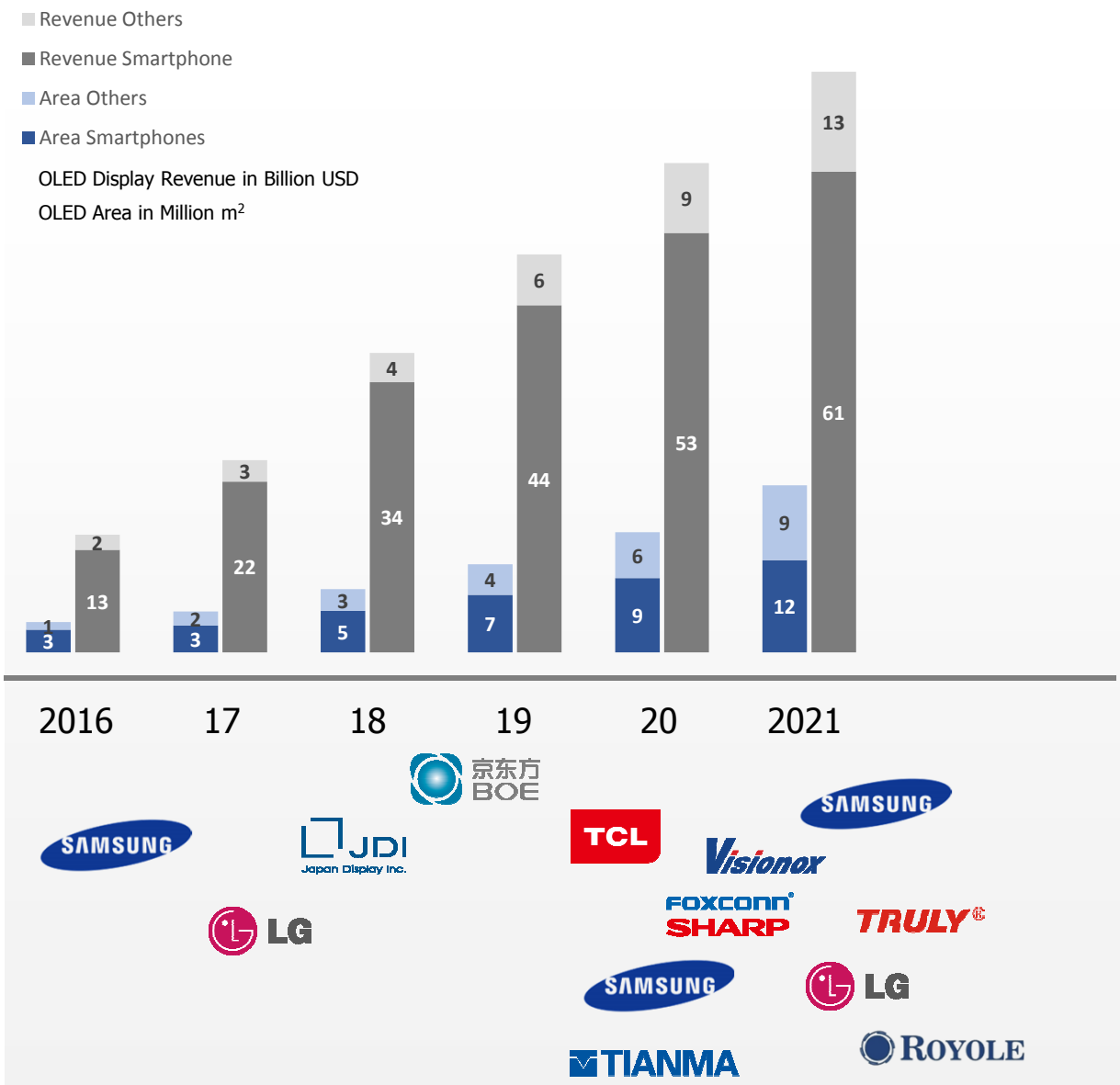
Unlocking the OLED display markets

March 2018

APEVA

OLED technology reaches the volume market and is one of the fastest growing segments in the technology sector



$50 bn OLED display revenue by 2021 expected

- 23% CAGR in OLED panel shipments until 2021
- 25% revenue growth p.a. expected
- Adoption of OLED displays is now spreading from Samsung to Apple and Chinese smartphone makers
- Chinese government has announced strategic investment program

Novel form factors and display performance drive OLED adoption, also beyond 2021

- Foldable and flexible displays the next key driver in displays with potential 2-3x in market size post 2021
  - Better energy efficiency, brighter colors and higher resolution offered by OLED technology
  - TV and lighting following the mobile market later on

Source: APEVA, IHS, DSCC

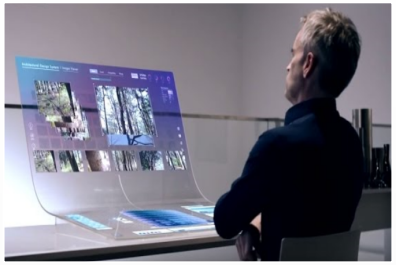
Further spreading of OLED displays in the future expected – step changes in display performance and cost are required

Displays everywhere




- Ubiquity of information, IoT and smart home drive number of OLED displays and display size
- Significant improvement of OLED display production cost needed to reach tipping points for additional markets

Novel form factors



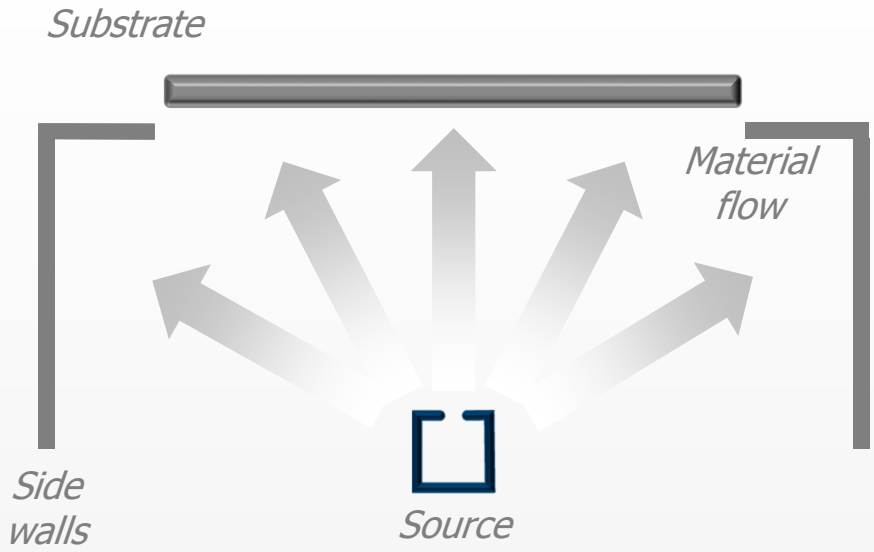

- New applications and functionalities enabled by flexibility and transparency of OLED displays
- Enhanced display lifetime, energy efficiency and color brightness needed to satisfy application needs

Next step in OLED display technology needed to address future's cost/ performance needs

Source: APEVA

Today's established VTE OLED technology faces challenges

Schematic of today's VTE technology



- Evaporation of material from heated crucible (source)
- Spreading of material into all directions
- Larger distance between source and substrate

Challenges of today's VTE technology

Limitations in display performance improvement

- Challenges in mixing materials
- High effort for controlling material flow
- Mainly simple OLED stacks

Limitations in substrate scaling

- High effort to produce desired uniformity
- Increasing complexity with substrate scaling

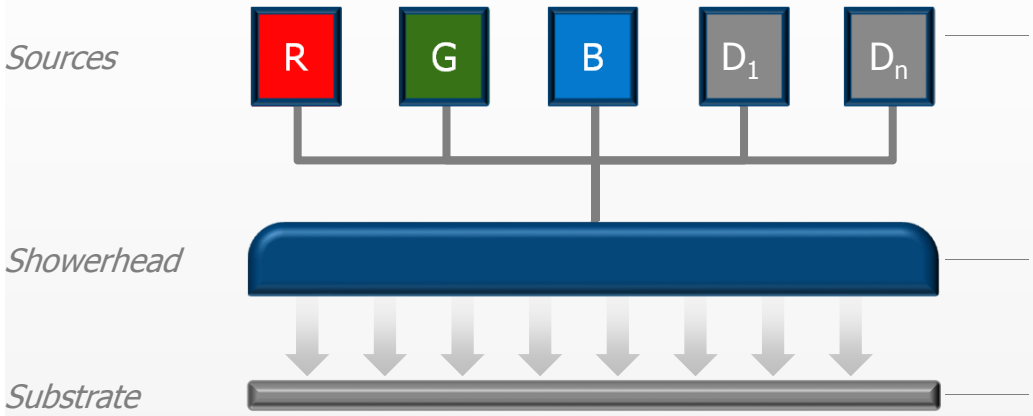
High production cost

- Lower efficiency in usage of expensive organic materials (up to several hundred USD per gram)
- Downtime from frequent cleaning

Source: APEVA

APEVA has developed a disruptive OLED display technology – Organic Vapor Phase Deposition (OVPD)

Schematic of OVPD technology



Principle of OVPD technology

Material flow is generated in patented sources:

- Material in powder from is brought into gas phase
- No damage to organic components from low temperature processing
- High uniformity and precision in dosing possible

Mixing of materials and spreading across the entire substrate

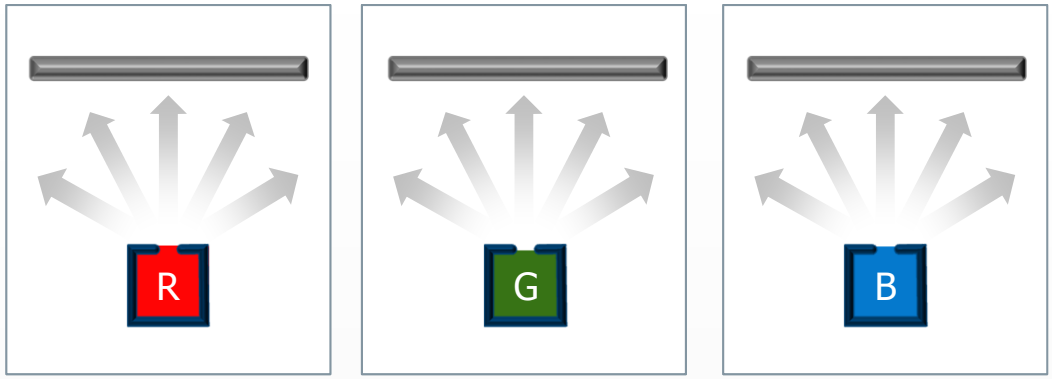
Deposition occurs by condensation on the cooler substrate

Key modules are IP protected

Source: APEVA

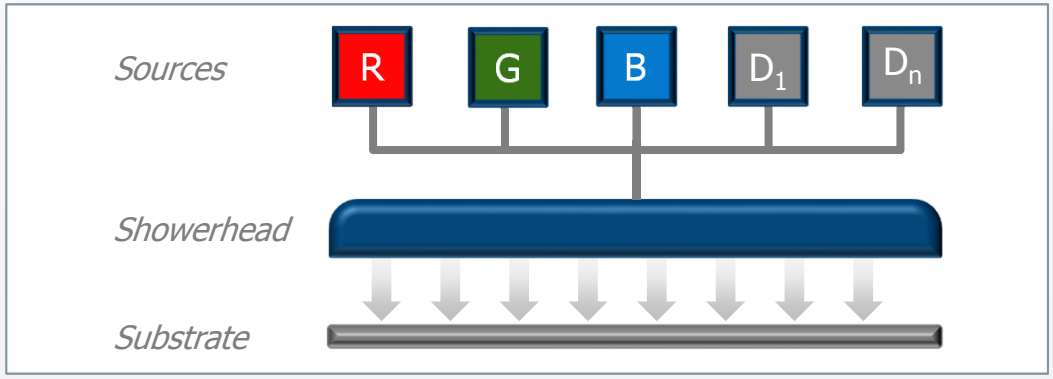
OVPD technology value proposition:
Enabler of improved OLED display performance

VTE technology



- Separate deposition chamber needed for each material
- Mixing of materials limited

OVPD technology



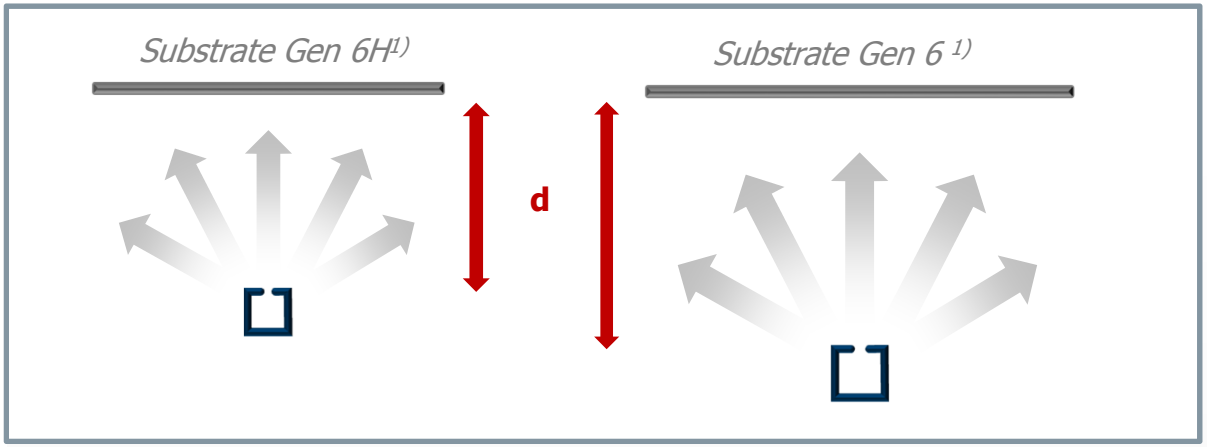
- Multiple materials can be mixed and well controlled in deposition system
- Improved display properties possible, e.g., better
  - Display lifetime
  - Color and brightness

OVPD technology opens the way to OLED display performance improvements

Source: APEVA

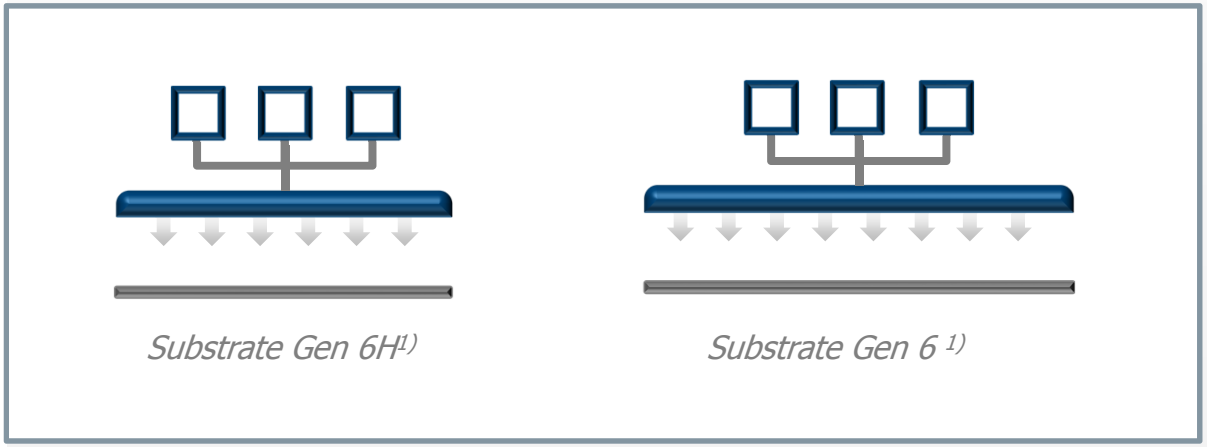
OVPD technology value proposition:
Scalability to larger substrate sizes while maintaining process performance

VTE technology



- Uniformity for large substrates require increasing distance (d) from source to substrate
- Complexity of system increases with scale-up

OVPD technology

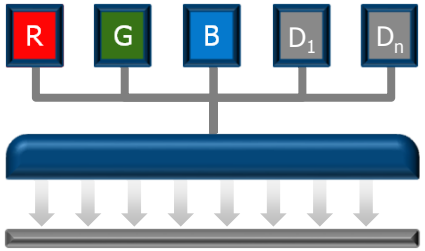
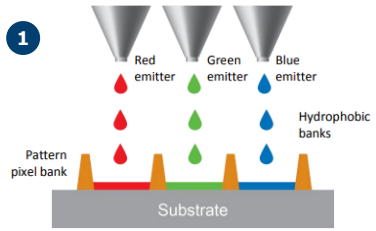


- APEVA's sources can be scaled up to provide throughput needed for larger substrates
- Scaling in size with limited effort while maintaining uniformity across larger substrates

OVPD can be scaled to larger substrates while today's VTE faces challenges

1 Gen 6H approx. 1,5 x 0,9 m ; Gen 6 approx. 1,5 x 1,8m ;
Source: APEVA

Rival alternative production technology OLED printing has several disadvantages compared to APEVA's OVPD technology

	OVPD (APEVA)	Organic OLED printing
		 Drop placement by inkjet Dry out solvent in vacuum
Resolution and applications	• Highest resolution • Patterning with mask technology possible → Resolution driven applications, e.g., mobile	• Limited resolution • Larger Displays eg TV, Outside panels → Lower resolution applications
Materials	• Existing materials in powder form from VTE can be used w/o changes	• New materials in liquid form
Production size/ energy cost	• Small footprint for reactor • No dedicated drying	• Larger area in factory needed for drying equipment

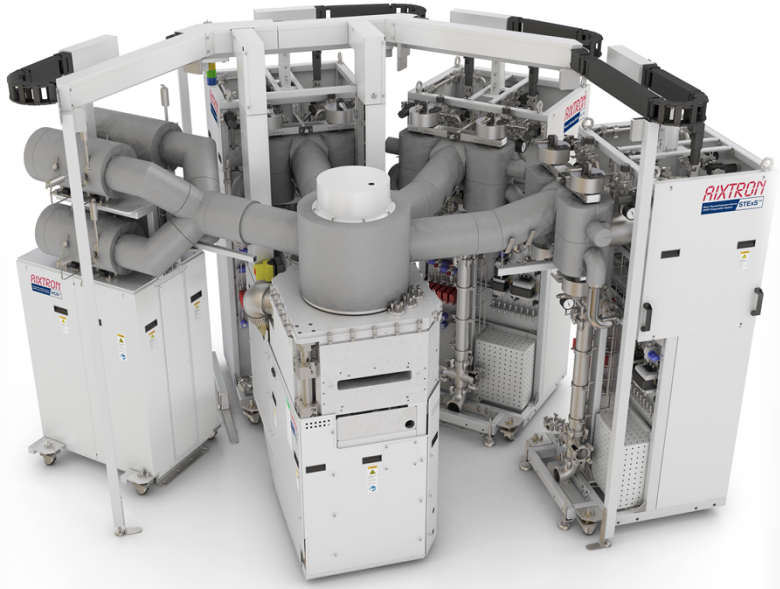
OVPD and OLED Inkjet printing to date address different segments of the OLED market

Source: APEVA; Printing process courtesy of Kateeva

APEVA's disruptive OVPD display technology comes with a strong value proposition for the OLED displays of today and of tomorrow

1. Enabler of improved OLED display performance

- ✓ Deposition of multiple materials in a single process chamber
- ✓ Precise flow rate control and high process stability
- ✓ Supporting display lifetime improvement



2. Scalability to larger substrate sizes

- ✓ Deposition uniformity is maintained upon scaling up substrates
- ✓ Higher material flow rates needed for large substrates possible

3. Significant Total Cost of Ownership (TCO) reduction in deposition of organic stack

- ✓ Reduced variable cost due to high efficiency in usage of expensive OLED materials
- ✓ Smaller production footprint possible

4. Compatibility to existing OLED materials and suppliers

- ✓ Usage of existing organic materials that are in mass production today

Source: APEVA

Image Credits

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