

# Development of Barrier Films for Packaging Flexible Electronics




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## Acknowledgements

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## Applications of Barrier Layers: Organic Electronics

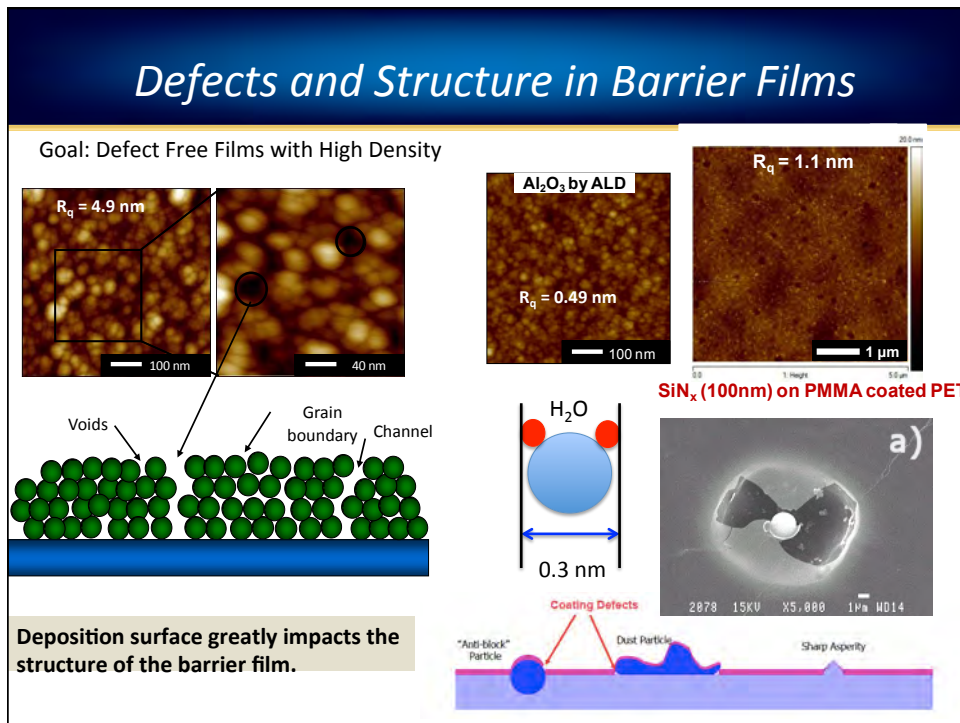
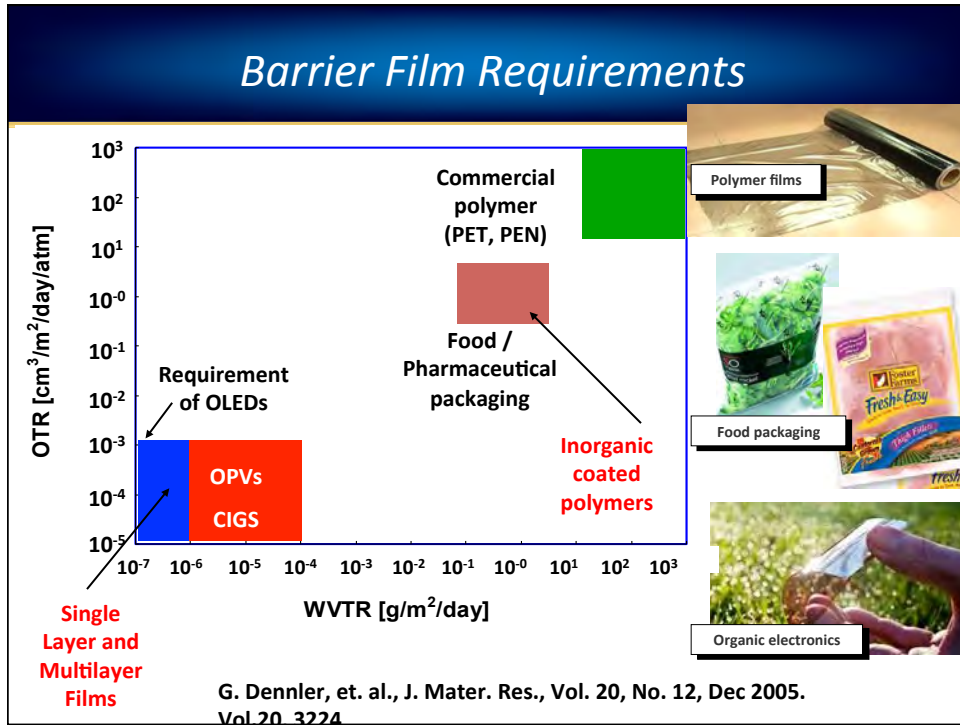
The collage illustrates various applications of barrier layers in organic electronics, including:

- Electrochromics:** Two glowing rectangular panels.
- Solar Cells:** A hand holding a curved solar cell.
- Flexible Transistors:** A hand holding a small, glowing flexible transistor.

## Challenges for Other Devices

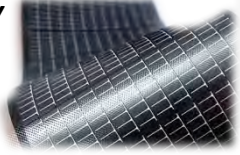
The graph shows Intensity vs. Wavelength (nm) for blue and red portions. The blue portion has an intensity of 0.0028 and a wavelength of 450 nm, with a 19% decrease to 0.0023 at 470 nm. The red portion has an intensity of 0.001 and a wavelength of 650 nm, with a 25% decrease to 0.00075 at 670 nm.

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



## ALD-based Hybrid Barriers

**Low-cost, flexible encapsulation for thin-film PV**

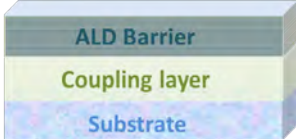


**Atomic Layer Deposition (ALD):**

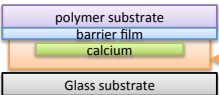
- Ultra-thin (<50 nm) conformal and flexible ceramic barriers
- WVTR < 10<sup>-5</sup> g/m<sup>2</sup>-day
- Spatial ALD: high throughput, cost efficient to address manufacturing

**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<sub>2</sub>O<sub>3</sub> at 100 °C.**



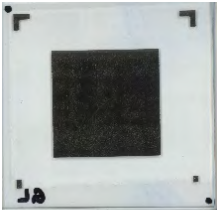

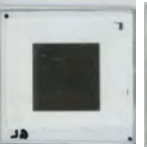
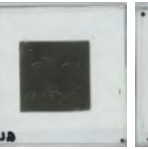
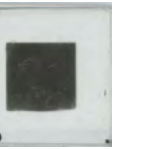
## Permeation Analysis and Defect Detection



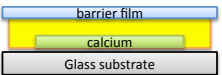
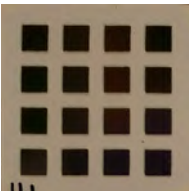
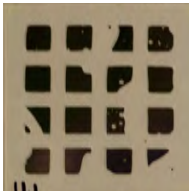
**Laminated Barrier**

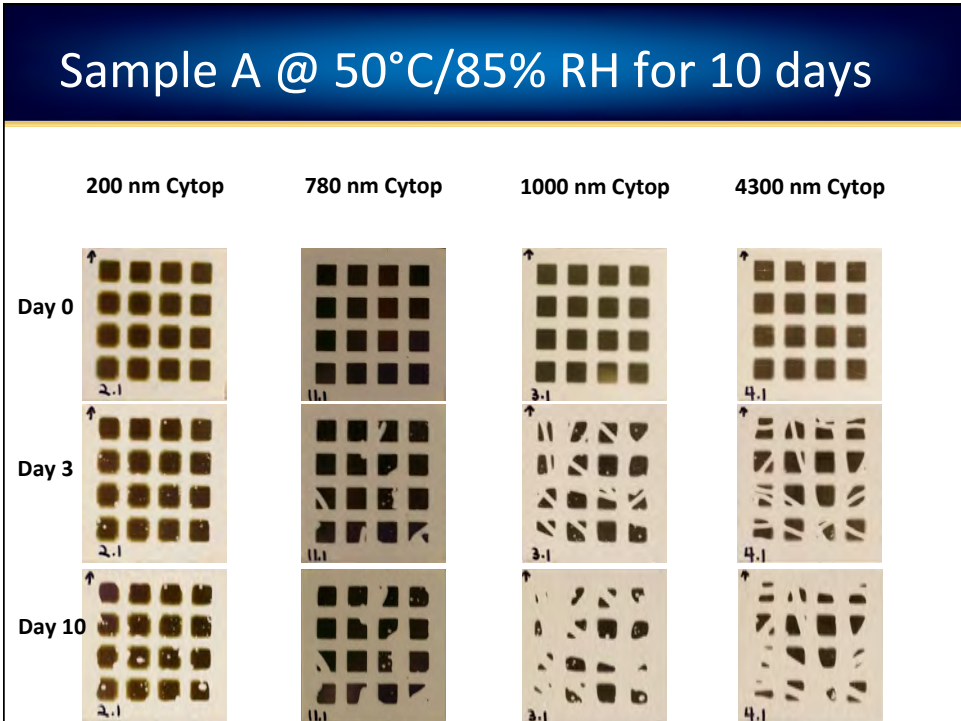
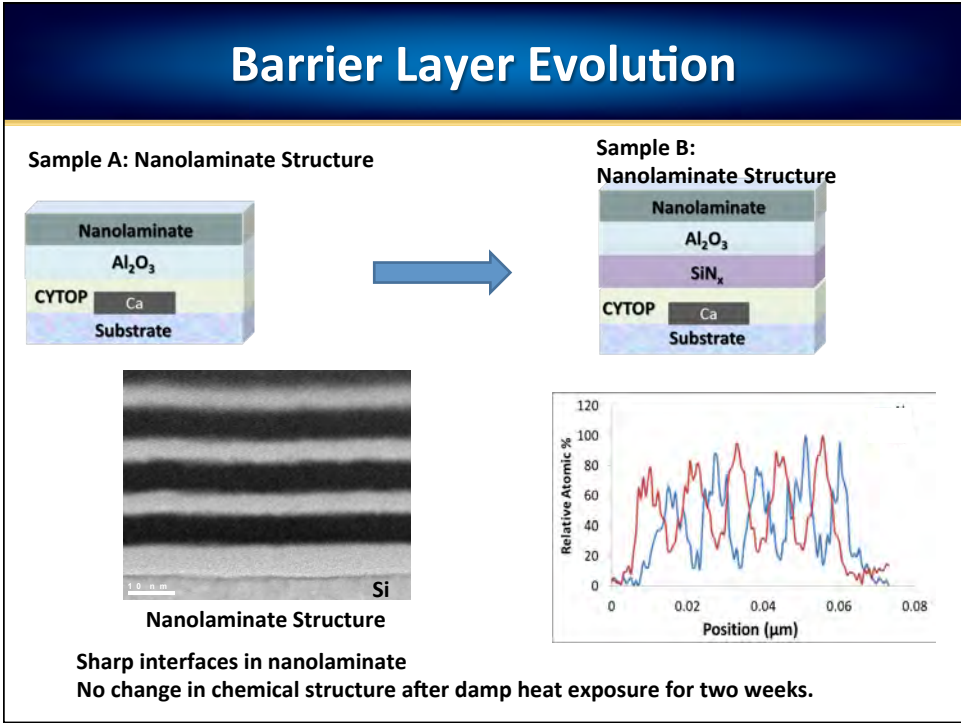
Transparent adhesive tape

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

**Direct Deposition**



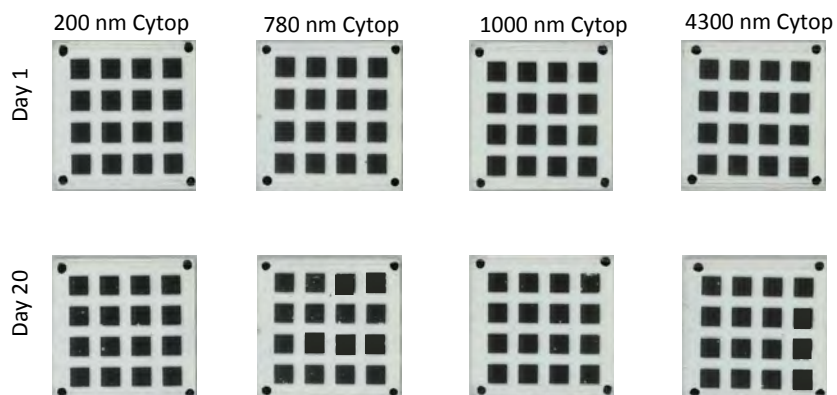


## Cracks in Barrier Films

- 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

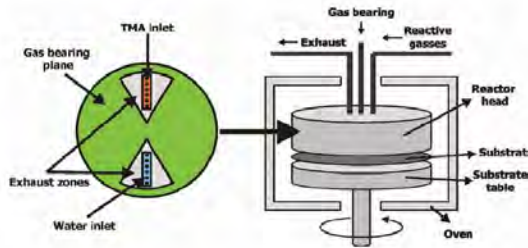


## Sample B @50C/85% RH

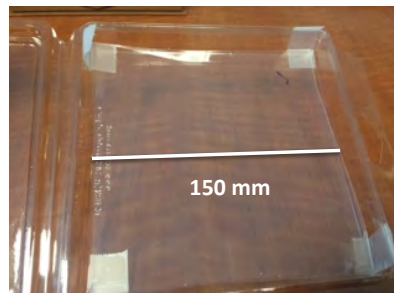


## Spatial ALD of Barrier Films

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.

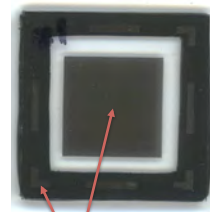


## Laminated Samples

Polymer (or glass) substrate  
barrier film  
calcium

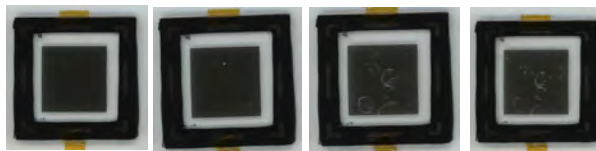
PIB sealant  
Glass substrate

ALD  
SiNx (250 nm)  
Substrate (PEN/PET)



Calcium

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



23 hr

40 hr

112 hr

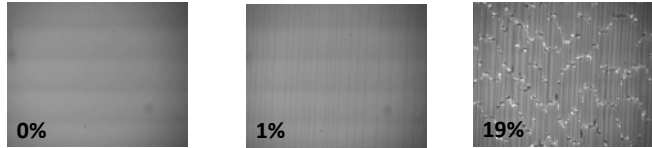
192 hr

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

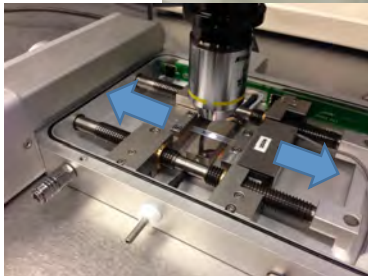
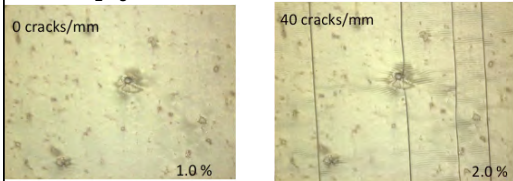
# Mechanical Reliability: Strain To Failure

- Mechanical Testing Using Laser Scanning Confocal Microscopy
- Optical Microscopy

SiNx Coated PET

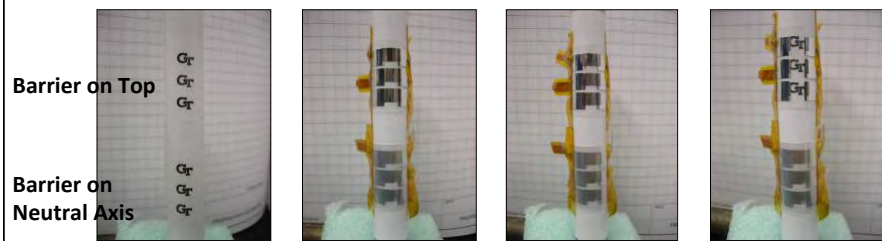


Al<sub>2</sub>O<sub>3</sub> on PEIE Coated PET



# 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.



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.