Thin-Film Encapsulation of Organic Light Emitting Devices (OLEDs)

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About Huntsman

Huntsman is a global manufacturer and marketer of differentiated chemicals.

- $8 billions annual revenue in 2009
- Operates from multiple locations worldwide
- 11,000 associates
Advanced Materials

End Markets

Based on 2009 Revenues

- Consumer 28%
- Electrical Engineering 16%
- Paints & Coatings 21%
- Aerospace Defense 8%
- Others 2%
- Tooling 4%
- Ind. Adhesives 7%
- Chemicals 6%
- Electronic 11%
- Sports & Leisures 3%
- D-I-Y 4%
- Others 2%

Business Highlights

- Leading global manufacturer, marketer of differentiated chemicals and formulated systems.
- Araldite® brand
- 13 locations worldwide
- ~2,000 employees
- Headquarters in Basel

1Q10 LTM

Revenue $1.1b

Locations

Huntsman Advanced Materials
Innovation at Advanced Materials

We are a global leader and partner in

- material science and chemistry to replace conventional materials because of their limitations
- innovative material technologies for new applications into new markets

Innovation at Huntsman is globally recognized via numerous prestigious innovation awards (JEC, Materialica, Euromold).

OLED integrated into rear view mirror composite
24h of Le Mans Race
The New OLED Lighting Market

Around 19% of all electricity is consumed by lighting

What if OLED gets 10% share in the replacement market for lighting:

~100,000,000 m² OLEDs/year needed!
Why ‘OLED Lighting’?

- The organic layers of an OLED allow them to be thin, and light.

- OLED substrates can be plastic rather than the glass which allow them to be flexible.

- They consume very little power.

- They can be made into large, thin sheets.
The Challenge: Encapsulation

So, what’s keeping the industry from selling in large scale?
- Cost, lifetime and brightness of OLED’s lighting are key elements.
  - Cost and lifetime are related to ENCAPSULATION
    - Water can easily damage OLEDs
    - Flexible and economical encapsulation is the key technology that needs to be developed

Right after processing

Cathode oxidation:
local degradation
leading to black spots

~10h at 20 °C / 50% RH
Standard Encapsulation OLED Lighting

- State-of-the-art encapsulation using metal or glass lid with cavity containing water scavengers (getters)

- No hermetic seal (getter required)

- Price of OLED (m²) are around 15,000 € – 20,000 €!!

- It is not applicable for:
  - Fast production
  - Large area devices
  - Flexible (foil-based) devices
Flexible OLED Design

Encapsulation
WVTR: $10^{-6}$ g/m².day

Barrier stack
Transparent

Inorganic layers and OLED processing: Philips and Holst
OLED Barrier and Encapsulation Technology

Multilayer Approach: Organic/Inorganic Barrier film

- **Inorganic**: The inorganic layer (SiN) is a very good barrier against water with intrinsic WVTR of $10^{-6}$ g/m².day. However, it contains lots of defects and holes which affect the barrier performance.
- **Organic**: polymeric matrix developed by Huntsman.

- Multi-layering creates a tortuous path through defects for water and oxygen.

- Organic layer covers particles and planarizes surfaces for deposition of high quality inorganic layers and absorbing mechanical stress in the layers.
Huntsman Activities in OLEDs

- Involved in barrier and encapsulation technology since 2006.

- Engaged in program TP2 at Holst Center/Eindhoven.

- TP2 program got EU funding from Fast2Light project - around 16 partners participating.

General objective:
Develop novel, cost-effective, high throughput, roll-to-roll, large area deposition processes for fabricating light-emitting polymer-OLED foils for lighting applications.
Holst/TNO - Open Innovation Center

Open Innovation Center for Wireless Autonomous Microsystems and Systems-in-Foil.

Located on the Philips High Tech Campus (> 90 companies, 7,000 researchers)
- Access to shared labs and equipment (www.miplaza.com)
- Access to 8,000 m² cleanrooms
Holst/TNO - Open Innovation Center

- Staff of 160 researchers and 70 resident researchers from industry and universities

Tackling R&D costs and risks

Leverage:
1. Innovating by combining ideas
2. Sharing of facilities and competencies
3. Reducing time to market
4. Sharing of R&D costs and risks
5. Opportunities for additional public funding
Global Network of Industrial and Academic Partners

- Did not find such consortium in Basel area...but opened to any suggestion:
  - Partners with testing capabilities (OLEDs, solar cells manufacturers)
  - University/Institutes interested in development of barrier technologies for organic electronic applications.

Gate to Market

Huntsman ↔ Philips ↔ Customer

B2B ↔ B2C

World Leader in Lighting
Current Status Barrier Development

What has been achieved with our partners (Holst and Philips):

- On functional OLEDs, 2 x 2 cm encapsulated with SiN - Huntsman Organic Coating - SiN:
  - No blackspots for at least 500 h at 60°C/90%RH with yield of 86%
  - Translates in 5 years at 20/50 condition.

- Integrated S2S production process under development
- R2R process targeted for 2012
Thank you for your attention

Any question?