Ultra-Barrier Films: Scale Up of Roll to Roll Production

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BASID March 2016
Flexible, Transparent, Ultra-Barrier Film Products

• A Novel Solution for Encapsulation of Flexible Electronics
• Enabling the Next Wave of Large-Area Electronic Products
Barrier Film Applications

QD Films

Flexible OLED Display

Flexible OLED Lighting

Flexible Solar PV
The goal is a flexible polymer film with glass-like properties

- **Low WVTR** (*Water Vapor Transmission Rate*) – The key parameter [g/(m²day)]
- **High Optical Transmissivity** – Low absorption & haze at wavelengths of interest
- **Mechanical Robustness** – Resistance to impact, scratching, soiling, etc.
- **UV Stability** – For outdoor applications like solar
- **Cost Effective** – Roll-to-Roll Processing

Current area of focus for Vitriflex
Key Benefits Of Polymer Encapsulation

UNBREAKABLE

THIN

FLEXIBLE

TRANSPARENT

LIGHTWEIGHT
Flexible Transparent Ultra-Barrier Films (on rolls) from Vitriflex

- Low water vapor & oxygen transport rate (WVTR & OTR)
- Low cost via roll-to-roll manufacturing
- Direct lamination of electronic devices & flexible modules

![Diagram of Roll to Roll Manufacturing process involving Glass-Based Electronics, OLED Device, Vitriflex Barrier Film, and Flexible Electronics.]

RIGID

Roll to Roll Manufacturing

FLEXIBLE
Vitriflex has a novel, proprietary barrier film architecture

- Proprietary mixed-oxide material set
- Proprietary thin-film stack based on a “triad” structure
  - Diffusion barrier layer
  - Reactive layer
  - Diffusion barrier layer
- Proprietary hybrid top seal
Additional Benefit of Vitriflex Barrier Stack: Enhanced Optical Transmission

Vitriflex Optically Tuned Barrier Stack with Reference Uncoated Substrate

Optical tuning enables improved light extraction
Proof of Feasibility
- $10^{-5}$ g/m²-day
- 125 mm web
- R2R Prototype

Scaled Up Platform
- $10^{-6}$ g/m²-day
- 1400 mm web
- R2R Production

12 months
Aegis: Internally-Designed Deposition System

Key Features

- Modular Architecture
- 6 Deposition Zones
- Throughput $\sim 1\text{M} \text{ m}^2/\text{year}$
- Substrate Web Width up to 1.4 m
- Substrate Thicknesses 25-200 um
- Liner Removal & Replacement
- Particle Management
AEGIS Deposition System
Full range of all measured samples between $6.9 \times 10^{-6}$ and $9.7 \times 10^{-6}$ g/m$^2$-day

Outstanding uniformity and consistency at 355 mm width
Superb results of scale-up to wide web in 2015
Cross Web Uniformity: Wide Web 1200 mm

Outstanding uniformity and consistency at 1.2 m width
At Production Speed, this is equivalent to a run of 1.7 Km!!
Vitriflex received the “Best Technical Development Manufacturing Award”

- Award recognizes the most significant development of a manufacturing device, process or production plant in the industry over the last 24 months.
- Manufacturing developments optimize the process of lab-scale or mass-scale production by improving productivity, quality, reliability, uniformity, or scale.
Significant Progress in Ultra-Barrier Film Manufacturing

- **AEGIS deposition system operational**
  - Innovation in materials, process and equipment design
  - Proven excellent WVTR performance
  - R2R capability
  - 1400 mm web width

- **Strong IP portfolio**
  - Multiple patent applications in process

- **Production facility**
  - Located in Silicon Valley, CA

- **Positive customer feedback**
  - Customer sampling underway
  - Applications in display, lighting and PV
Acknowledgements

**Vitriflex**

- Mark George
- Rex Chang
- Jason Bloking
- Martin Rosenblum
- Olivier Postel
- Teresa Ramos
- Eric Ha
- Rob Munns
- David Parker

**Investors**