OLED-Materialien und Anwendungen

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OLED serving two Markets - Lighting and Display

- **Display**
  - AM
  - PM

- **Lighting**
  - Large area
  - Low power consumption
  - Surface emitters

Merck BU OLED
Products and Technology Range

Merck BU OLED

The only company offering commercial volumes of both,

SMALL MOLECULES and **POLYMERS**

Small Molecules

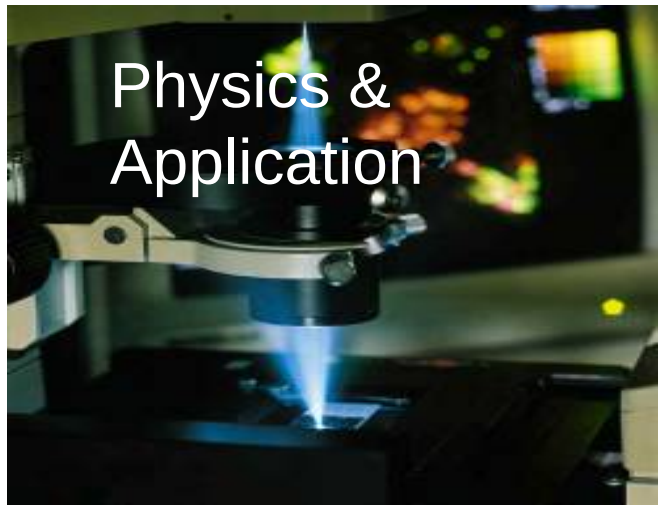
- **Range of red and green triplet emitters**
- **Respective matrixes**
- **Blue and green singlet emitters with matching hosts**
- **Hole and electron transport materials**

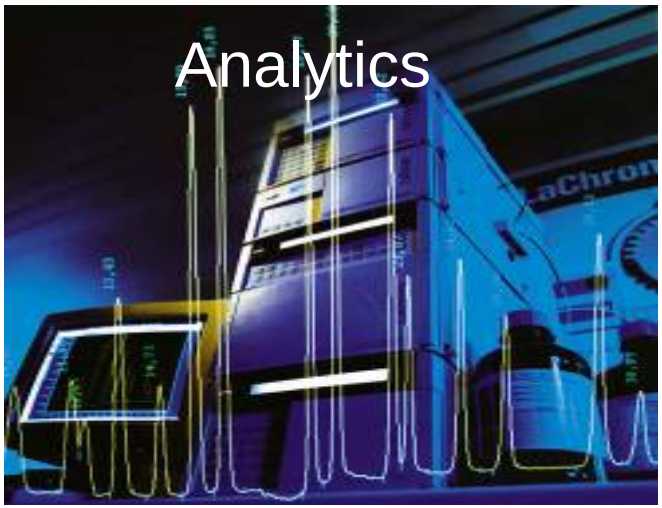
Polymers

- **Range of polymers for R,G,B, PM and AM applications**
- **With or without interlayer**
- **Hole injection materials**
- **Formulations for printing applications**
- **White polymers for display and lighting applications**

Merck BU OLED

Fully Integrated Material Development Process





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Why OLED Displays ...

- **Mobile Display Applications**
  - **Crispy picture**
  - **Thin**
  - **Low power consumption**
  - **Potentially low manufacturing cost**

Why OLED Displays...

- **TV Applications**
  - **Crispy and brilliant picture**
  - **Thin**
  - **Fast switching time**
  - **Wide viewing angle**
  - **Low power consumption**
  - **Potentially low manufacturing cost**

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Mobile Display Applications

- Mobile Display Applications are characterized by a large pixel density (ppi) combined with a small display size
- Depending on display resolution the pixel density varies from 180ppi up to 340ppi
- To achieve this high pixel density (ppi) and a low power consumption top emission AM-OLEDs are best suited
  - Currently, either R,G,B side by side using precision shadow masks or white plus colour filter (mainly R,G,B,W as proposed by Kodak) are in discussion at various OLED panel maker to fulfil the product needs of a crispy picture and low power consumption

TV Applications

- TV Applications are characterized by a low pixel density (full resolution HDTV :55 ppi at 40 inch) combined with a large display size.
- Main focus is on excellent picture quality (>100% NTSC ratio)
  - Top emission AM-OLED with micro cavity effect
  - White plus colour filter AM-OLED
- There are several options to overcome the difficulty of scalability of precision shadow masks for R,G,B side by side vacuum based small molecule deposition processes.
  - LITI process of 3M / Samsung SDI (film donor sheet)
  - LIPS process of Sony (glass donor sheet)
  - or white plus colour filter
- Alternatively, solution processed R,G,B side by side utilizing ink jetting.

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Mobile Display Applications

- R,G,B side by side
  - Very efficient NTSC red (triplet)
  - Very efficient colour tuneable green (singlet or triplet)
  - Efficient colour tuneable deep blue (singlet)
- White plus colour filter
  - All singlet white stack or preferable hybrid white stack (singlet blue and green plus at least triplet red)
- In all cases a long life time is required

TV Applications

- R,G,B side by side
  - Very efficient NTSC red (singlet or triplet)
  - Very efficient colour tuneable green (singlet or triplet)
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  - All singlet white stack or a hybrid white stack (singlet blue and green plus at least triplet red)
- In all cases a ultra long life time is required

Lifetime Requirements

- For Mobile Display as well as TV Applications the lifetime up to 50% of initial luminance ($LT_{50\%}$) has to be fulfilled, which is typically in the range of
  - Mobile: > 10000 hrs
  - TV: > 50000 hrs
- In addition no burn-in should be visible
  - Typically, a difference between the worst (long time used pixel) and the best pixel (short time used pixel) of a individual colour should not exceed a few percentage in brightness, otherwise it will be visible by eye (typically 2 to 5% depending on application)
  - This means the difference in life time of the best to the worst pixel of a individual colour should not exceed a few percent. However, this is **not** necessarily equal to e.g. $LT_{98\%}$

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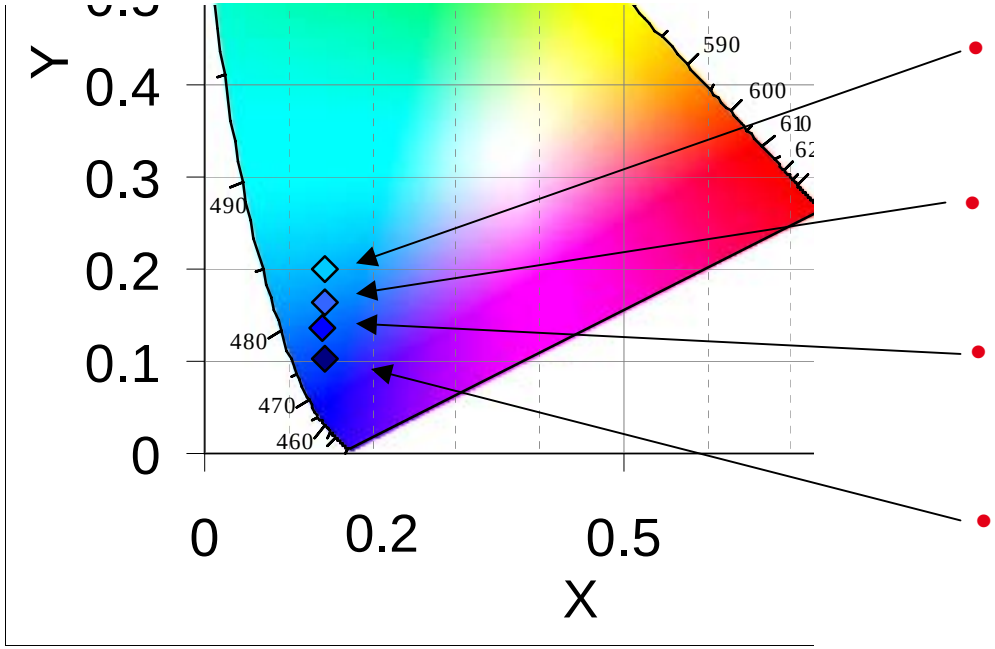
Deep Blue Dopant Development

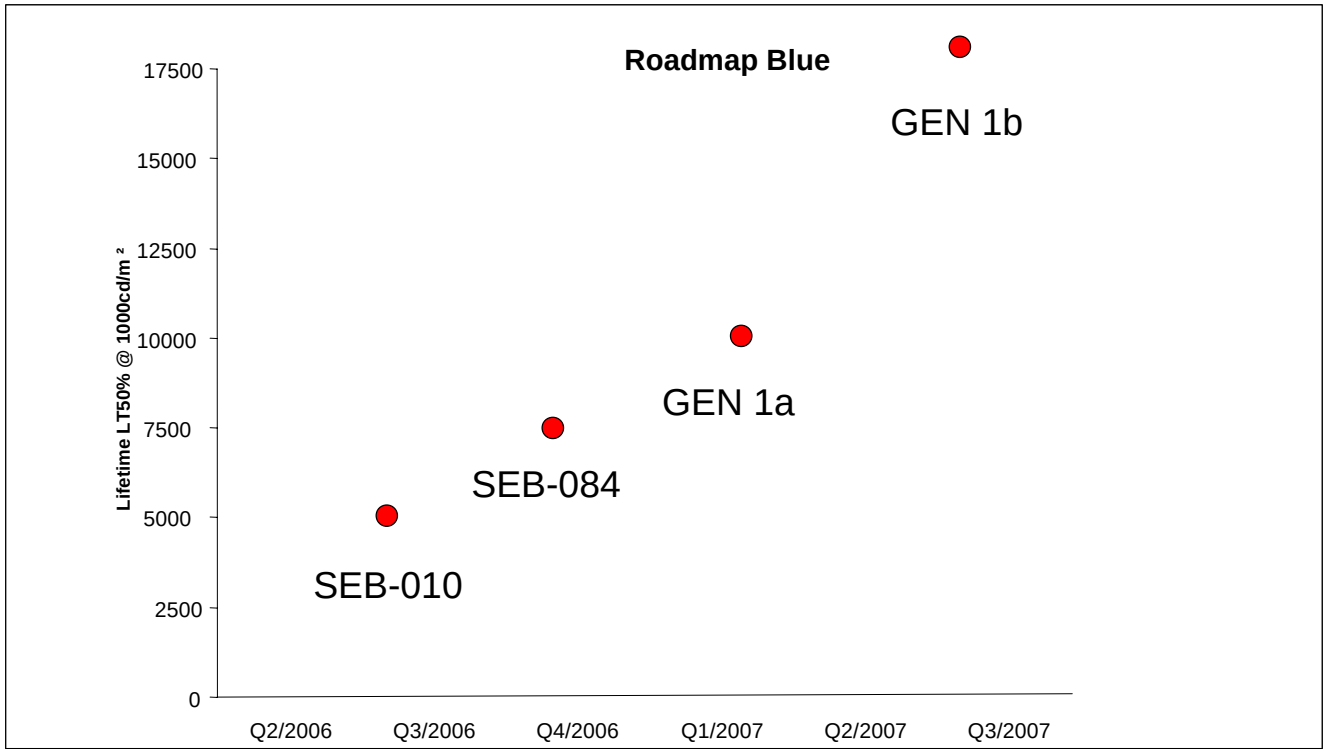


- Dopant 1 7.0 Cd/A
  - x:0.14 ; y:0.20
- Dopant 2 6.5 Cd/A
  - x:0.14 ; y:0.17
- Dopant 3 4.6 Cd/A
  - x:0.14 ; y:0.13
- Dopant 4 4.0 Cd/A
  - x:0.14 ; y:0.10

⇨ Merck has developed a new series of Singlet Blue Dopants.

⇨ The materials are best suited for bottom and micro cavity top emission AM-OLED Mobile Display and TV Applications

Blue Matrix Development



Dopant 2

Color y 0.17

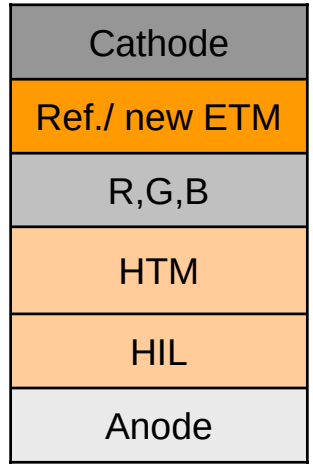
Up to 10 cd/A

bottom emission

⇨ With Merck´s new Generation of Blue Matrix materials a significant improvement in singlet Blue OLED lifetime is achieved

Improved Luminance and Power Efficiency using a new ETM

@ 1000 Cd/m²		Reference	new ETM	
blue	CIE 1931	0.135 / 0.198	0.125 / 0.182	
	lum. eff. / Cd/A	6,5	9,6	48%
	EQE / %	4,5	7,1	
	power eff. / lm/W	3,6	5,4	50%
	U / V	6,0	5,5	
	LT 50%	1,0	0,95	
green	CIE 1931	0.325 / 0.637	0.320 / 0.639	
	lum. eff. / Cd/A	22,8	28,4	25%
	EQE / %	5,8	7,2	
	power eff. / lm/W	11,0	18,1	65%
	U / V	6,5	4,9	
	LT 50%	1,0	1,2	
red	CIE 1931	0.685 / 0.315	0.685 / 0.315	
	lum. eff. / Cd/A	5,6	7,4	32%
	EQE / %	8,3	10,7	
	power eff. / lm/W	2,8	3,7	32%
	U / V	6,3	5,8	
	LT 50%	1,0	1,2	



⇨ Merck has developed a new ETM improving luminance efficiency and power efficiency for all colours without deteriorating life time

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Simulation of various white OLEDs

	CIE 0.33/0.33 (pure white)	**CIE 0.31/0.315 (NTSC white)**	CIE 0.28/0.29 (D9300)
All singlet (based on G: 28.4 cd/A, CIE 0.32/0.64; R*: 10.8 cd/A, CIE 0.66/0.34)			
Dopant 3 (deep blue)	12.0 cd/A	11.5 cd/A	10.5 cd/A
Dopant 4 (ultra deep blue)	12.7 cd/A	12.3 cd/A	11.4 cd/A
Hybrid Merck (based on G: 37 cd/A, CIE 0.33/0.61; R 25 cd/A, CIE 0.62/0.38)			
Dopant 3 (deep blue)	15.5 cd/A	14.3 cd/A	12.6 cd/A
Dopant 4 (ultra deep blue)	16.7 cd/A	15.6 cd/A	13.9 cd/A
Hybrid potential (based on G*: 67 cd/A, CIE 0.38/0.59; R*: 27 cd/A, CIE 0.66/0.34)			
Dopant 3 (deep blue)	17.9 cd/A	16.4 cd/A	14.1 cd/A
Dopant 4 (ultra deep blue)	20.0 cd/A	18.3 cd/A	15.9 cd/A

* published reference data

- ⇨ Hybrid white OLED has the potential for a high luminance efficiency
- ⇨ White OLEDs achieve high luminance efficiency by applying blue dopants with very deep blue colour coordinates. However, the luminance efficiency of the dopant in a single colour device is lower then that of a lighter blue

White Hybrid OLED

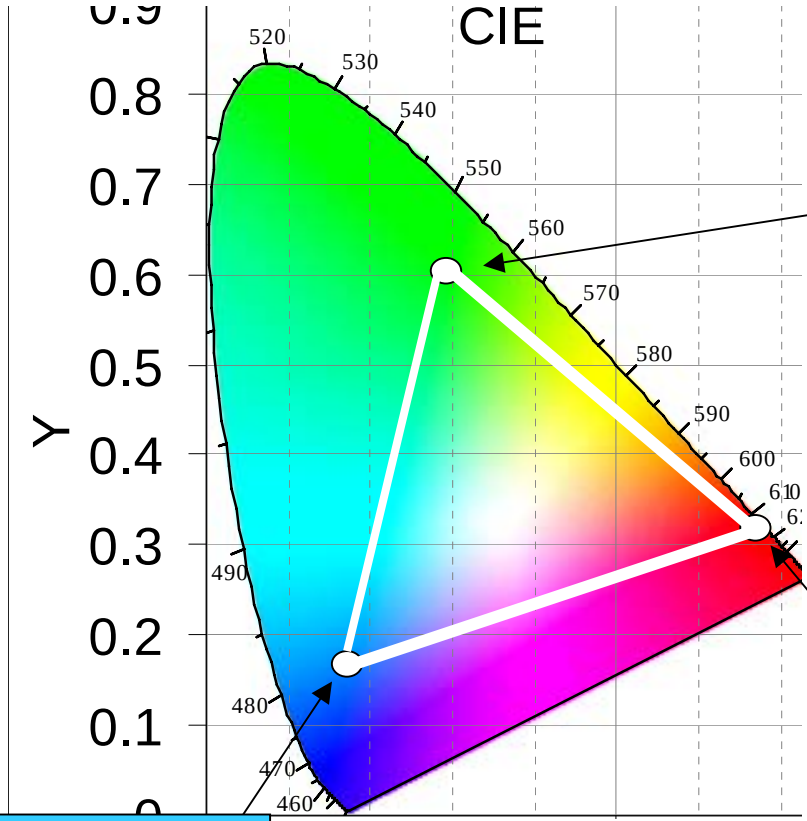
- **Current Development Status**

Title	CIE x/y	Efficiency [cd/A] @ 1000 cd/m²	Efficiency [lm/W] @ 1000 cd/m²	Voltage [V] @ 1000 cd/m²	EQE [%] @ 1000 cd/m²	Est. LT_{50} [h] @ 1000 cd/m²	ΔCIE x/y @ LT_{50}
Extrapolated	**0.33/0.33**	**15.5**					
Display white deep blue	**0.335/0.333**	**17.8**	**10.8**	**5.2**	**8.4**	**>10000**	**0.00/+0.01**

⇨ A pure white is experimental only possible with a deep blue dopant

⇨ The luminance efficiency in the actual device is even better than that from the single colour device extrapolated

AM-PLED: Colour gamut without specific cavity effects

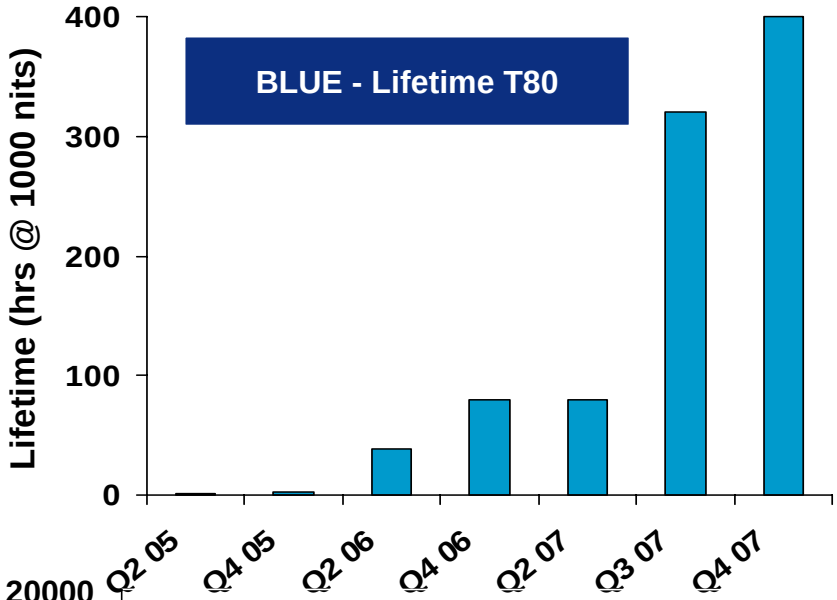


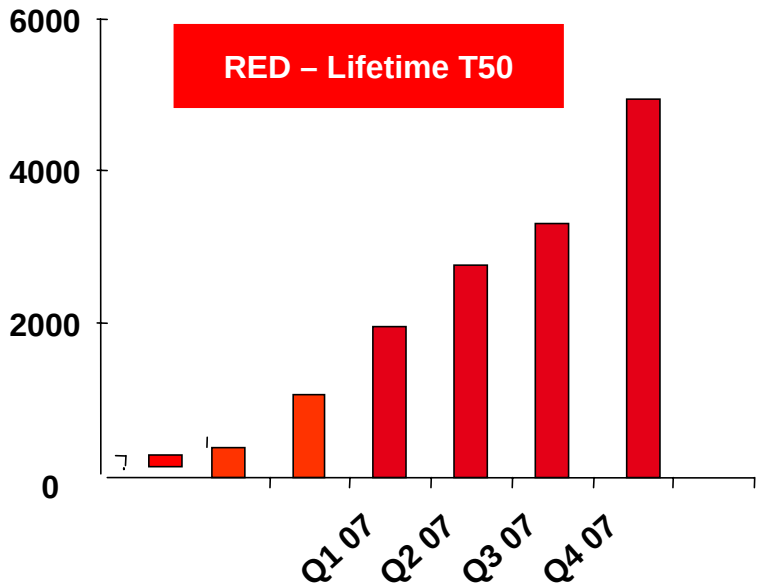
Green copolymer
x0.29; y0.61

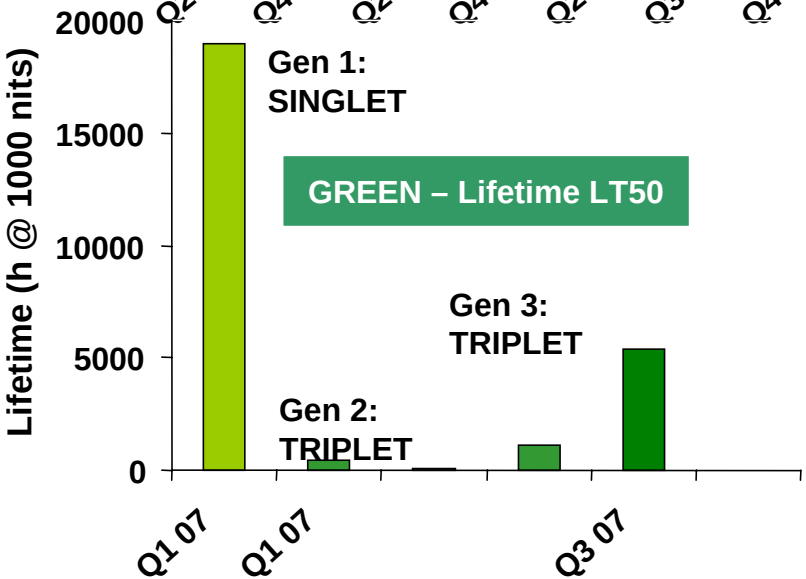
Red copolymer
x0.68; y0.31

Blue copolymer
x0.15; y0.18

AM-PLED: Material progress RGB







- **Steady progress in RGB lifetime**
- **Red and Green polymers move from singlet to triplet based materials**

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Summary and Outlook

- Merck is the only company offering commercial volumes of both, POLYMERS and SMALL MOLECULES.
- The needs for Mobile Display and TV Applications and the respective material parameter have been discussed.
- We have developed a full range of new small molecule deep blue dopants with colour coordinates from Y=0.20 down to 0.10 and respective blue matrices.
- A new small molecule ETM shows a significant improvement in luminance as well as power efficiency for red, green and blue without deteriorating life time.
- A small molecule hybrid white OLED stack with high luminance efficiency has been introduced.
- The recent development status of red, green and blue polymer for AM-PLED application has been introduced.

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THANK YOU FOR YOUR ATTENTION.