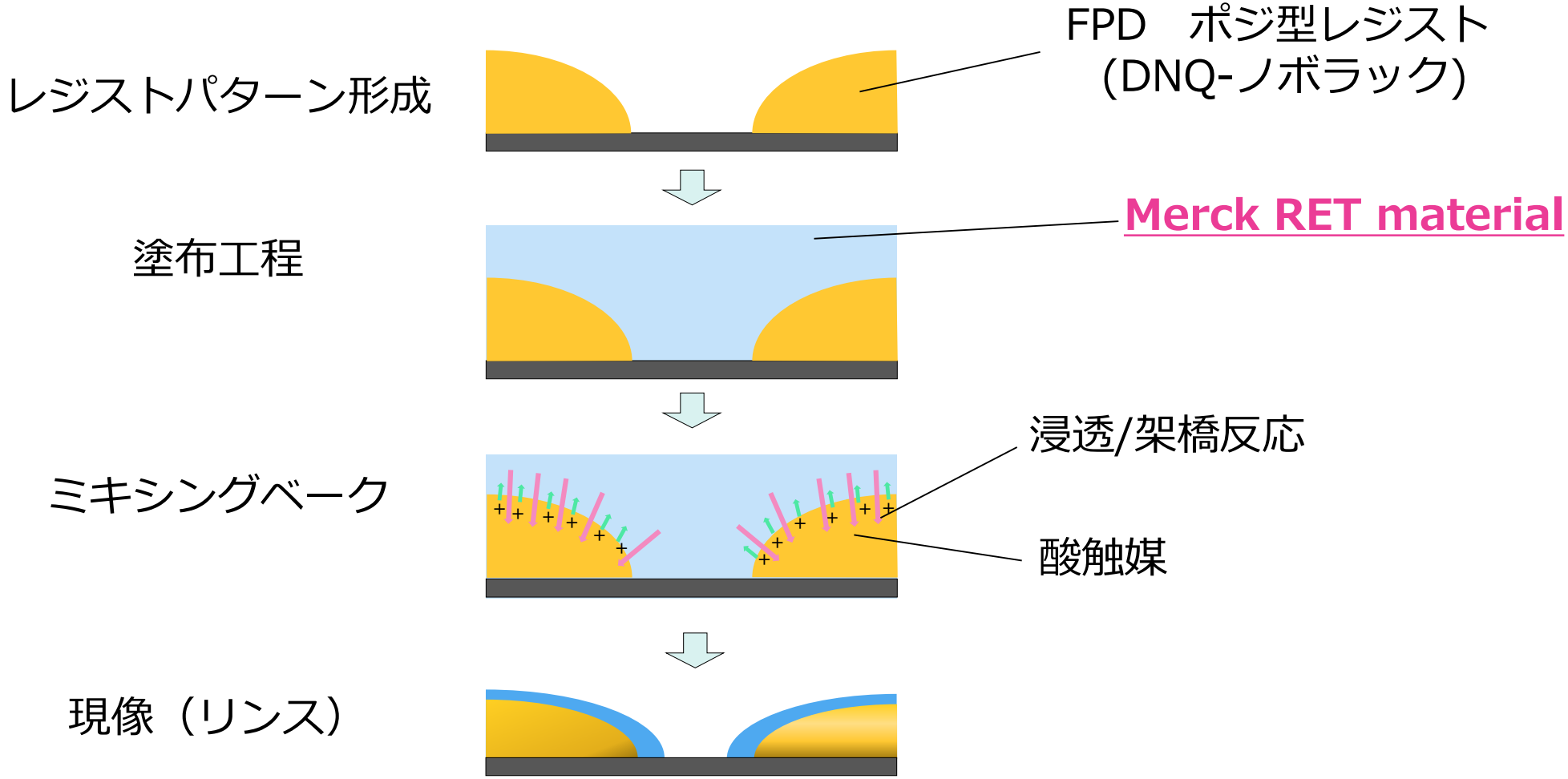
Resist thickness
1.3 µm

Mask design
(L/S)=1:1

Exposure
ASML i-line stepper
(NA=0.48)

Development
2.38% TMAH 60 sec

スペース・ホールの微細化プロセス (RET: Resolution Enhancement Technology)



Novel High Resolution Photolithography Process

Merck Display RET material

PR Process

↓

RET Coating

↓

Mixing Bake

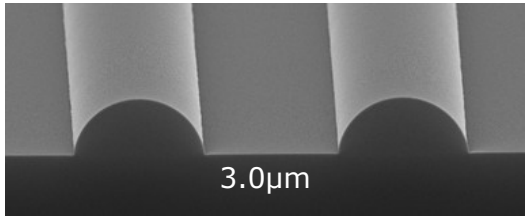
↓

Development

↓

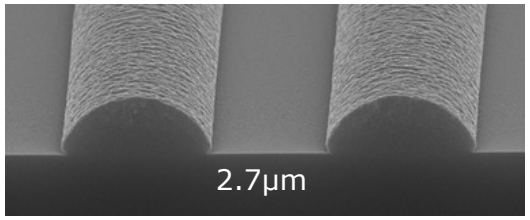
2nd Post Bake **Optional**

Original Resist Pattern

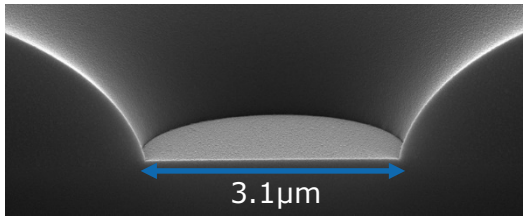


▲0.3μm

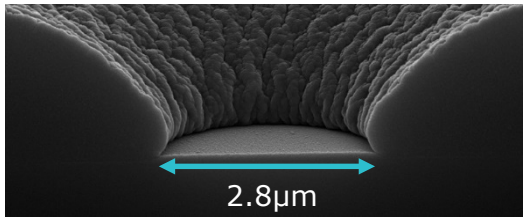
After RET



Original Resist Pattern



After RET



RET Process
Mixing bake: 100 ℃
Development: Pure Water
2nd Post bake: None

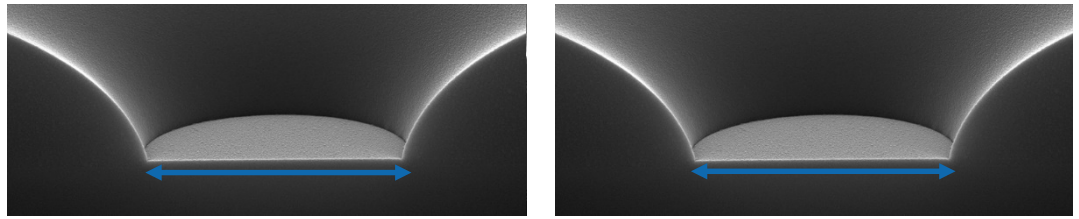
Novel High Resolution Photolithography Process

Contact Hole Shrinkage

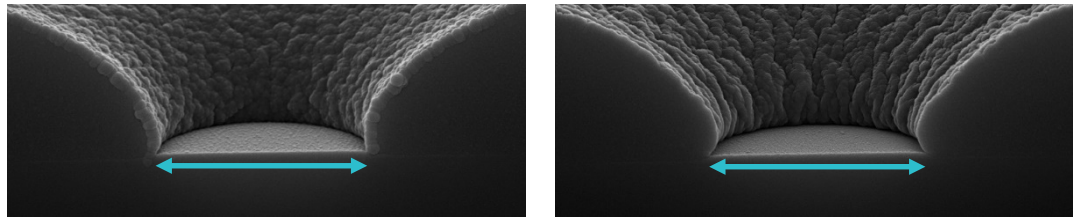
PR Process
Film thickness: 2.4 µm
Exposure: Nikon FX-604 (NA=0.1)
g+h line stepper
Mask size: 3um Hole

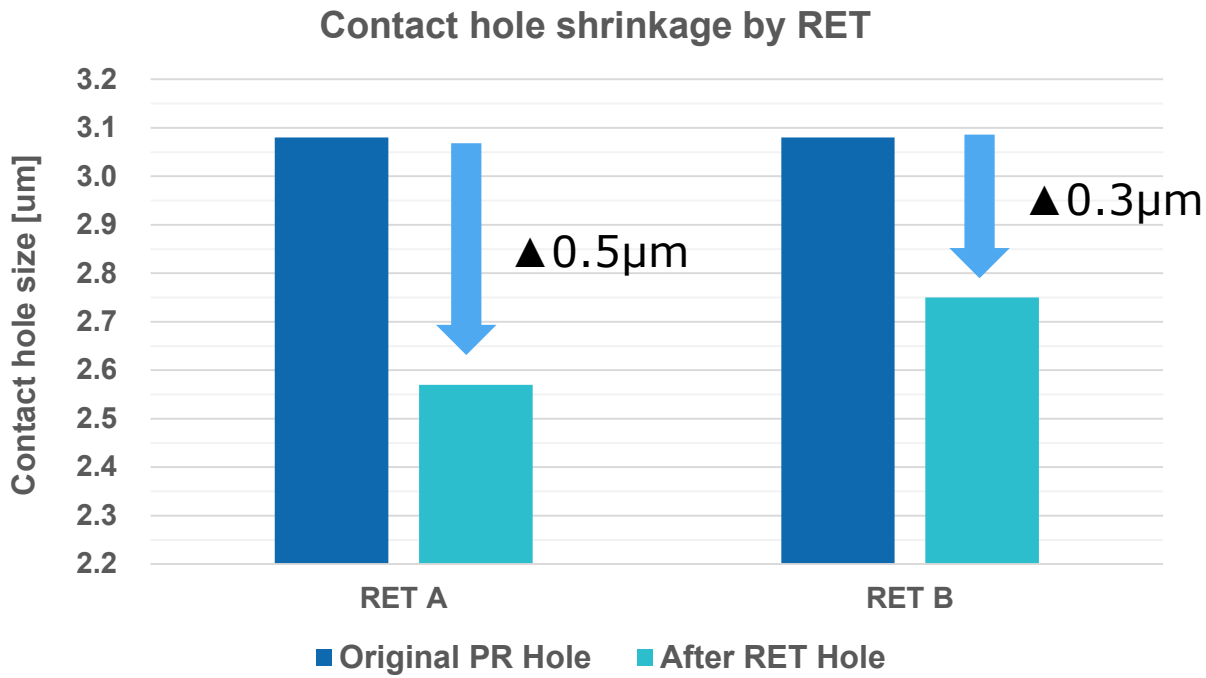
RET Process
Mixing bake: 120ºC
Development: RET developer or Pure Water
2nd Post bake: None

Original Resist Pattern **Original Resist Pattern**



After RET A **After RET B**





Outlines

大型・高精細ディスプレイの課題と酸化物半導体について

High resolution(8K)

	FHD	4K	8K
G Lines	1080	2160	4320
SG cross	2M	8M	33M
1H@120Hz(μs)	7.6	3.8	1.9
Time constant (RC) ratio	1	4	16

8K resolution
- Shorter 1H
- Larger Time Constant (RC)

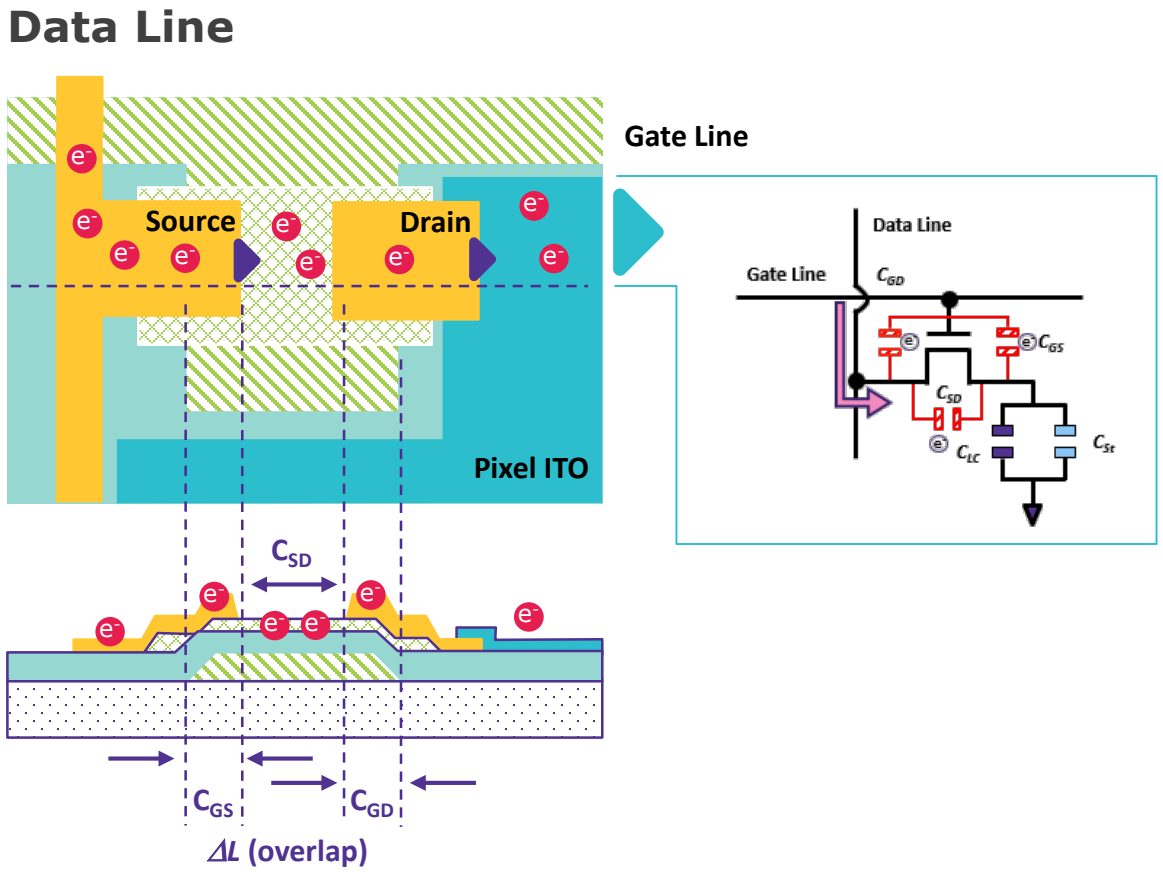
Charging ratio depends on
①Signal line resistances
②Signal line crossing capacitance
③Parasitic capacitance (Cgd) of TFT

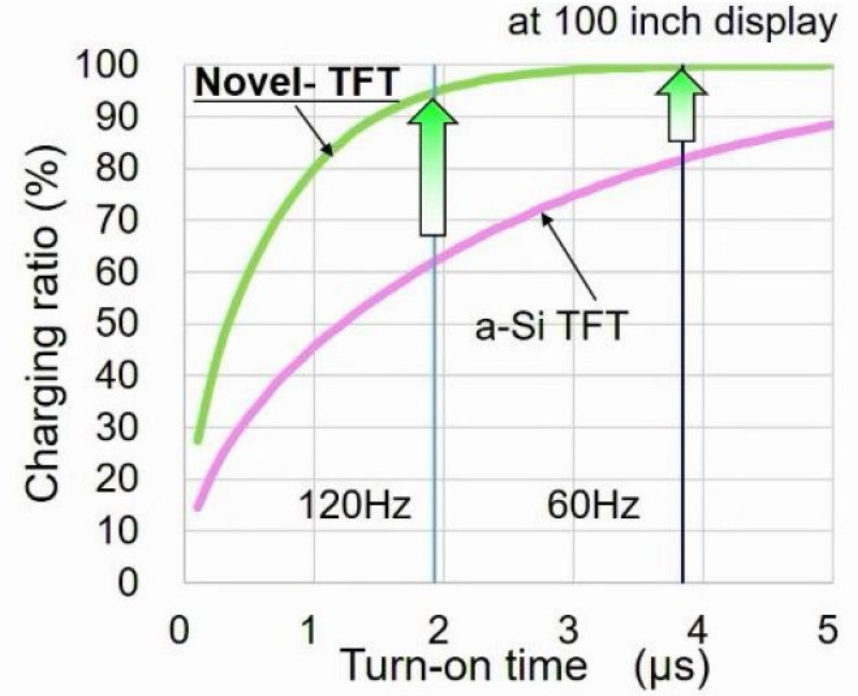
Required technology
- High mobility & Minimum size TFT
- Reduction of Capacitance
- Reduction of Wiring Resistance

Source：Session 53-3, SID2018

- 高性能TFT (大画面化可能な選択として酸化物半導体)
- 信号遅延対策として電極抵抗と寄生容量の低減

大型・高精細ディスプレイへの取り組み　(信号遅延)

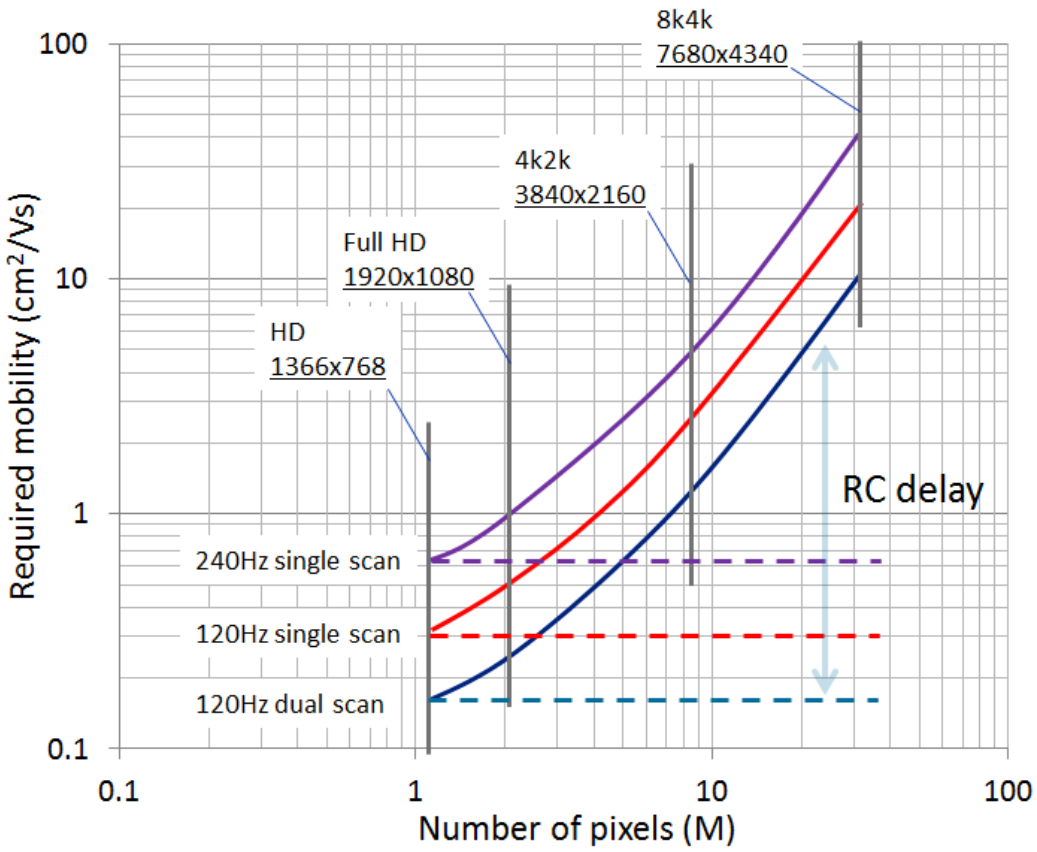




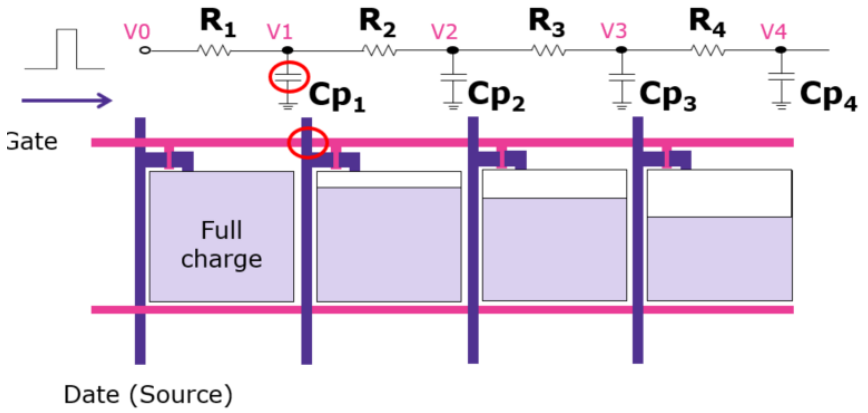
Source：Session 53-3, SID2018

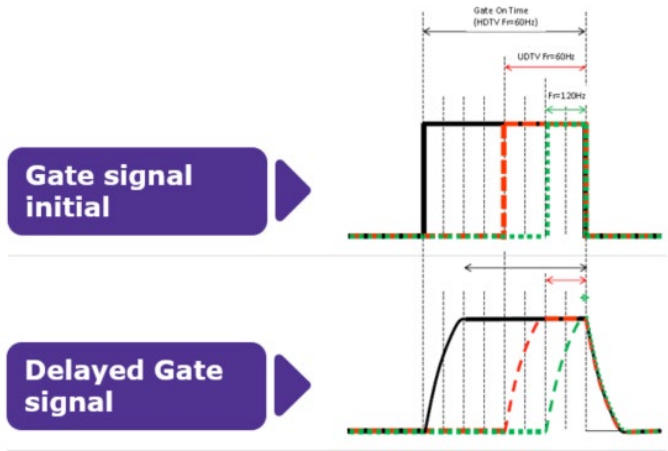
信号遅延と要求されるTFTの移動度

50” TFT-LCD with Cu bus line



Source: ITTC (international thin film transistor conference 2010, Matsueda)

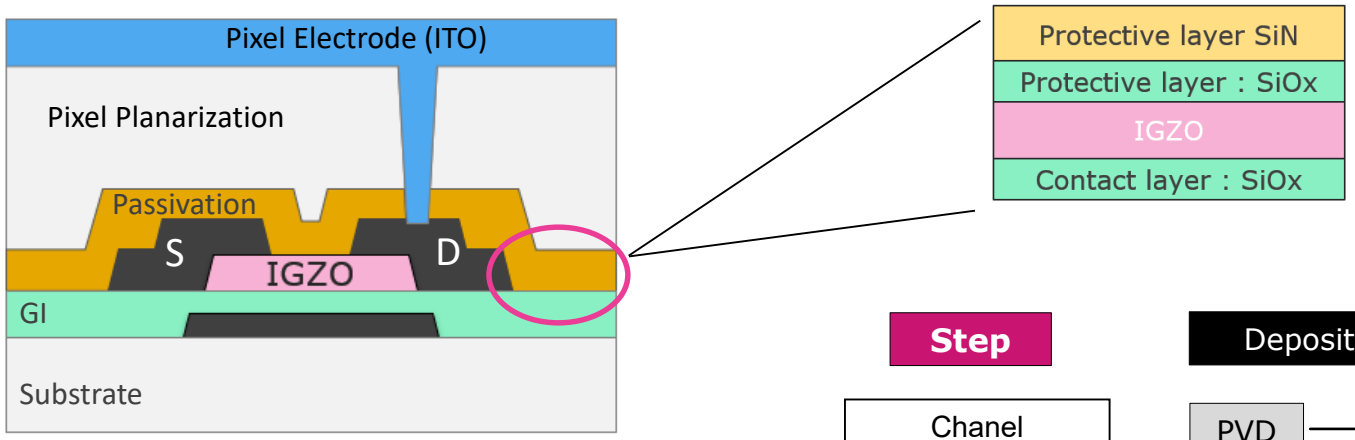




Type of TFT and Application

	OLED	QLED	LCD	EP	Remarks
Single Crystal Si	OK	OK	OK	OK	Limited size (ex, LCOS)
Poly Crystal Si (LTPS)	OK	OK	OK	OK	Limited size (<G6)
Amorphous metal Oxide (IGZO, IZO)	OK	OK	OK	OK	Concern about reliability
Amorphous Si (a-Si)	NG	NG	OK	OK	
Organic Semiconductor	NG	NG	(OK)	OK	Under development

Oxide TFT Passivation (BCE Structure)



IGZOの課題

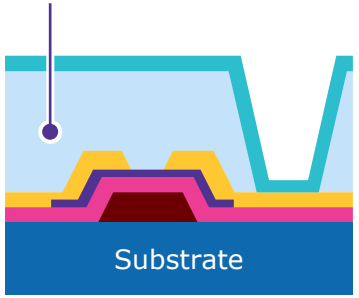
1. 大画面でのIGZO製膜の均一性
2. IGZO薄膜トランジスタの信頼性
3. IGZO保護膜の製膜プロセス

塗布型保護膜のプロセス

Step	Deposition	Coating	Etching	Others
Chanel	PVD		Wet	
Source/Drain	PVD		Wet	
Via/Planarization		Coating	Development	Cure + Annealing
Pixel Electrode	PVD		Wet	

Summary of Coating Passivation for a-IGZO

Coating
passivation + Planarization

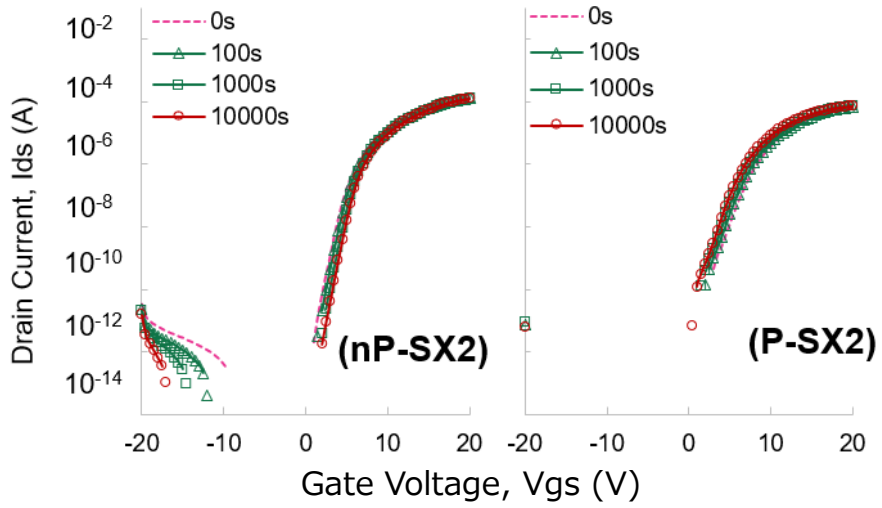


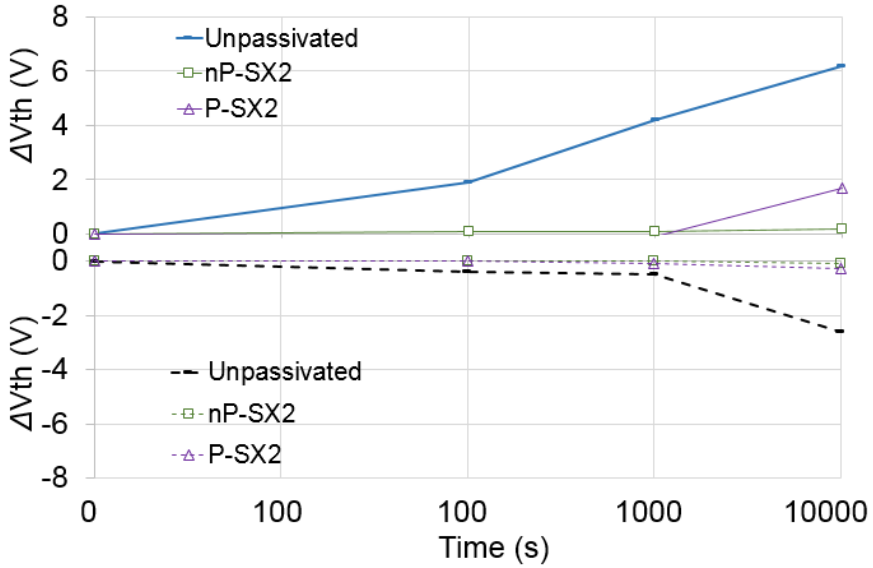
Sample	mobility	V_{th}	S
Un-passivated	7.4 ± 1.6	6.5 ± 0.3	0.22
nP-SX2	11.0 ± 0.4	3.8 ± 0.1	0.17
P-SX2	10.1 ± 0.7	3.8 ± 0.5	0.17

Mobility ↑ 8.0 cm^2/Vs ⇒ 11.0 cm^2/Vs

Reliability ↑ (PBS,NBS,NBIS)

Reliability after NBST





Merck Coating Functional Dielectric Materials