Development of Barrier Films for Packaging Flexible Electronics

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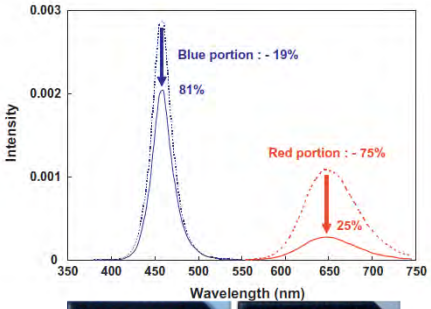
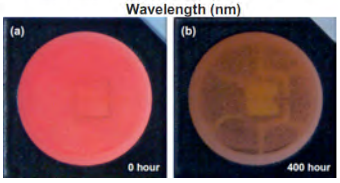
Applications of Barrier Layers: Organic Electronics

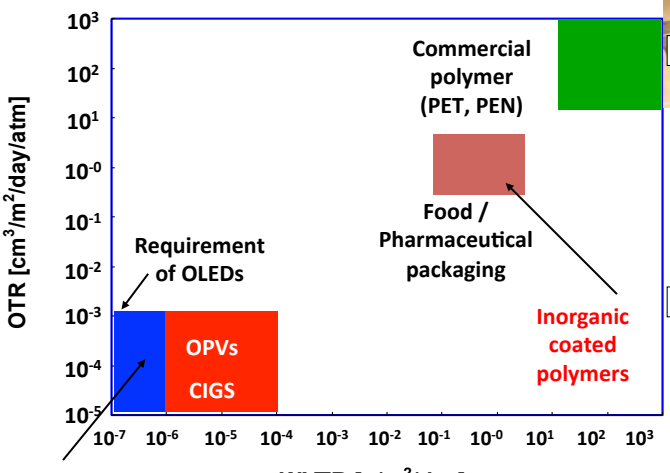
Challenges for Other Devices





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

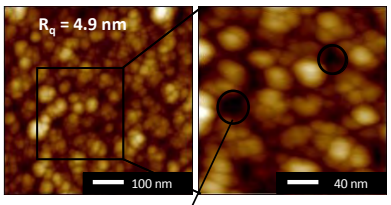
Barrier Film Requirements

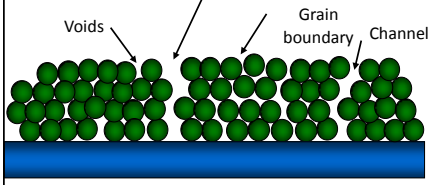


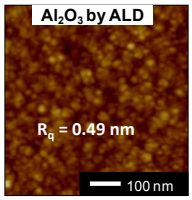
G. Dennler, et. al., J. Mater. Res., Vol. 20, No. 12, Dec 2005. Vol 20, 3224

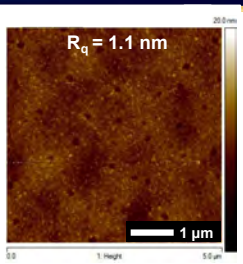
Defects and Structure in Barrier Films

Goal: Defect Free Films with High Density

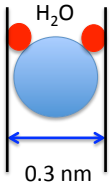


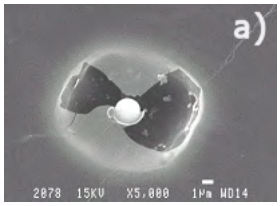






SiN_x (100nm) on PMMA coated PET

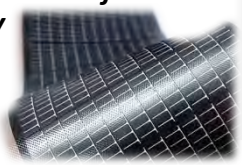




Deposition surface greatly impacts the structure of the barrier film.

ALD-based Hybrid Barriers

Low-cost, flexible encapsulation for thin-film PV



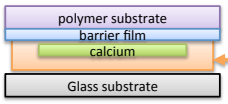
Atomic Layer Deposition (ALD):

- *Ultra-thin (<50 nm) conformal and flexible ceramic barriers*
- *WVTR* < 10^{-5} g/m^2-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 Al_2O_3 at 100 °C.**

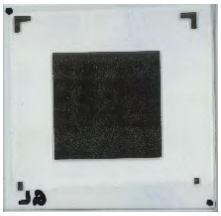
Permeation Analysis and Defect Detection

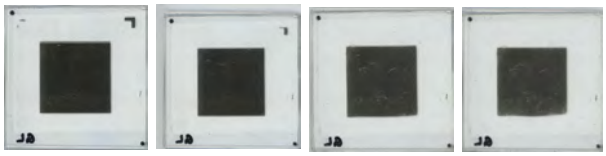


Laminated Barrier

Transparent adhesive tape

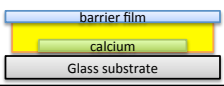
Test in an environmental chamber at 85°C/85%RH

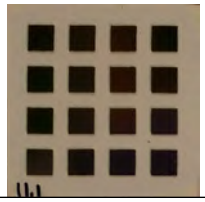


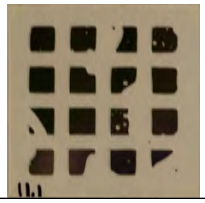


22 hr **48 hr** **148 hr** **192 hr**

Direct Deposition

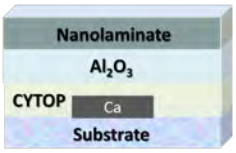




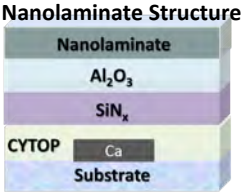


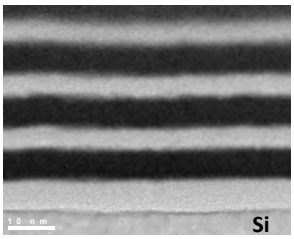
Barrier Layer Evolution

Sample A: Nanolaminate Structure

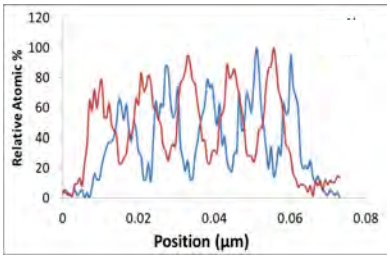


Sample B: Nanolaminate Structure



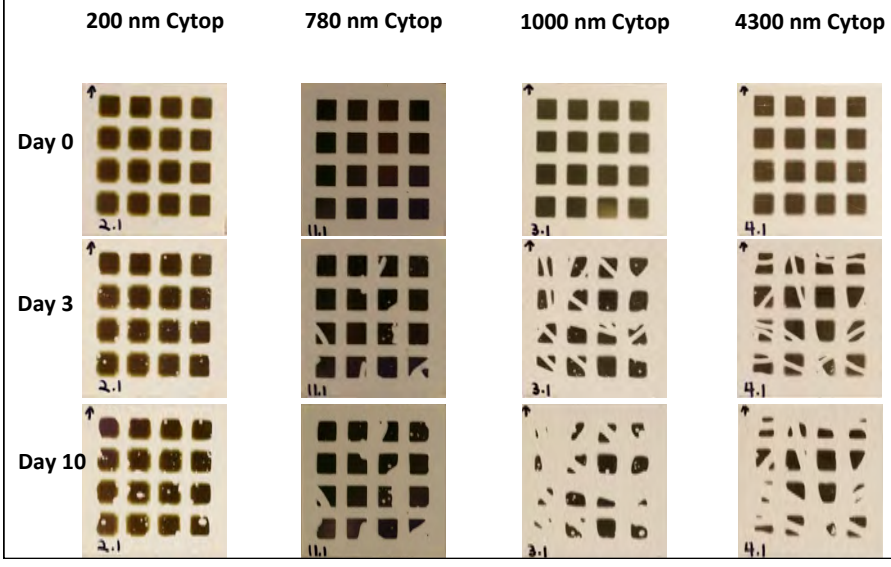


Nanolaminate Structure



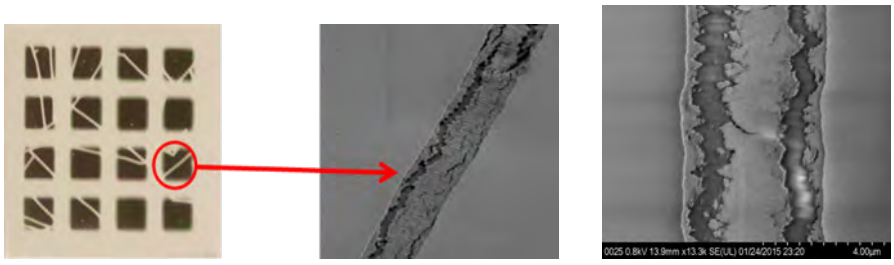
Sharp interfaces in nanolaminate
No change in chemical structure after damp heat exposure for two weeks.

Sample A @ 50°C/85% RH for 10 days

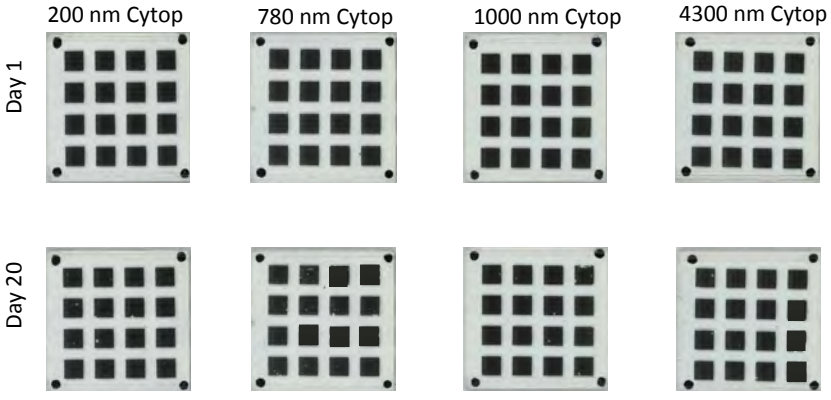


Cracks in Barrier Films

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

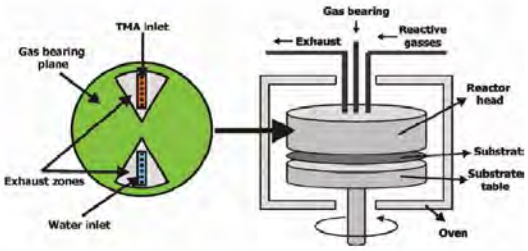


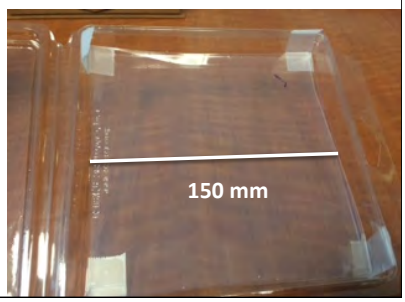
Sample B @50C/85% RH



Spatial ALD of Barrier Films

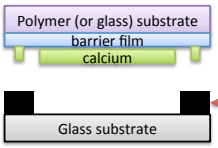
Collaborate with TNO/Holst Centre-Findhoven, NL

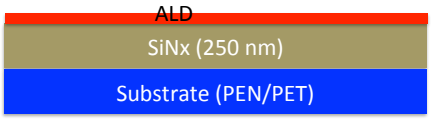


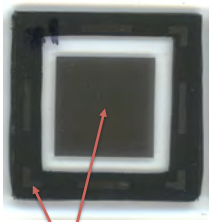


- Visit to TNO/Holst Center to deposit ALD layers on PECVD SiNx. Deposition of 10 nm ALD layers occurred within 10 minutes at 100°C using rotary reactor.
- Roll-to-Roll system is expected to take approximately 1 minute compared to 3-4 hours in viscous flow reactor.

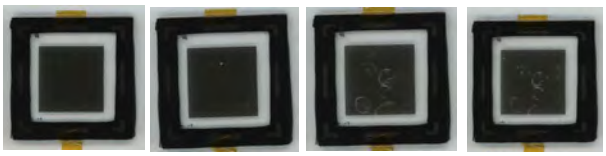
Laminated Samples







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



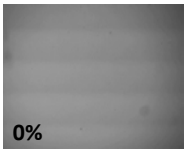
23 hr	40 hr	112 hr	192 hr

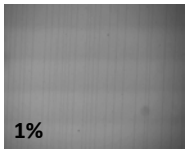
No noticeable change at least for ~200 hr at 85°C/85%RH

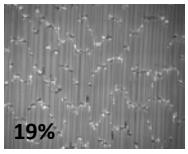
Mechanical Reliability: Strain To Failure

- **Mechanical Testing Using Laser Scanning Confocal Microscopy**
- **Optical Microscopy**

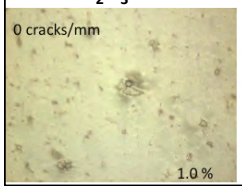
SiNx Coated PET

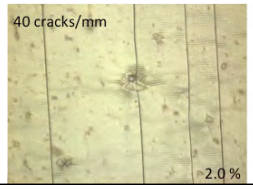


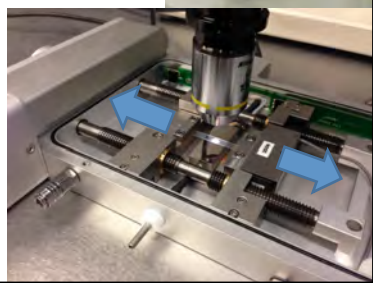




Al_2O_3 on PEIE Coated PET





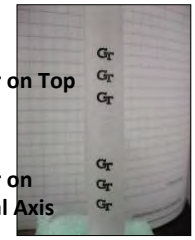


Extending the Performance of Brittle Barriers

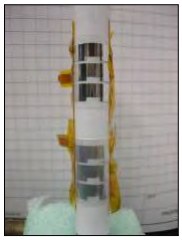
Designing the architecture such that you place the barrier on the neutral axis can reduce the strain on the film and improve performance under flexural deformation.

Barrier on Top

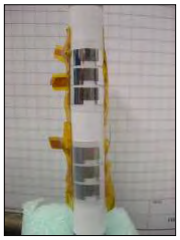
Barrier on Neutral Axis



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.

N. Kim and S. Graham, Thin Solid Films, 2013.