Development of Barrier Films for Packaging Flexible Electronics

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Applications of Barrier Layers: Organic Electronics

Exposure to moisture can cause degradation in both OLED and inorganic SSL technologies, thin film PV, and sensors.
Barrier Film Requirements

Defects and Structure in Barrier Films

Goal: Defect Free Films with High Density
ALD-based Hybrid Barriers

Low-cost, flexible encapsulation for thin-film PV

Atomic Layer Deposition (ALD):
• Ultra-thin (<50 nm) conformal and flexible ceramic barriers
• WVTR < 10^{-5} g/m²-day
• Spatial ALD: high throughput, cost efficient to address manufacturing

ALD-based hybrid barriers:
• Coupling layer: Mitigate Surface Defects and Control ALD Nucleation
• Materials: Range of metal oxides
• Create monolithic or nanolaminate films of stable ALD layers with Al₂O₃ at 100 °C.

Permeation Analysis and Defect Detection

Laminated Barrier

Test in an environmental chamber at 85°C/85%RH

22 hr 48 hr 148 hr 192 hr

Direct Deposition
Barrier Layer Evolution

Sample A: Nanolaminate Structure

Sample B: Nanolaminate Structure

Sharp interfaces in nanolaminate
No change in chemical structure after damp heat exposure for two weeks.

Sample A @ 50°C/85% RH for 10 days

Day 0

Day 3

Day 10
Cracks in Barrier Films

1) Cracks developed with increasing thickness of Cytop opened large areas in the barrier film for water permeation
2) Local degradation rate from cracks was much more than that due to cracks

Sample B @50C/85% RH
Collaborate with TNO/Holst Centre-Eindhoven, NL.

- Visit to TNO/Holst Center to deposit ALD layers on PECVD SiNx. Deposition of 10 nm ALD layers occurred within 10 minutes at 100°C using rotary reactor.
- Roll-to-Roll system is expected to take approximately 1 minute compared to 3-4 hours in viscous flow reactor.

Laminated Samples

- Sample in an environmental chamber at 85°C/85%RH
- No noticeable change at least for ~200 hr at 85°C/85%RH
Mechanical Reliability: Strain To Failure

- Mechanical Testing Using Laser Scanning Confocal Microscopy
- Optical Microscopy
  
  SiNx Coated PET
  
  Al₂O₃ on PEIE Coated PET

Extending the Performance of Brittle Barriers

Designing the architecture such that you place the barrier on the neutral axis can reduce the strain on the film and improve performance under flexural deformation.

Barrier on Top
Barrier on Neutral Axis
 GT logo for eye inspection
After bending: R= 5mm
10 min
2 days

Solution deposited barriers and changes in material chemistry also provide routes to mechanically flexible barrier technologies.