OLED Lighting in Automotive Applications
State of the Art and Future Demands

OLEDs World Summit 2017, San Francisco, Dr. Werner Thomas, AUDI AG
Agenda

1. Overview 1st automotive series applications

2. High-luminance OLED: future demands

3. Flexible OLED: technology evolution and modularization

4. Automotive OLED business: status and acceleration factors
History: 2016 – OLED in series production with AUDI TT RS
AUDI TT RS – features of series tail lamp

Appearance and styling
› Unique styling with 2.5D arrangement of OLEDs
› Multi-segmented OLEDs
› “Mirror” in off state

Functions
› Individual segment control
› Animated tail function, e.g. “welcome scenario”
› Dynamic turn-indicator

Status 2017: Overwhelming market resonance since introduction
2017: OLED technology in new AUDI A8
Series OLED-lighting applications in automotive

Overview
Features of 1st automotive series applications #1

› Lamp setup and functions
  › Rear lighting applications
  › Hybrid solutions: OLED- with LED-technology
  › Tail functions using OLED-technology
  › Animated tail function: welcome & good bye sequence

› Automotive OLED design
  › Custom design
  › Design configurations:
    › Identical OLEDs per lamp
    › Different OLEDs per Lamp
    › Combinations

Approach 1
OLED Panels with identical design

Approach 2
OLED panels with different design

Source: Lumileds
Features of 1\textsuperscript{st} automotive series applications #2

› Package
   › 2D glass-substrate
   › Off state appearance: Mirror finish / no outcoupling film
   › Thin-Film encapsulations, no cavity glass

› Optical characteristics (Organic stack)
   › Color: \( \lambda_{\text{dom}} > 623 \text{ nm} \), Lambertian emission
   › Solutions with 1.000-2.000 cd/m\(^2\) available
   › Single or multi-stack architectures on the market

› Ageing and temperature behaviour
   › Highly different ageing behaviour when comparing different OLED suppliers

No automotive “standard solution” available
OLED tail lamp composition

*State of the art solution*

- **Lamp Housing**
- **PCBs** with electrical driver and LED-light sources
- **Design and optical bezels**
- **OLED Modules**
  - OLED panel, flex PCB & connector
- **OLED support**
  - Injection molded
- **OLED panel**
  - 4 segments, dark red
- **Outer lens**
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OLED: Future perspectives

- 3D design - flexible - substrate
  - Low-brightness (2016)
  - High-brightness (>2016)

- 2D design
  - Low-brightness (2016)
  - High-brightness (>>2016)

Design & integration level vs. Performance
Enabling more lighting functions in OLED-technology

Required luminous intensity [cd] *)

- Tail light: Today, 10; Future, 125
- Center High mounted brake light: Today, 60; Future, 100
- Brake light: Today, 100; Future, 125
- Direction indicator - rear: Today, 10; Future, 125

Required luminance [cd/m²] *)

- Tail light: Today, 2,000; Future, 50,000
- Center High mounted brake light: Today, 12,000; Future, 20,000
- Brake light: Today, 12,000; Future, 20,000
- Direction indicator - rear: Today, 12,000; Future, 20,000

Future demands

- Solutions needed for increased luminance (e.g. materials, stack-architecture, multi-stack solutions)
- Advanced thermal management and control concepts
- Light extraction and beam shaping solutions

Need for high-brightness OLED solutions

*) typical values
Development goals

Application demand: increased luminance

<table>
<thead>
<tr>
<th>Options</th>
<th>Light distribution: regulatory requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current density ↑</td>
<td>Relative luminous intensity</td>
</tr>
<tr>
<td>Lifetime ↓</td>
<td></td>
</tr>
<tr>
<td>No. of stacks ↑</td>
<td>Self heating ↑</td>
</tr>
<tr>
<td>Complexity ↑</td>
<td></td>
</tr>
<tr>
<td>Luminous efficacy ↑</td>
<td>Required</td>
</tr>
<tr>
<td>Limited</td>
<td></td>
</tr>
</tbody>
</table>

How to overcome?

Light distribution with application adapted beam shape needed
Angular stability of OLED parameters
Evaluation of different deep red OLED-stacks

Luminous intensity

![Graph showing angular stability of luminous intensity](image)

Color stability *

![Graph showing color stability](image)

Differentiated requirements profile in automotive light functions

<table>
<thead>
<tr>
<th>Automotive function</th>
<th>Example</th>
<th>Angular stability</th>
<th>Luminance</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Always on”</td>
<td>Tail</td>
<td>High, e.g. ≤ 0.01 in x,y</td>
<td>≤ 2.000 cd/m²</td>
</tr>
<tr>
<td>“High luminance “</td>
<td>Stop</td>
<td><strong>Reduced</strong> requirements, <strong>trade-off discussion needed</strong></td>
<td>≥ 20.000 cd/m²</td>
</tr>
</tbody>
</table>

*) Detailed discussion in: Rabenau et al: Investigation of Red, Flexible OLED devices for Automotive Rear Lighting, IFAL 2017
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Design study - flexible OLED technology
Challenges in OLED and 3D-module design

Angular stability of:
- Color coordinates
- Luminous intensity

Reflections:
- Ambient light
- Self reflections

Angular stability

Design vs. Assembly

Surface quality

Integrating challenge
- Design rule violations, e.g. delamination

Surface Quality
- Before Module Assembly
- Overstress in Module Assembly:

Regulatory values
- Angular distribution
OLED Modularization
Rigid and flexible technology

2D-OLED: application needs

› Light source is styling surface
› **OLED Module** is needed for integration into automotive applications
› **OLED Module** comprises more than OLED-panel: determines system costs
OLED Modularization
Rigid and flexible technology

3D-OLED: Extra efforts
› Simulation demand rises: 3D appearance, regulatory values
› Handling stability and off state characteristics of flexible OLED
› Assembly: Modularization and integration of flat foil- OLED into 3D-OLED module
OLED Modularization
Rigid and flexible technology

3D-OLED: Extra efforts
- Simulation demand rises: 3D appearance, regulatory values
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- Assembly: Modularization and integration of flat foil- OLED into 3D-OLED module

Flex OLED module assembly will significantly influence total system costs

Panel costs have to decrease
Integration costs will grow
Cost effective solutions needed
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Outlook and technology portfolio

Flexible

Source: Sony

Transparency

Source: IPMS
Source: OSRAM

3D

Source: ARC
Source: Philips

RGB

Source: LG-D

Source: IPMS
Source: OSRAM

Source: LG-D
Source: Philips

Source: IPMS
Source: OSRAM
Status of automotive OLED

› Projects
  › Increasing number of OLED series projects
  › OLED as styling feature combined with animation

› Technology
  › Automotive-ready solutions available (low luminance)
  › Standardized architecture not available & complex validation needed

› Costs
  › High OLED costs: OLED panel > Tail lamp costs
  › OLED module costs have to be considered, not only OLED-panel costs
Acceleration factors for automotive OLED
„What is needed that automotive OLED lighting grows faster?“

› **OLED Projects**
  ‣ **Processes**: direct communication OEM – OLED supplier is crucial for OLED projects: OLED = styling surface
  ‣ **Costs**: solutions to decrease OLED panel costs and integration costs are needed

› **Technology**
  ‣ **Design**: clear design rules, fast and accurate simulations
  ‣ **Modules**: more module competence at OLED supplier
  ‣ **USPs**: OLED USPs have to be strengthened – *more than* homogeneous light surface
Thank you