OLED – Status quo and our position

Information Day 2013 – A Deep Dive into the LC&OLED Business

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OLED at Merck KGaA, Darmstadt, Germany and basics

OLED vapor versus printing

Our perspective on OLED

Strategic update and position

Summary

We start from strong platforms

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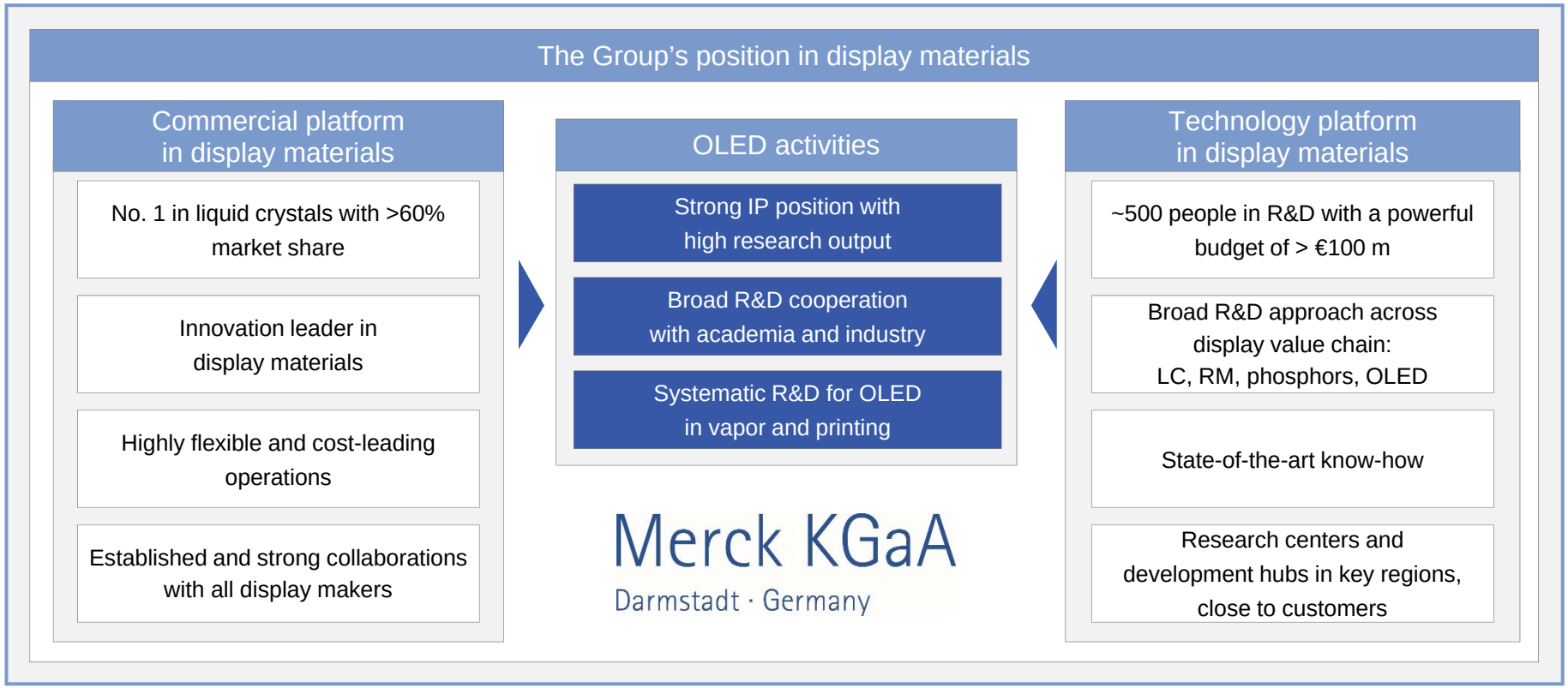

OLED: A fundamental part of our R&D strategy for more than a decade

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Our history of OLED development

OLED activities in Mainz

2001

- Schott & IBM Project Luminescence Technologies
- We acquired Project Luminescence Technologies
- First white OLED lighting designs for ambient lighting
- New strategy from component manufacturer to material supplier

2007

OLED activities in Frankfurt

1992

- Hoechst AG R&D Project
- Covion GmbH established
- 100% subsidiary of Avecia Ltd.
- 100% subsidiary of Merck KGaA, Darmstadt, Germany
- Integration into Merck KGaA, Darmstadt, Germany

2007

2010

Merging of both in Darmstadt

OLED today

- ~80 R&D experts
- M&S experts in all 4 key countries
- ~1,400 patents
- Commercial production

OLEDs are carbon-based light-emitting components

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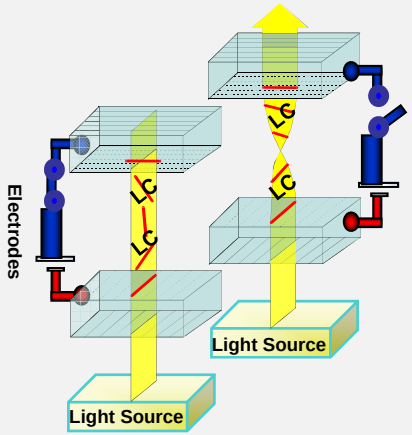
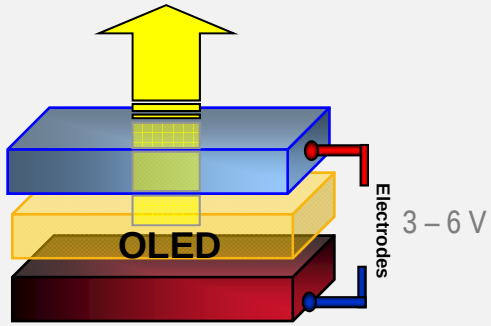
Fundamentals of liquid crystals versus OLED

Liquid crystals - Light Modulation



OLED - Light Generation



Advantages of OLED

OLED displays versus liquid crystal displays

- Slightly thinner
- Slightly lighter

OLED: A fully controllable micro light bulb with the correct color in every pixel

Our focus is to provide solutions for the full OLED stack, addressing all layers

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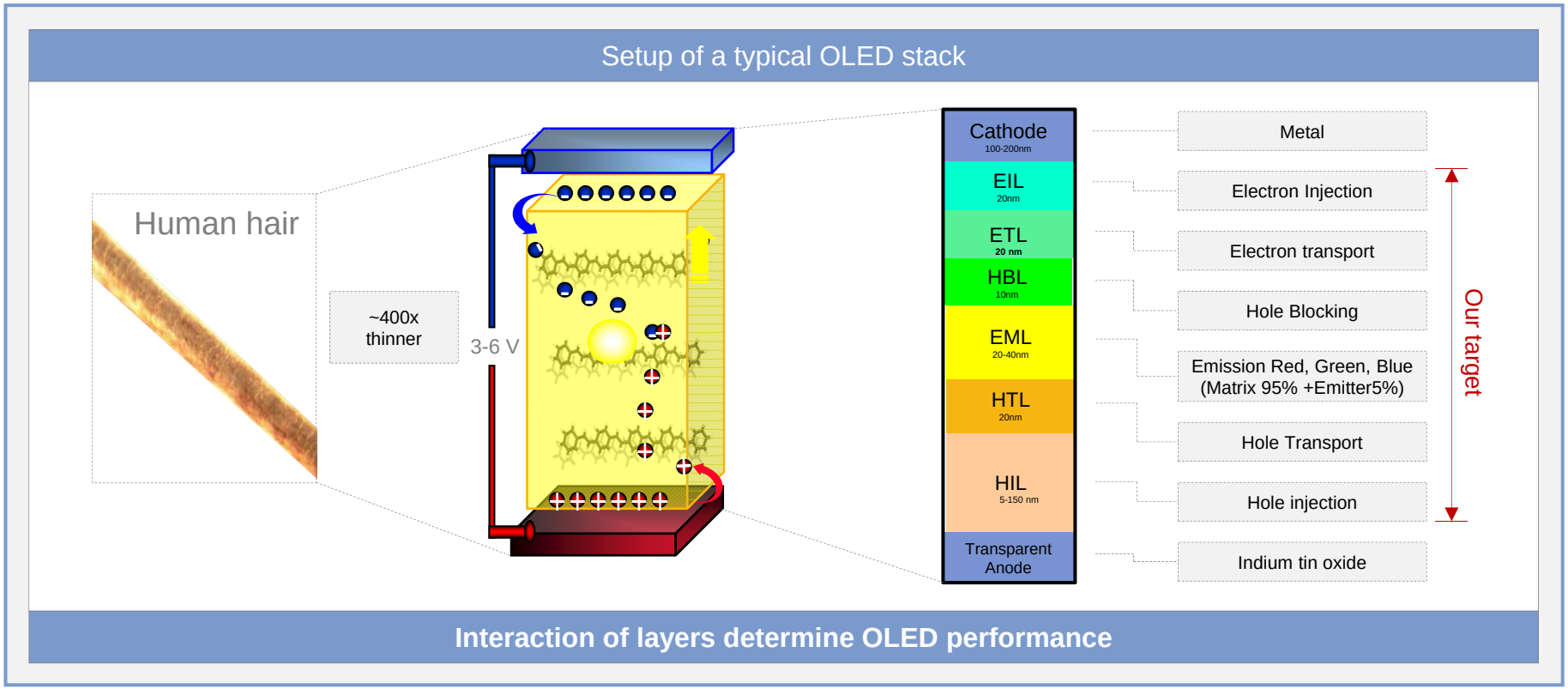

OLED can be used for display as well as lighting applications

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Our OLED application fields

Flexible displays

Curved surfaces

Non-breakable

Non-flexible displays

Very thin

Low energy consumption

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Lighting

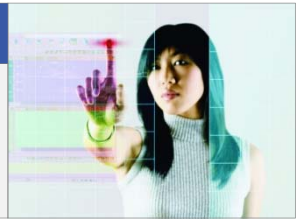
OLED lighting concepts

Wallpaper

Transparent

New applications

Combining displays and lighting



OLED is more than just TVs

While further production capacities for OLED will be built, their overall level will remain low near-term

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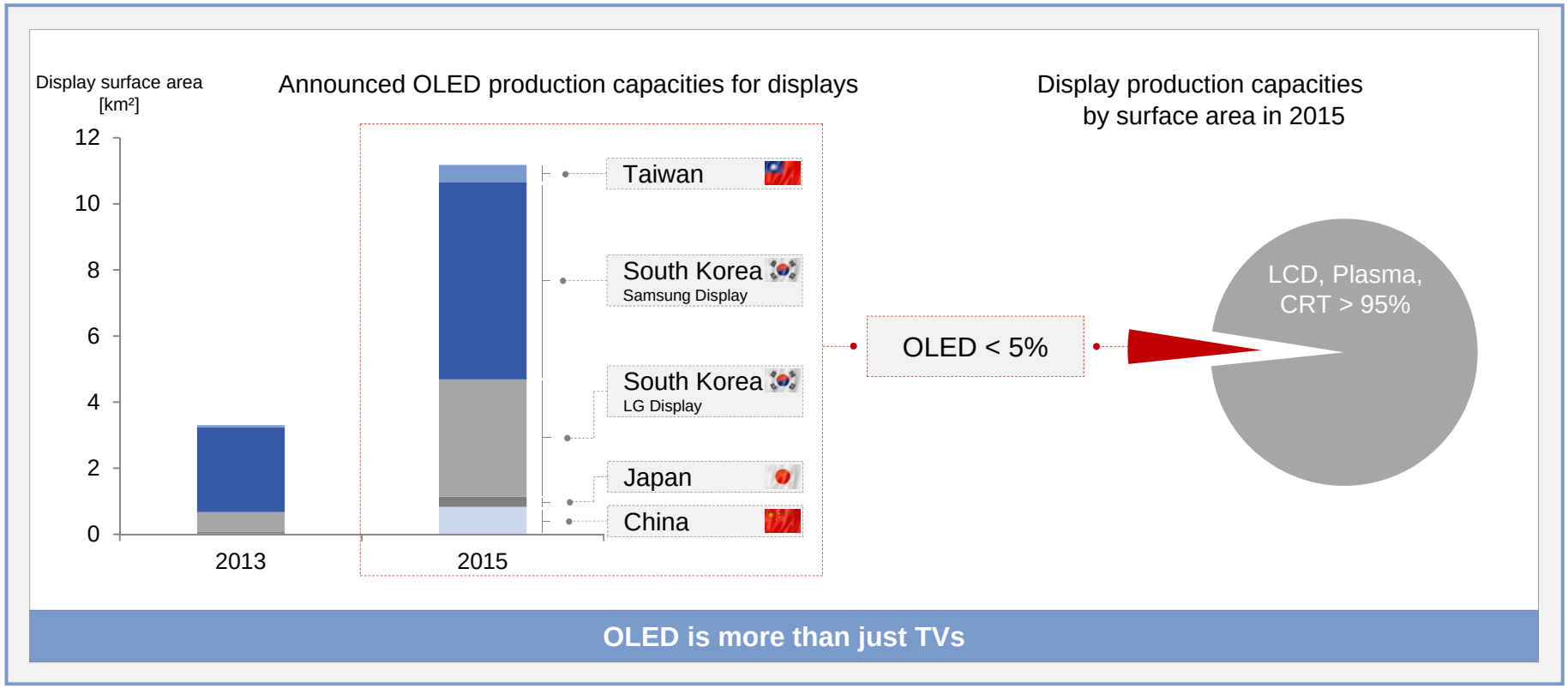

Source: DisplaySearch Quarterly FPD Supply/Demand & Capital Spending Report, Q1 2013, AMOLED, year-end capacities with likelihood >=30%

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The development of OLED displays already started 20 years ago, gaining momentum only recently

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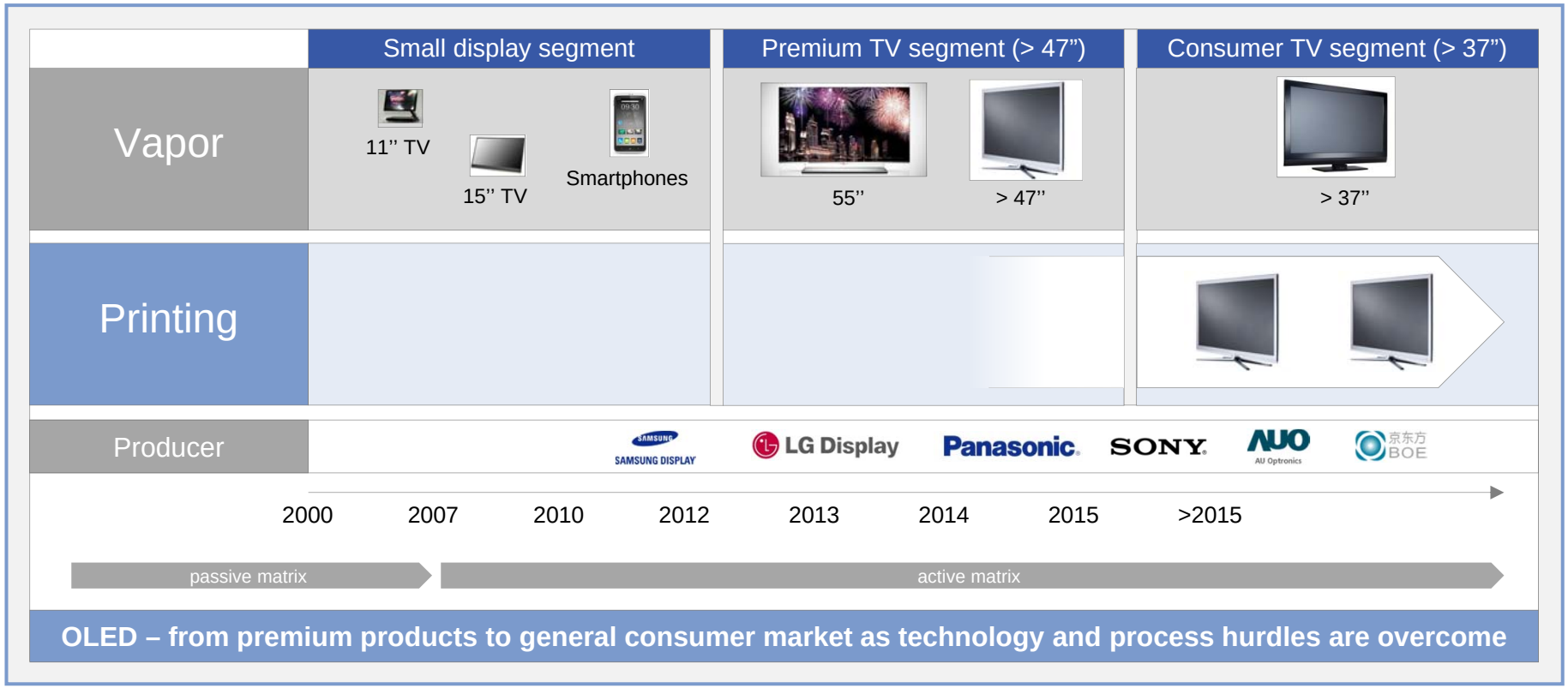

Today, two technologies are used for the commercial production of OLED displays: RGB and White

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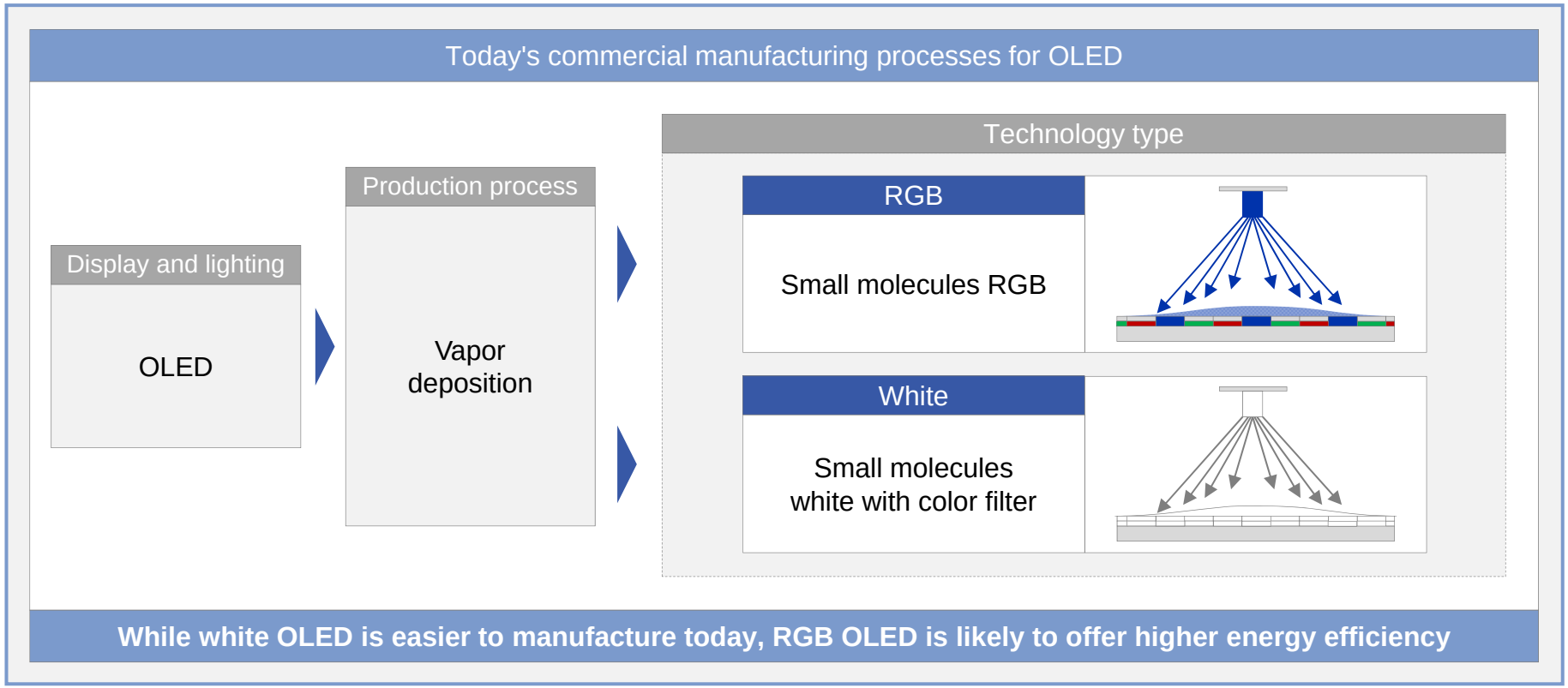

Acronyms: RGB = Red, green and blue

The vapor process for RGB OLED production has a limited intrinsic yield

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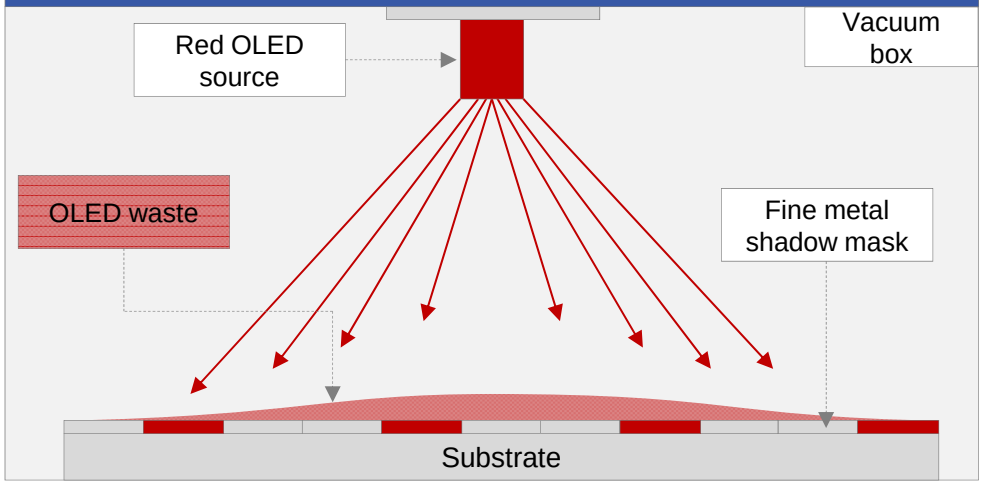
Chemical vapor deposition (CVD) process

1

Step 1: Application of red emission layer



Deposition yield:

<30%

Significant loss of red OLED material due to deposition on mask

The vapor process for RGB OLED production has a limited intrinsic yield

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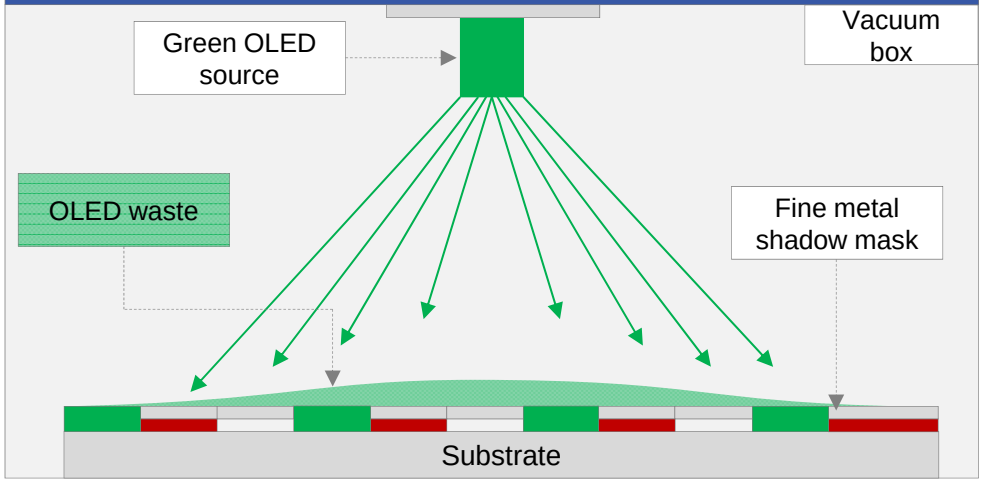
Chemical vapor deposition (CVD) process

2

Step 2: Application of green emission layer



Deposition yield:

<30%

Significant loss of green OLED material due to deposition on mask

The vapor process for RGB OLED production has a limited intrinsic yield

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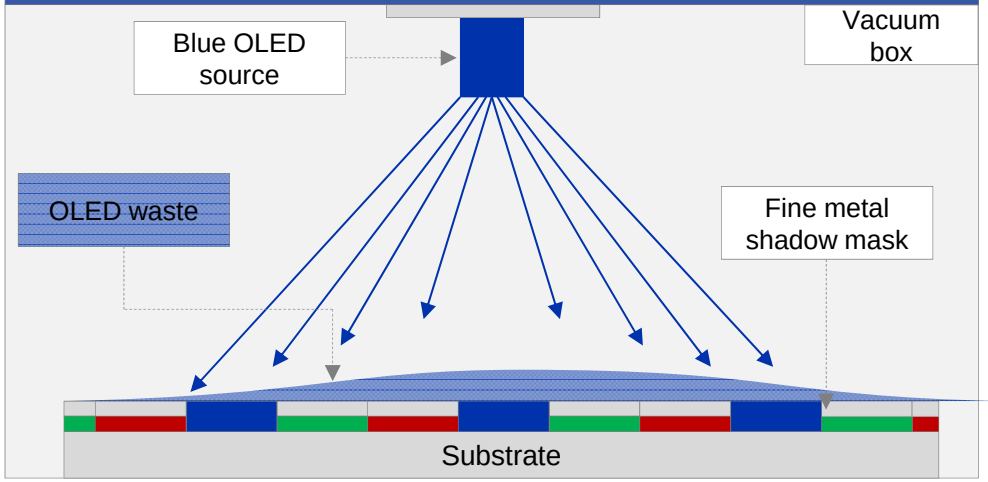
Chemical vapor deposition (CVD) process

3

Step 3: Application of blue emission layer



Deposition yield:

<30%

Significant loss of blue OLED material due to deposition on mask

RGB OLED vapor process is attractive for small displays but is challenging for large displays

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Characteristics of Chemical Vapor Deposition (CVD) process for RGB OLED

Pros	Cons
Established and well controllable process	Limited substrate size due to challenges arising from handling of large metal masks
High resolution possible	High amount of waste due to need for masking
Successful in small devices	Limited scalability
	Uneven deposition of material

RGB OLED production based on chemical vapor deposition can hardly be cost competitive to LCD

Printing is a proven technology for the targeted deposition of materials

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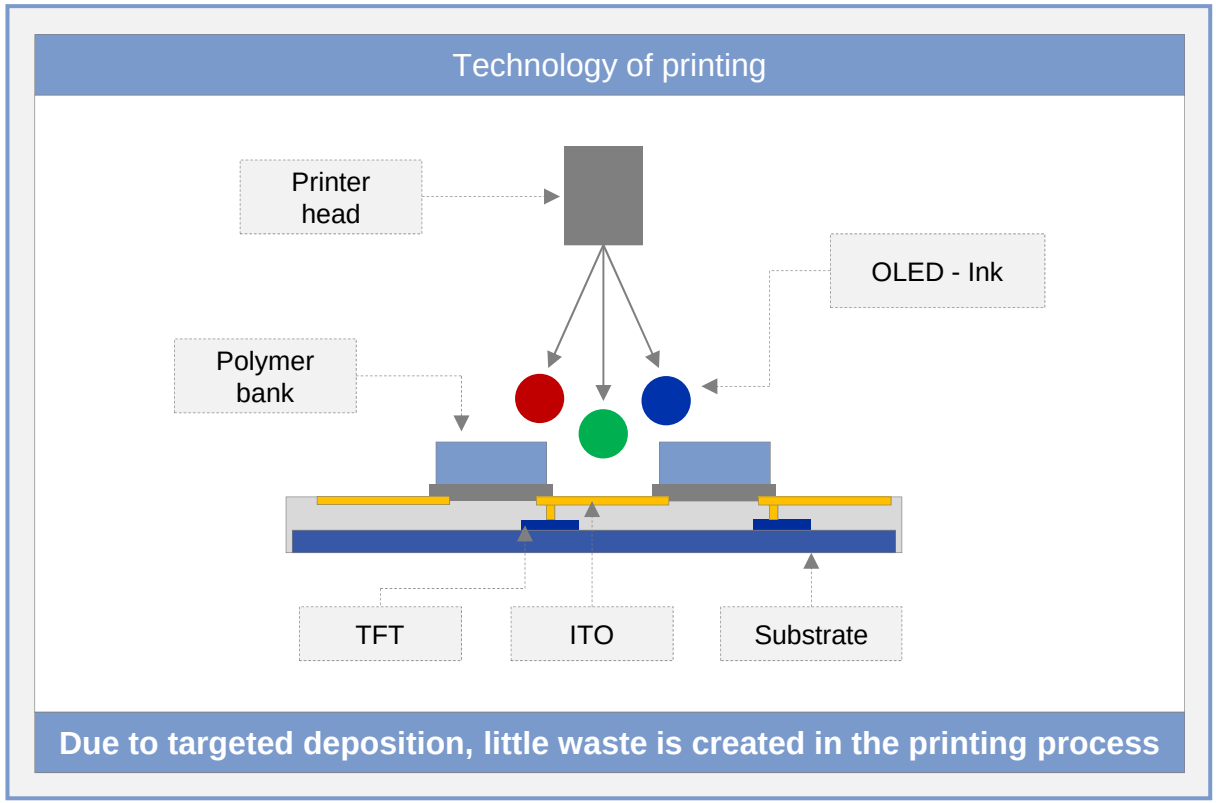

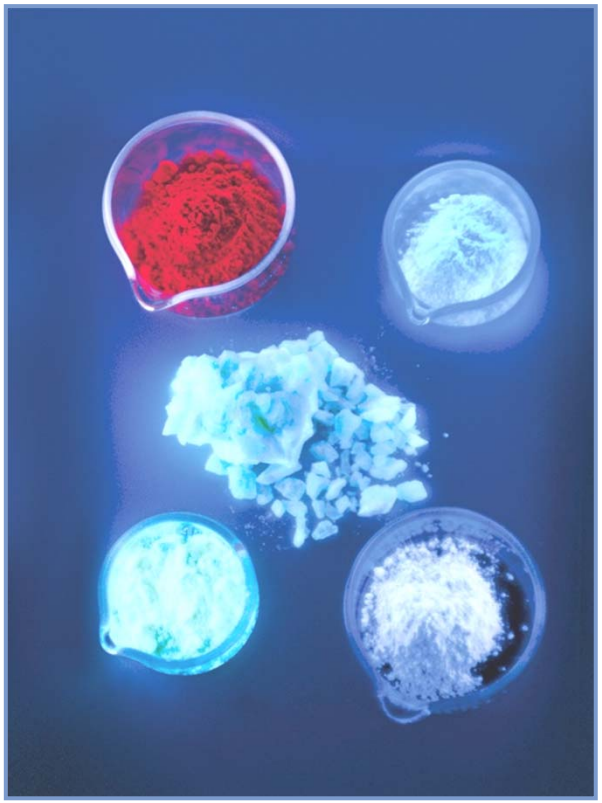

Acronyms: TFT = Thin-film transistor; ITO = Indium tin oxide

OLED printing: A scalable and efficient production technology for displays, but still in its infancy

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Characteristics of printing process

Pros

- Very efficient use of materials with high throughput
- Scalability to large areas
- Less complex process
- Open technology access

Cons

- No established process for mass production yet
- Requires availability of technology and corresponding inks

RGB OLED production based on printing has the chance to be cost competitive to LCD

OLED printing can solve the waste dilemma and the size limit of the RGB vapor process

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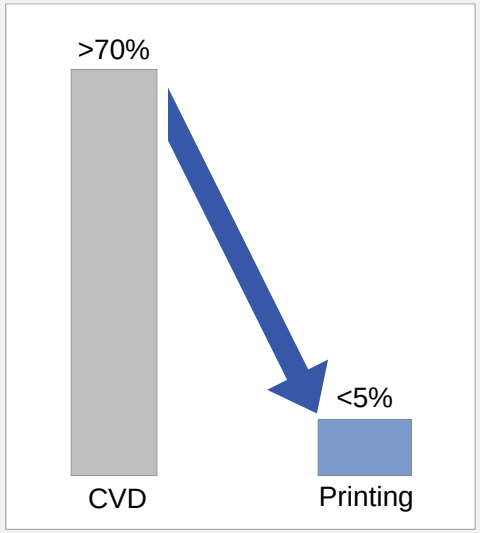
Characteristics of OLED production technologies

Chemical vapor deposition

2012 price per square inch:
~$10 US*

No targeted deposition of OLED materials on substrate
- inefficient material use
- high costs

OLED material waste



Printing

2014 price per square inch:
~$5 US*

Targeted deposition of OLED materials on substrate
- very efficient material use
- lower costs

*Source: Display Search, Quarterly Worldwide Flat Panel Forecast Report, Q1 2013

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If OLED technology advances further, it could gain meaningful share in the TV market

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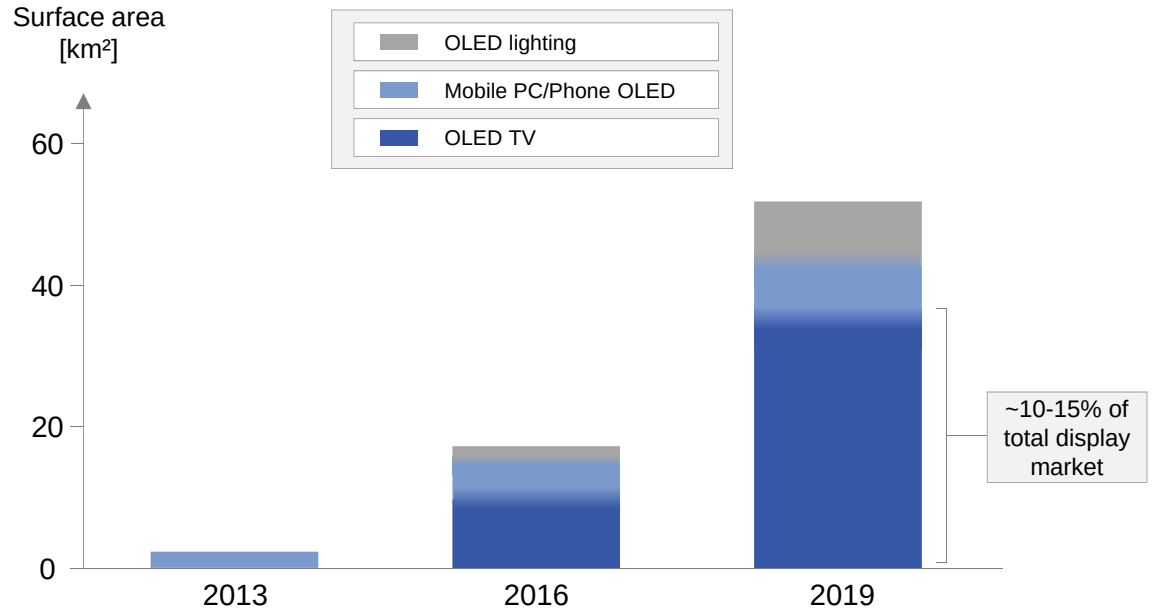
Market forecast for OLED surface area



OLED market

- Today, small displays play dominant role for OLED
- Additional growth driver for OLED could be TVs
- OLED lighting is expected to play a meaningful role from 2020 onwards

OLED could capture ~10-15% of the total display market by 2019

Source: DisplaySearch, Quarterly Worldwide Flat Panel Forecast Report, Q1 2013; Nanomarkets, Special Report for: The FlexTech Alliance - OLED Lighting Markets, May 2012

RGB printing has technological advantages compared to rivaling RGB vapor process

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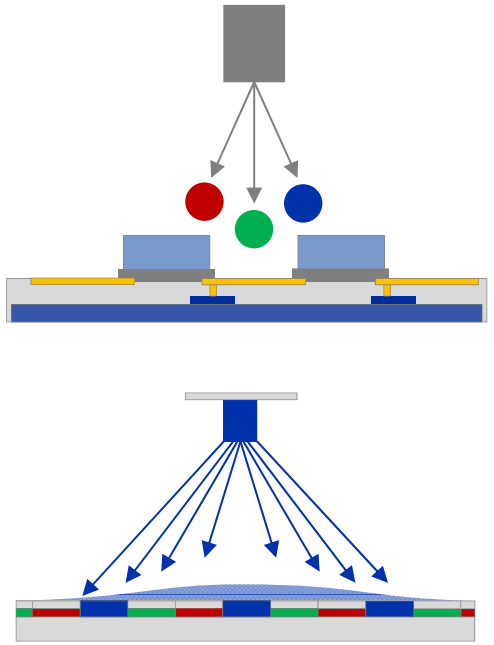
Comparison of OLED printing versus OLED vapor deposition		
	Processing	
	Printing	Vapor deposition
Performance Materials Advantage	▪ Scale to large area ▪ Less complex process ▪ High material utilization ▪ High production yield ▪ High throughput ▪ Open technology access	▪ Established state-of-the-art ▪ Suitable for ultra high resolution
Performance Materials Challenge	▪ No established production technology for OLED yet	▪ Scale to large area ▪ Production yield ▪ Complexity of process



Due to its scalability, OLED printing has the potential to enter the large display mass market

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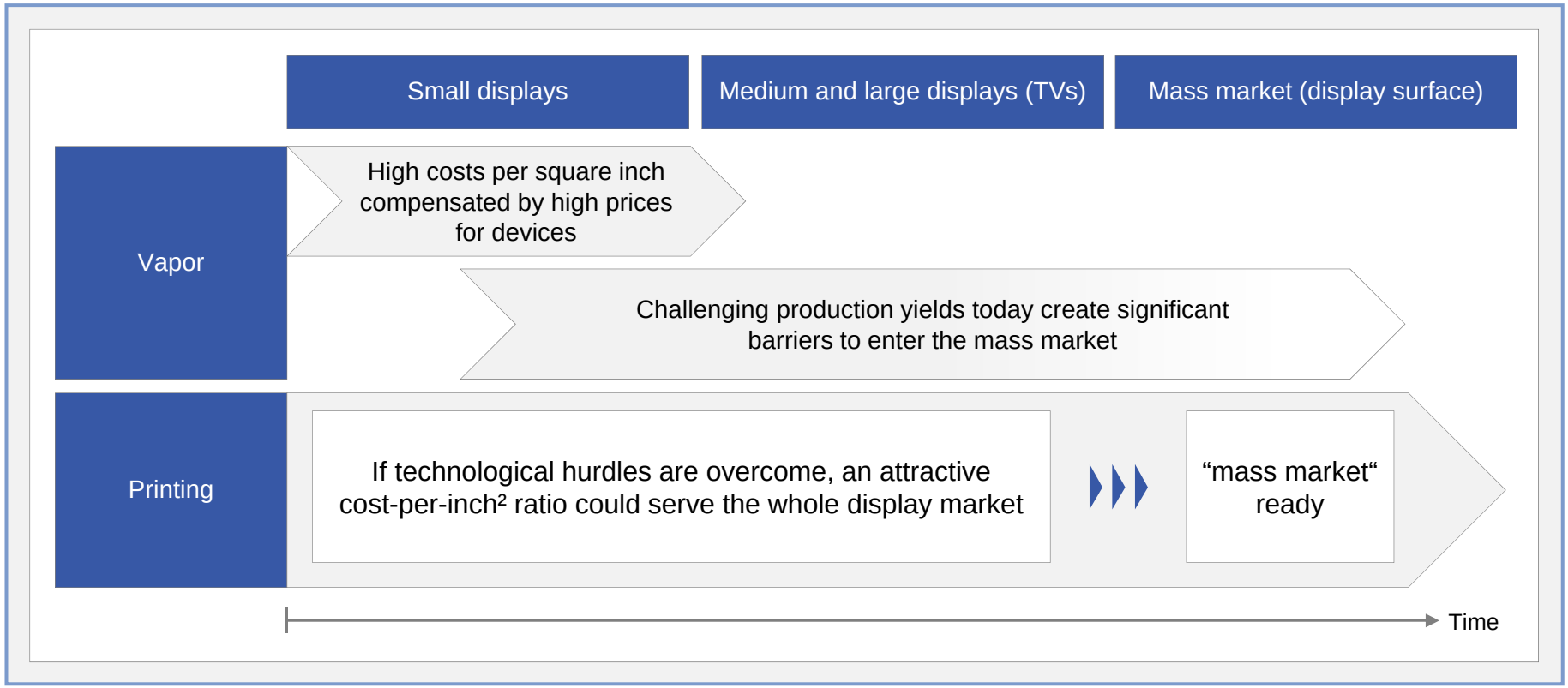

Alliance of our company and EPSON creates significant momentum in development of OLED printing

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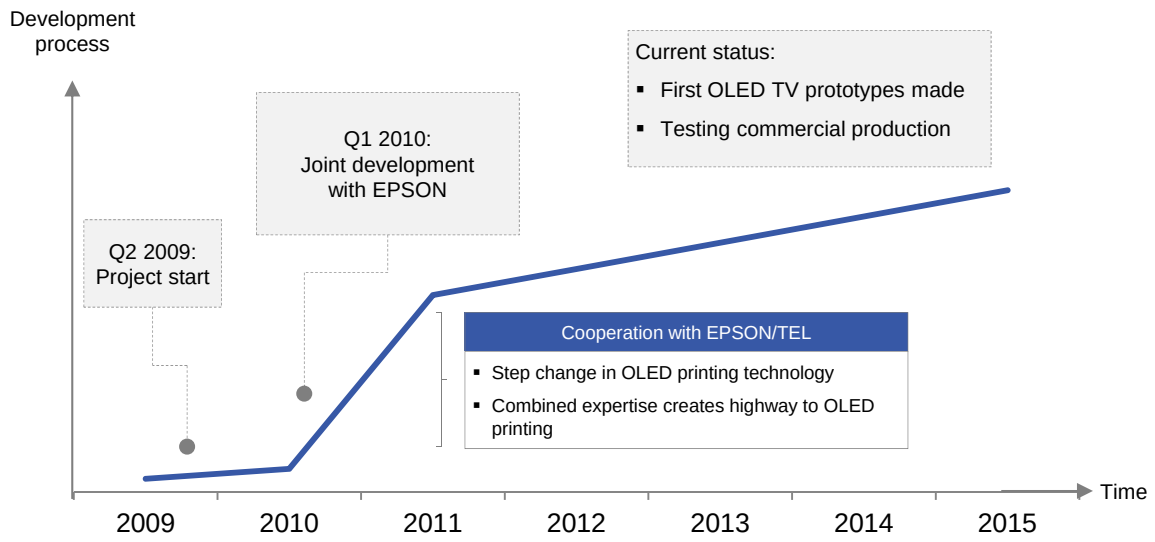
The Group's commercialization roadmap of OLED printing



Combining our strong expertise in display materials with Epson's strength in printing

Positioned for OLED printing leadership

Our position in OLED printing

- Consolidated market
- We are one out of ~3 players

Our position in OLED vapor

- Fragmented market
- We are among ~10 players

We have positioned ourselves to become market leader in OLED printing

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OLED takes the same strategic approach that has proven successful for liquid crystals

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Value-adding strategy in liquid crystals and OLED

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Single material supplier

- Limited development scope
- Highly depending on “customer pull”

Solution provider

- Difficult to exchange
- Differentiation by performance
- Can stimulate “customer push”
- Accelerates technology development
  - triple win for customer, consumer and provider

Liquid Crystal Strategy	Liquid crystal single material	Translate chemistry into physics	Customized liquid crystal solution
OLED Strategy	OLED material	Added value	Customized OLED full stack

Transition to solution provider maximizes value for us and our customers

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If OLED takes off in large displays and lighting, we are ready to participate

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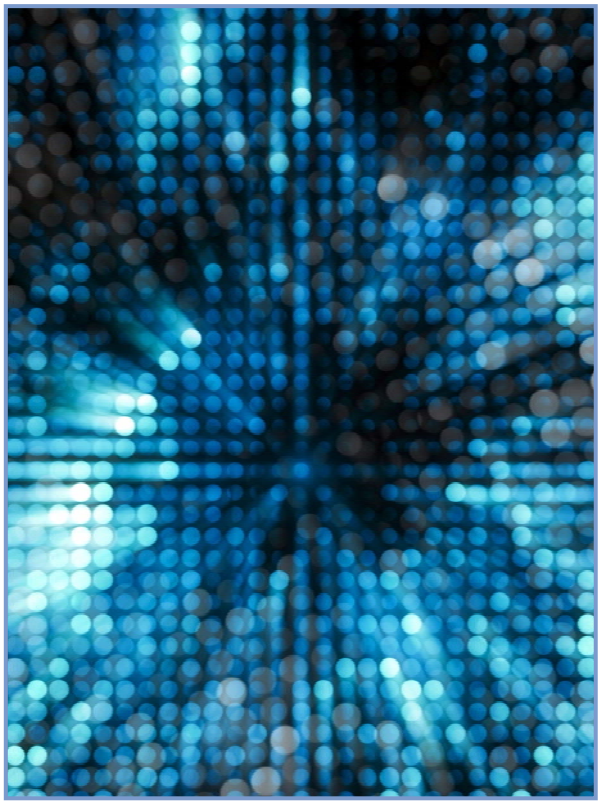
- Powerful commercial and technology platforms in display materials
- Strong position in OLED vapor and printing
- We are ready to capture the OLED opportunity



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Appendix

White OLED displays: Higher yields in the vapor process, but also higher energy consumption

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Characteristics of Chemical Vapor Deposition (CVD) process for white OLED

Pros	Cons
+ Established and well-controllable process	− Highly complex stack
+ High resolution possible	− Uneven deposition of material
+ Successful in small devices	− ~2/3 of light intensity held back by color filters
+ No need for masking	

White OLED displays: easier to manufacture, but even less differentiation to LCD than RGB OLED