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ENCAPSULATION BARRIER LAYERS

PUBLICATION REVIEW ON SAVANNAH & FIJI

07.20.2015

Humidity Barriers

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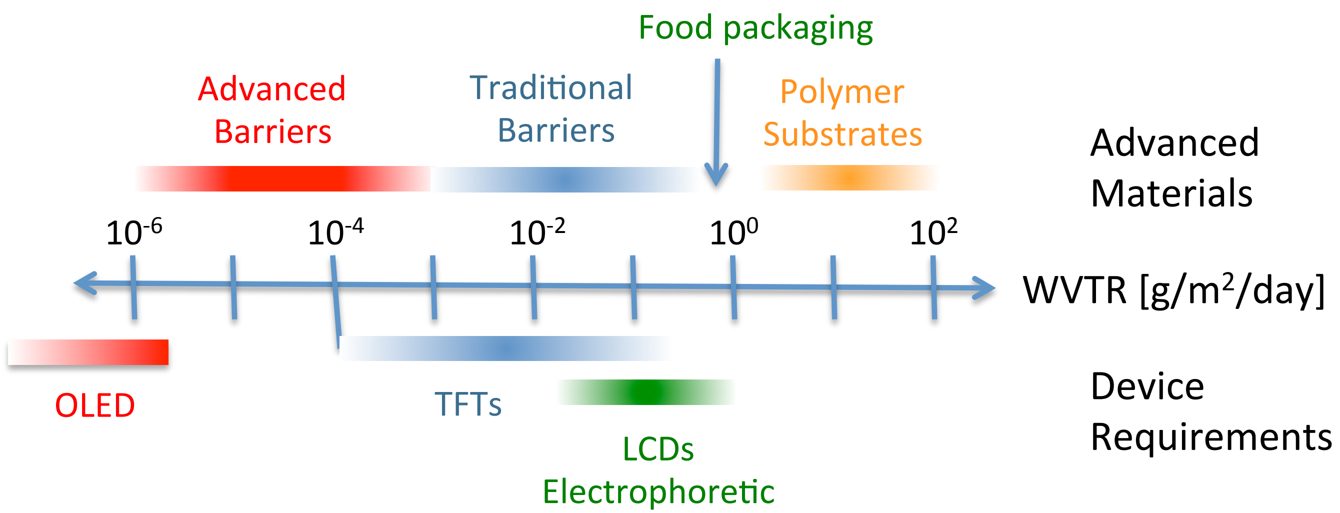
* WVTR: Water Vapor Transmission Rate [g/m²/day]

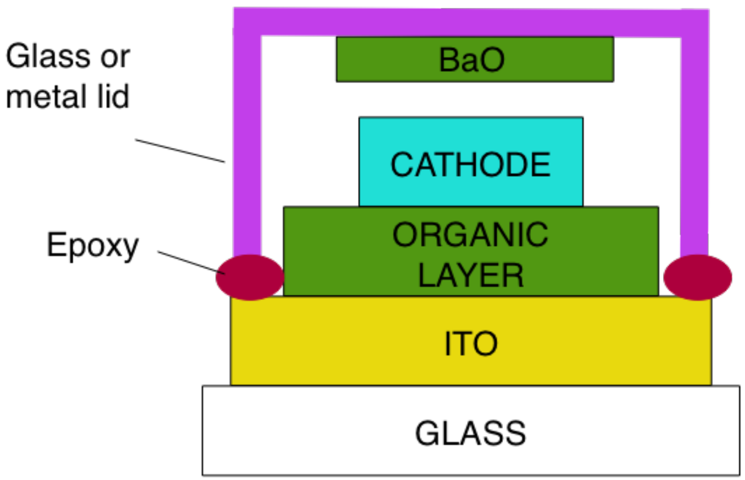


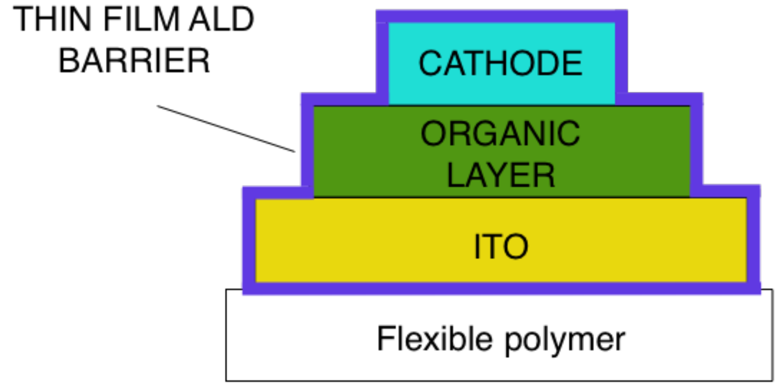
Advanced Materials **2009**, *21*, 1845-1849

- MEMs and OLED packaging driving use of ALD
- Glass slide/epoxy/polymer based technology not adequate
- WVTR* < 10^{-6} g/m²/day demonstrated in lab via ALD
- ALD films now used routinely in production

Humidity Barriers

J.S. Park, Semicond. Sci. Technol. 26 (2011) 034001





Conventional Encapsulation	Thin Film Barrier Coating

- MEMs and OLED packaging driving use of ALD
- Glass slide/epoxy/polymer based technology not adequate
- WVTR* < 10^{-6} g/m^2/day demonstrated in lab via ALD
- ALD films now used routinely in production

Al_2O_3 Encapsulation

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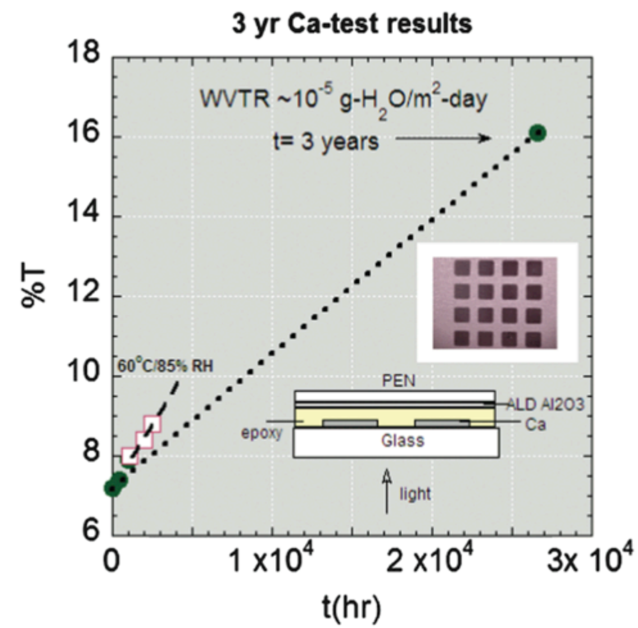
Carcia, P. F., J. Nanosci. Nanotechnol. 11(9), 7994–7998 (2011)

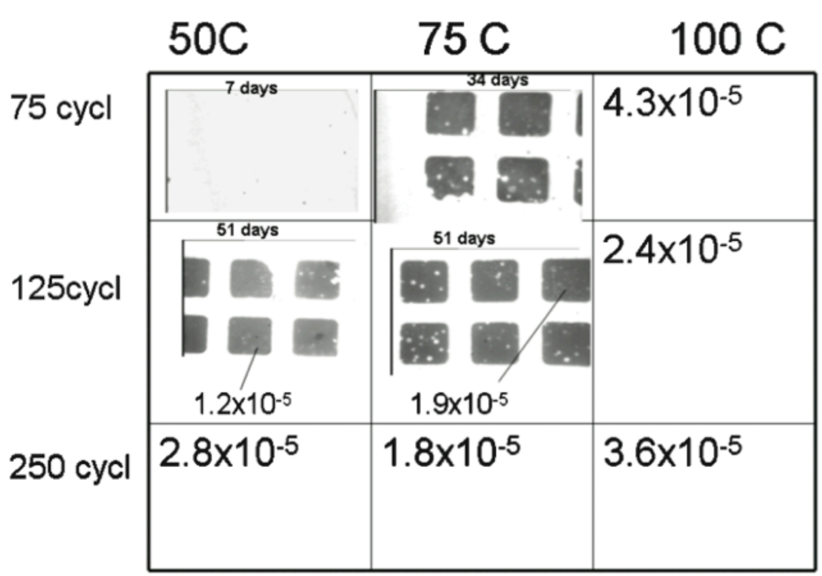
Change in optical transmission over 3 yrs for 25nm Al_2O_3 on PEN (WVTR ~1E-5)



Experimental

- ❑Savannah S200, deposition at 50-100˚C
- ❑Study impact of process temperature and thickness on WVTR

Aging at 38˚C / 85%RH of Al_2O_3 films (Ca px. after 1200h)



Results

- Thicker films grown at higher temp. are superior to thinner films at lower temp.
- Polymers that can withstand higher temp. should be selected (e.g., PEN, PET)

Nanolaminate Encapsulation

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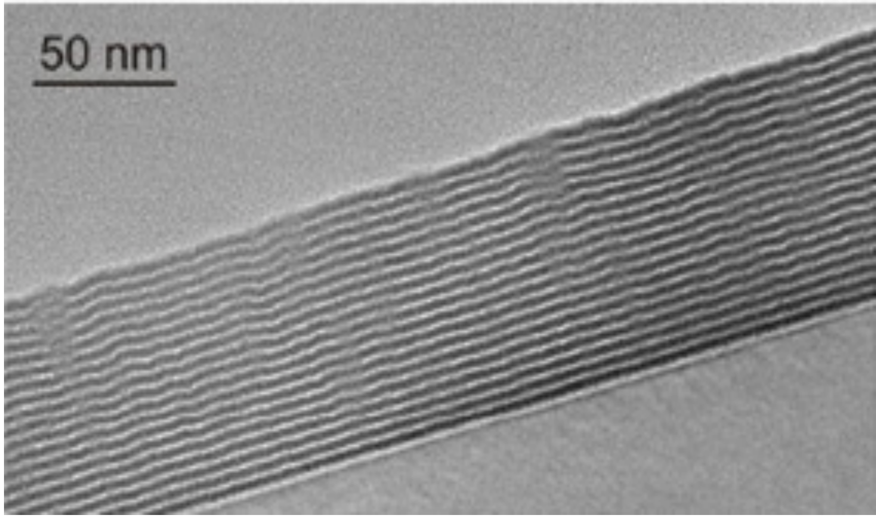
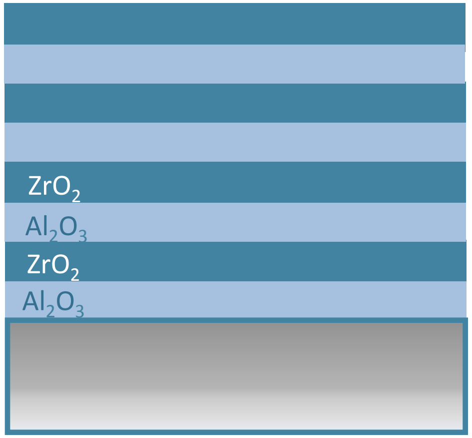
- Savannah S200, deposition at 80°C
- Enables encapsulation of low cost OLED
- Encapsulation films being used for microelectronics packaging, optical, MEMS



encapsulation	permeation rate for water (g/m² day)	permeation rate for oxygen (cm³/m² day)
Al_2O_3 130 nm @ 80 °C	8.8 x 10^{-5}	3.9 x 10^{-2}
Al_2O_3 & ZrO_2 130 nm @ 80 °C	4.7 x 10^{-5}	2.1 x 10^{-2}

with E_a = 92 kJ/mol → 5 x10^{-7} (at RT)

Test Conditions: 80°C at 70% Relative Humidity



1. Meyer, J., et al. (2009) *Applied Physics Letters*, *94*(23), 233305
2. Meyer, J., et al. (2009) *Advanced Materials*, *21*(18), 1845–1849

Al_2O_3/ZrO_2 Encapsulation

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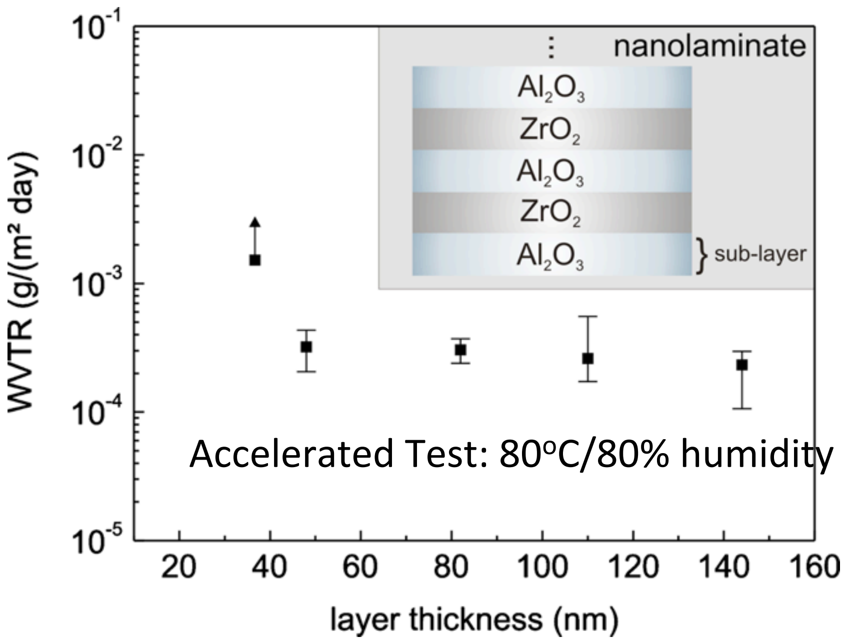
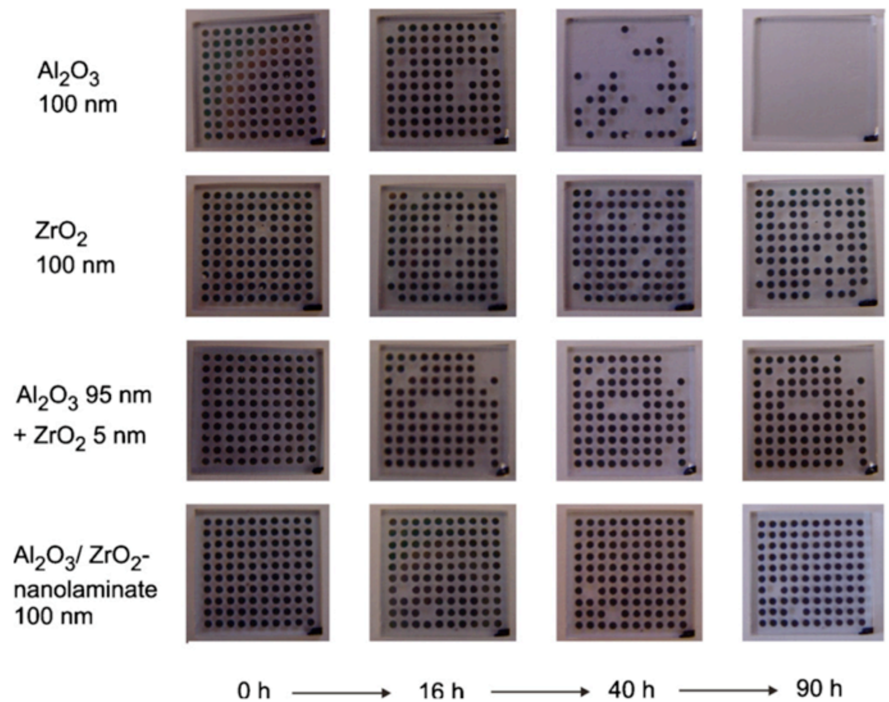
Meyer, J., et al. Applied Physics Letters, 96, 243308 (2010).

Savannah S200, deposition at 80˚C

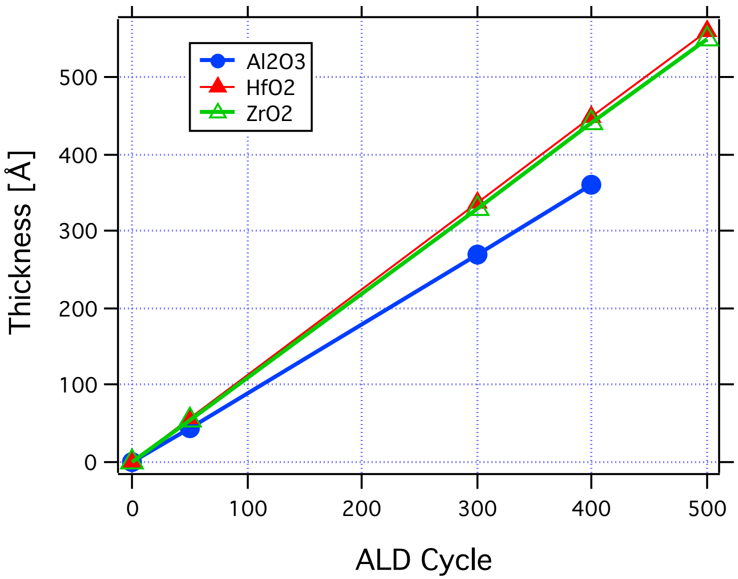




- WVTR ($g/m^2/day$) = 3.2E-4 at 80°C for 40nm film → 8.7E-7 at RT
- Al_2O_3-ZrO_2 nanolaminate combines the barrier performance of Al_2O_3 with anti-corrosion performance of ZrO_2

Thermal ALD film properties for Al_2O_3, HfO_2, and ZrO_2

	Al_2O_3	HfO_2	ZrO_2
Precursors	TMA + H_2O	$Hf(NMe_2)_4$ + H_2O	$Zr(NMe_2)_4$ + H_2O
Temperature	95°C	100˚C	95°C
Growth Rate per Cycle	0.9 Å	1.12 Å	1.1 Å
Typical Thick. Uniformity 200mm Ø 150mm Ø	 <1.5% <1.0%	 <2.0% <1.5%	 <2.0% <1.5%
Refractive Index	1.62-1.65	2.07-2.1	2.03-2.05



Key Encapsulation References on Savannah and Fiji's

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Summary

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- ALD Al_2O_3 is an excellent moisture barrier
- ALD Al_2O_3 corrodes in contact with saturated water vapor
- ALD Al_2O_3-ZrO_2 nanolaminate is resistant to corrosion and meets the requirement of WVTR < 10^{-6} g/m^2/day
- Cambridge Nanotech/Ultratech ALD deposition tools are at the forefront of encapsulation research in academia and industry
- Used for encapsulation at the pilot scale and in mass production