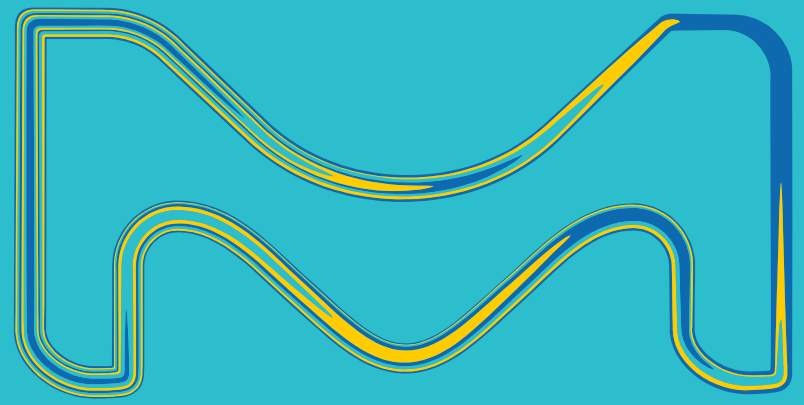


OLED solutions for lighting applications

Advanced Materials for Next Generation OLEDs

Michele Ricks
DOE SSL Workshop 2020
January 2020

EMD Performance Materials

we are unique

Since our founding more than 350 years ago, we've become truly global with more than **56,000 employees in 66 countries** working on break-through solutions and technologies.

Merck KGaA
Darmstadt, Germany

EMD Serono MilliporeSigma EMD Performance Materials

We are known as "Merck" internationally except for the United States and Canada, where we operate as EMD Serono in the biopharmaceutical business, MilliporeSigma in the life science business, and EMD Performance Materials in the high-tech materials business.

we are the company behind the companies advancing digital living

Advancing Display

From large TVs to touch screens and free-form displays: We have played a part in all **key display innovations** and can be found in more than half of all flat-screen televisions, smartphones and tablet computers.

Today, our customers use our unrivalled breadth of product, depth of understanding and specialist expertise to make the most of the increasingly vital role of display in a digital era:

LC materials

Market Leading Innovation

OLED materials

Revolution in display & lighting

Photoresists

A global leader in Display Resists

Reactive Mesogens

Ultra-thin coatings and optic films

Siloxanes

New backplanes and Barriers

Quantum materials

Major leap in display color

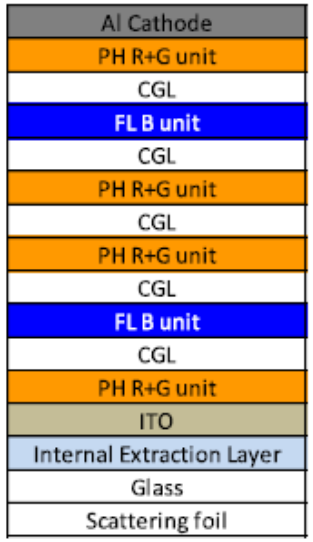
LED Phosphors

Bright, energy-efficient & vivid

challenges for OLED lighting

01

Transport Materials for OLED Lighting
Opportunities and Challenges



CGL materials can contribute to lowering voltage

Blue unit is critical to increase efficiency,
as R/G is usually de-tuned to balance color

Figure 5: Brite2 white OLED stack

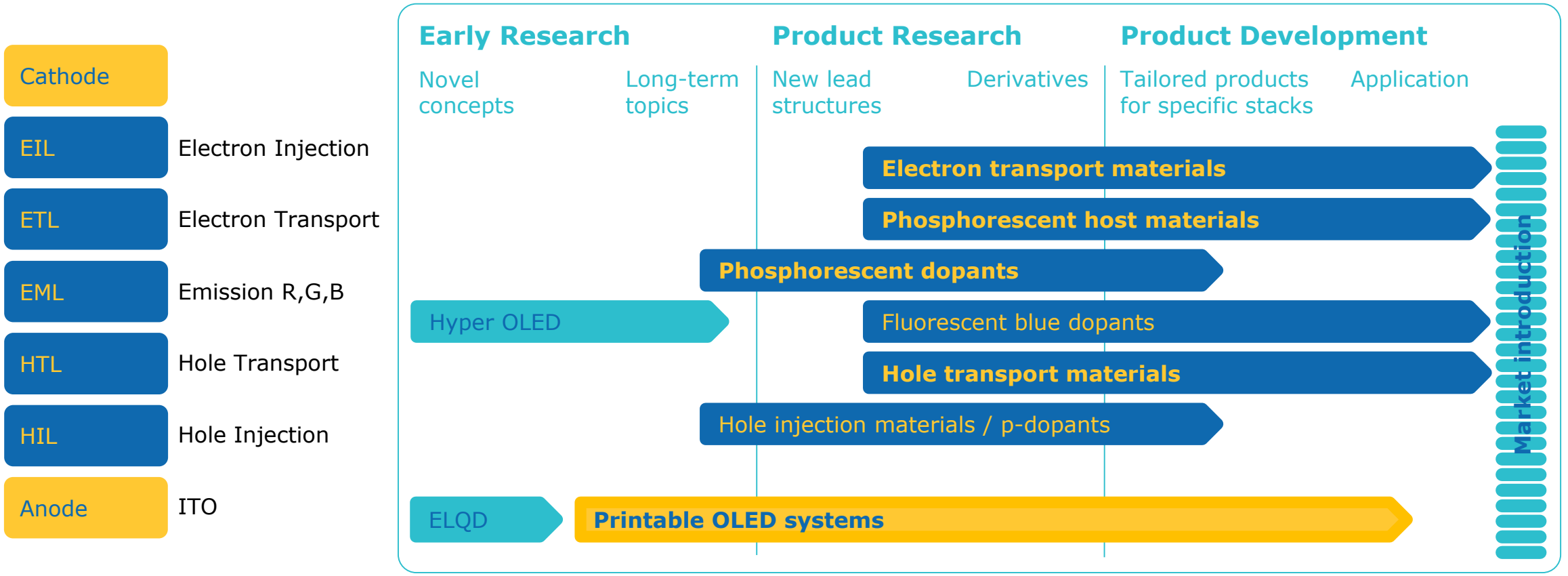
J. Spindler et al. "24-2: *Invited Paper*: High Brightness OLED Lighting", *SID INT SYMP DIG TEC*, 47 (2016).

Higher lm/W devices can broaden the market for OLED lighting.
Improve lm/W by increasing efficiency and lowering voltage.

OLED @ Merck KGaA, Darmstadt, Germany, Performance Materials

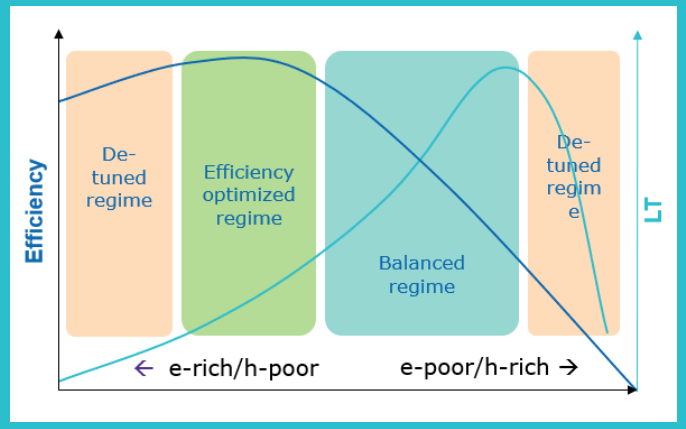
02

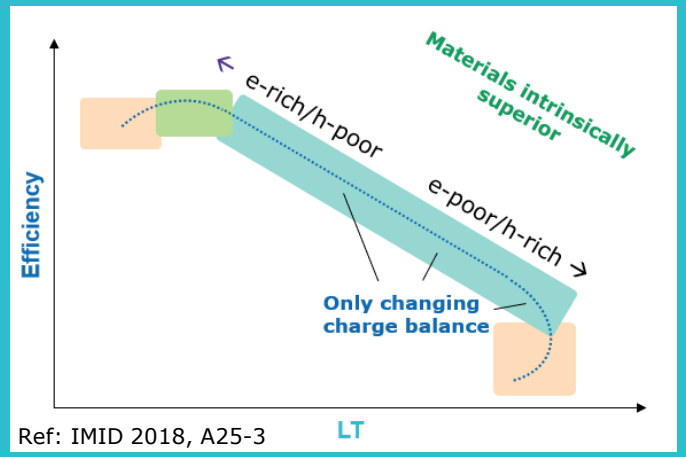
We offer state-of-the-art materials developed for the full stack of both processing technologies, printing and vapor



R&D portfolio covering the full range from early hot topics to mature products

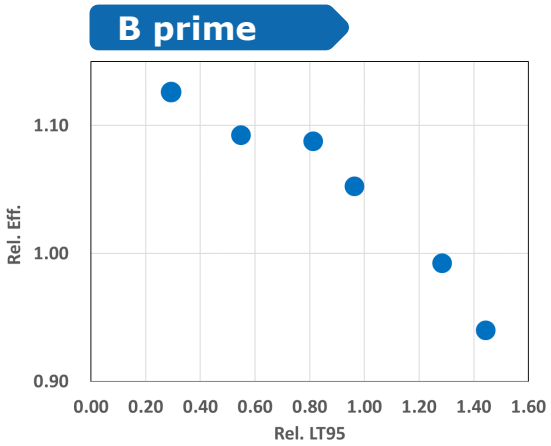
Our Approach
Broad Material Portfolio

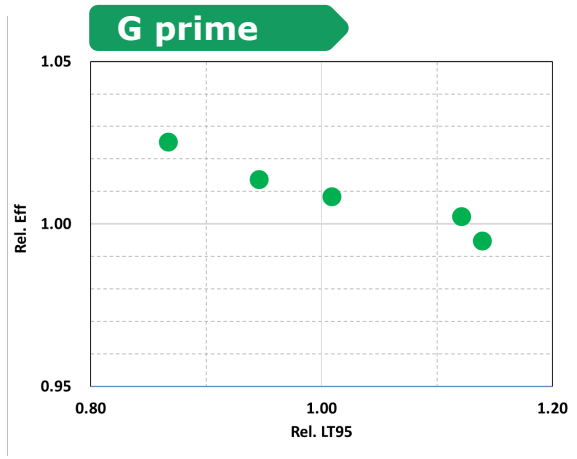


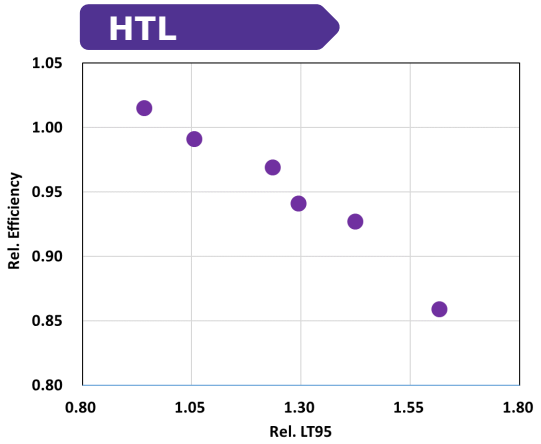


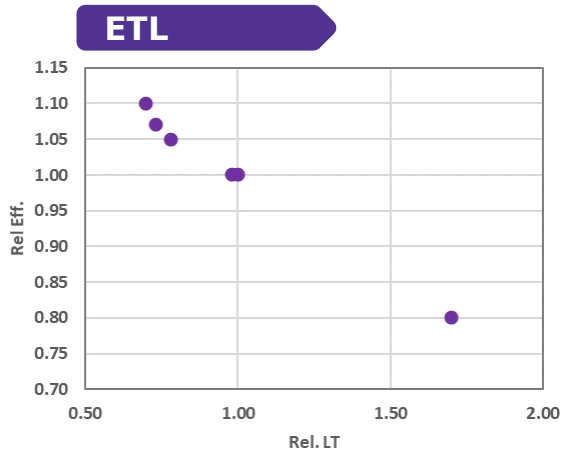
Ref: IMID 2018, A25-3

Charge Balance Effect





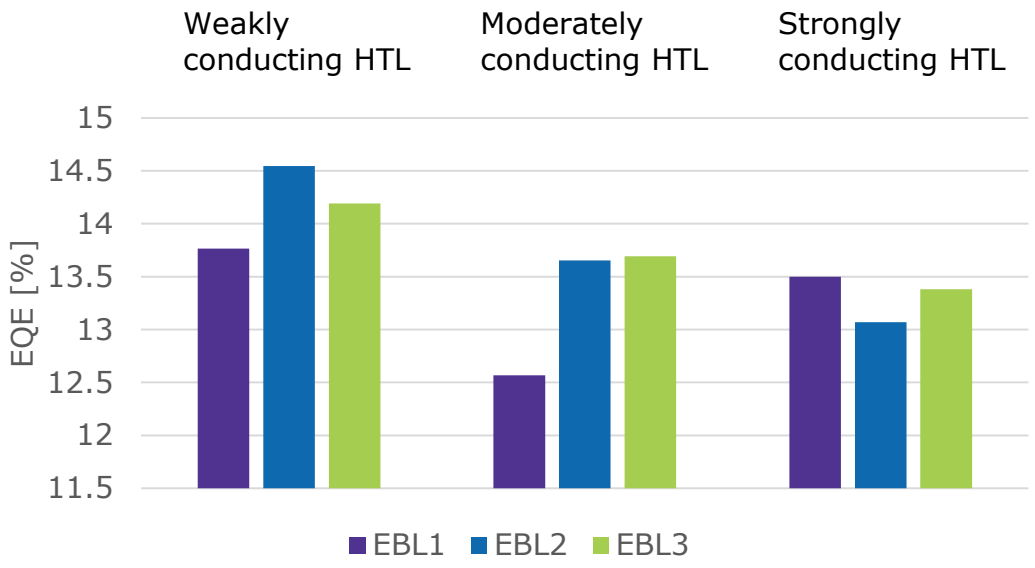




Freedom to tune device performance independently in RGB

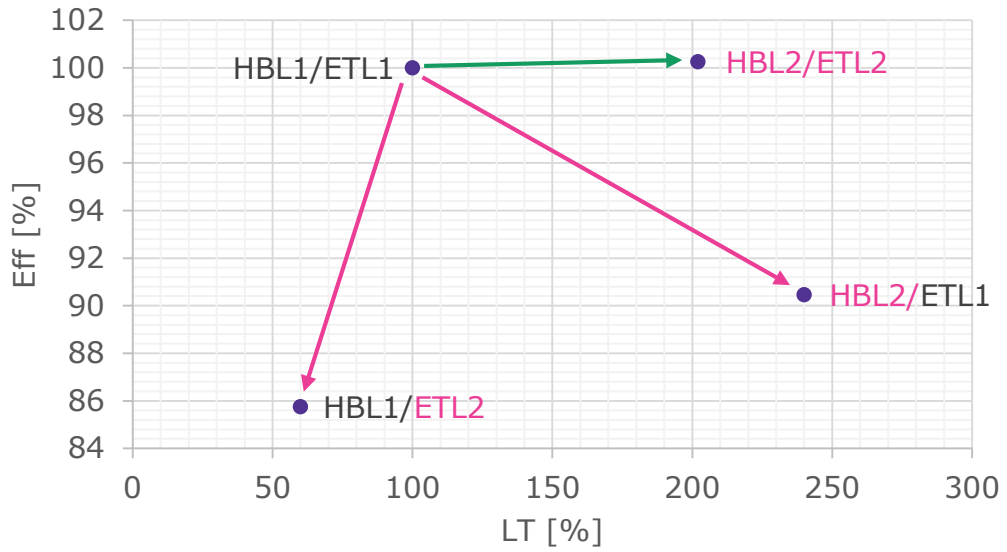
Our Approach
Material Combinations and Full Stack Understanding

Example 1: Interaction between HTL and EBL



There is no universally best material!

Example 2: Interaction between HBL and ETL

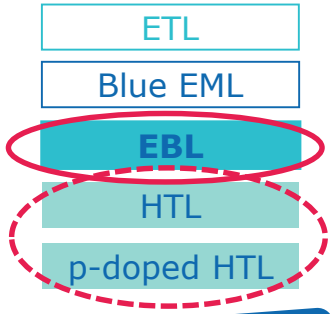


One by one replacement does not bring solution!

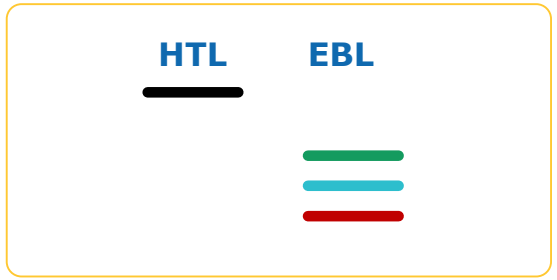
We leverage a broad portfolio and understanding of interactions within the device to optimize performance for specific applications

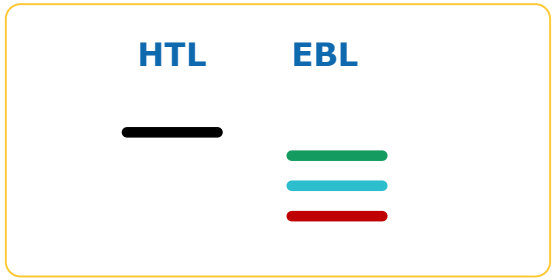
Example

Interaction between HTL and EBL

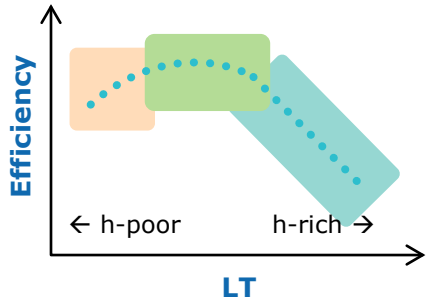


HOMO

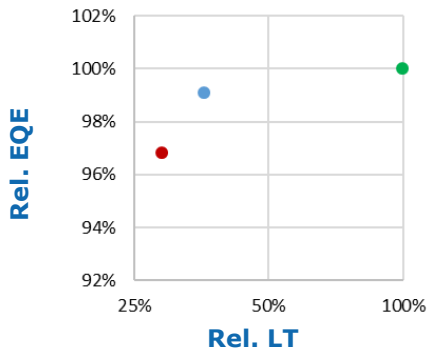




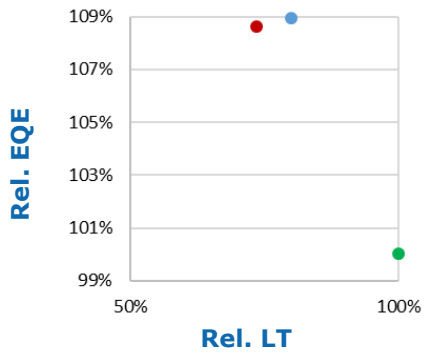
Reminder



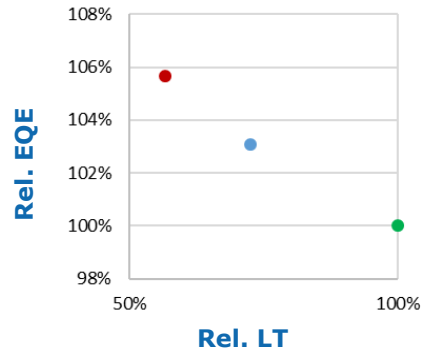
EBLs on high HOMO HTL



EBLs on medium HOMO HTL



EBLs on deep HOMO HTL



- **Strong interaction with HTL**
- **Most efficient EBL in one device can be least efficient in another!**

How to adjust the charge balance?
Our Electron Transport Material portfolio (selection)

ETL

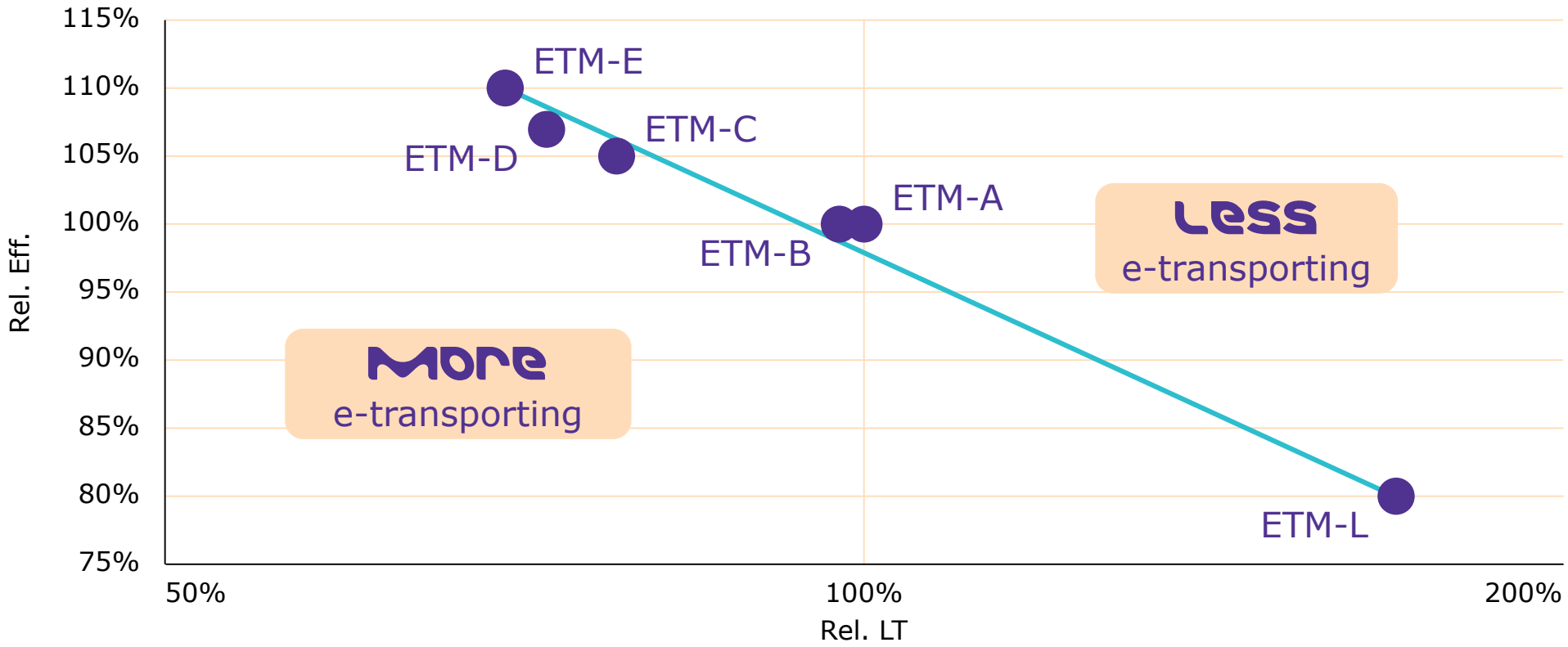
Blue EML

EBL

HTL

p-doped HTL

ETMs in vapor blue stack



ETM portfolio covering a wide range of charge balance for tuning between LT and eff.

Example
Electron Blocking Material portfolio for fluorescent blue (selection)

ETL

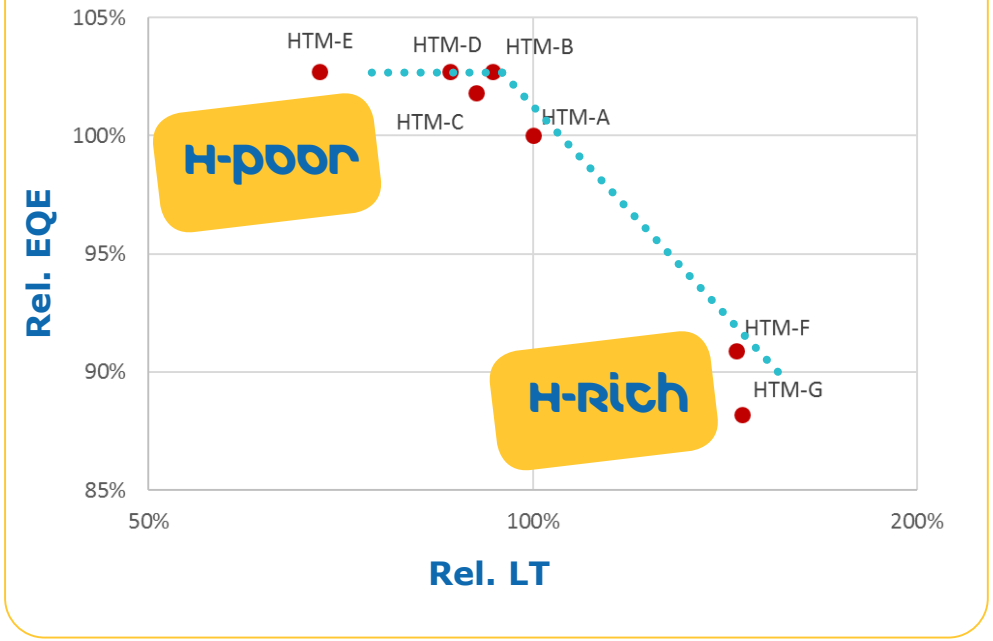
Blue EML

EBL

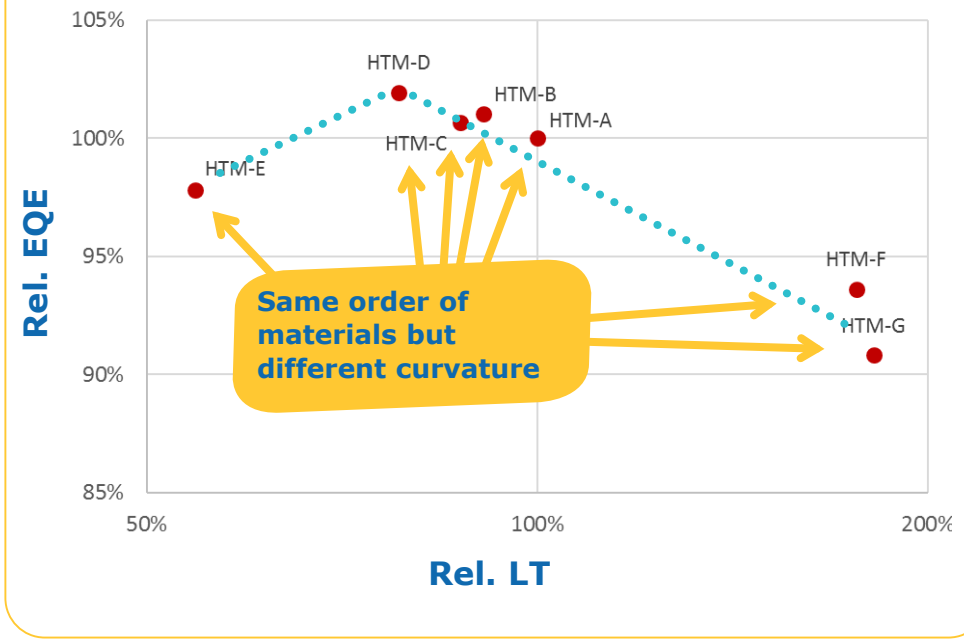
HTL

p-doped HTL

EBLs in blue stack with moderately e-rich ETL



EBLs in blue stack with strongly e-rich ETL

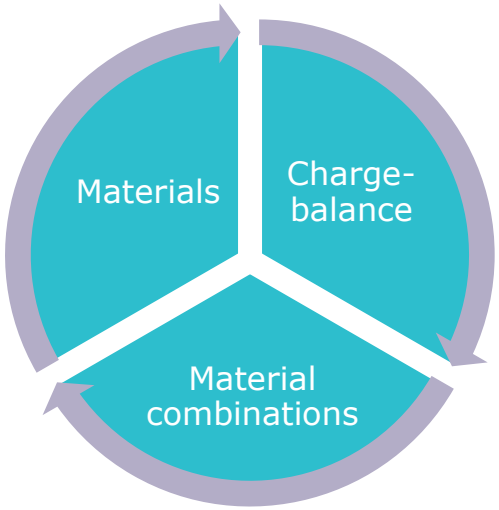


HTM portfolio for tuning between LT and efficiency by choice of EBL
Interaction with choice of ETL has to be considered

Example

Optimizing lifetime and driving voltage

Lifetime and driving voltage can be optimized with the right combinations of materials



Stack	U [V]	Rel. EQE	Rel. LT
HTM-1 / EBL-1 / Ref-Host - Ref-Dopant / HBL-1 / ETM-1	Ref	1.00	1.00
HTM-1 / EBL-1 / New Host - Ref-Dopant / HBL-1 / ETM-1	-0.15 V	0.95	1.20
HTM-2 / EBL-2 / New Host - Ref-Dopant / HBL-1 / ETM-1	-0.52 V	0.97	1.55
HTM-2 / EBL-2 / New Host - Ref-Dopant / HBL-2 / ETM-2	-0.70 V	0.97	1.65

Full stack understanding

We aim for understanding the whole OLED device and interaction of the different layers and interfaces with each other.

Key Messages
Tuning efficiency by transport layers

- **Portfolio approach is key** for offering Transport Layers.
- Interplay between HTL/EBL/HBL/ETL determines **overall performance.**
- **Extensive combination screening** is necessary to optimize OLED stack.

„charge balance"
is often dominating the LT/efficiency performance

Our approach:
- Actively developing materials for various OLED layers to understand full stack
- Significant investments in physics / application lab resources

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