BAPVC Annual Project Report

Project Title: Tailoring Electrostatic Interactions to Produce Hybrid Barrier Films for Photovoltaics

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Summary:
The Kippelen and Graham groups developed alumina/zirconia, alumina/titania, alumina/hafnia nanolaminate films, synthesized at low processing temperatures by using atomic layer deposition, that show improved water barrier properties over single alumina layers. Use of an hydrophobic amorphous fluoropolymer layer was found to improve barrier properties by planarizing and covering substrate defects. Nanolaminate films synthesized on amorphous fluoropolymer layers display water vapor transmission rates estimated to be around 10^{-6} g/m^2/day.

Key Accomplishments:
The Kippelen and Graham groups investigated the barrier properties of alumina/zirconia, alumina/titania, alumina/hafnia nanolaminte films, synthesized at low processing temperatures (100 ^{o}C) by using atomic layer deposition (ALD). Nanolaminate films were synthesized by alternating 5 ALD cycles of alumina and 5 ALD cycles of a second metal-oxide a total of 20 times. Alumina and nanolaminate films of similar thickness were first synthesized on top of a ZnO film to conduct photoluminescence (PL) studies. Water-induced quenching of the PL of ZnO was used for an initial comparison of the barrier properties of the alumina and nanolaminate films. Samples were immersed in deionized (DI) water at room temperature for 10 days and the PL measured as described in Fig. 1a). Fig. 1b) displays the PL spectra of encapsulated ZnO films before and after water immersion. The PL of the alumina/ZnO film completely disappears upon water immersion while the PL signal of the nanolaminate/ZnO films remains relatively unchanged. This result clearly demonstrates the superior barrier properties of nanolaminate films over neat alumina films.

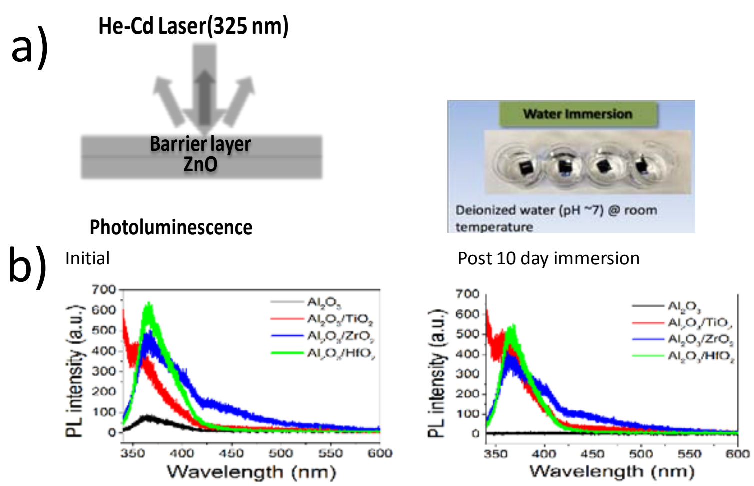

Fig. 1 a) Schematics of sample geometry used for PL studies and a picture that illustrate water immersion. b) PL spectra of ZnO films encapsulated with various barrier layers.

The Kippelen and Graham groups investigated the use of polymer coupling layers to planarize and cover substrate surface defects. Amorphous fluoropolymers such as CYTOP™ enabled nanolaminate layers to display improved barrier properties. Two hundred cycles of alumina were used as a seed layer to compensate for the delayed nucleation of the nanolaminate films on CYTOP™. Use of a seed layer enabled the alumina to fill in the pores and provide a more favorable surface chemistry for the nucleation of the nanolaminate film; resulting in reduced H_2O and O_2 permeation compared with nanolaminate films without the alumina seed layer. The barrier properties of nanolaminate/CYTOP™ films were studied by encapsulating calcium sensors deposited on glass substrates and exposing the samples at 50 °C to an atmosphere having 85% relative humidity inside an environmental chamber for 10 days. Fig. 2a) displays a schematic of the test sample geometry. Fig. 2b) displays images of typical calcium sensors before and after environmental exposure. Regions with no particles or surface defects display remarkable protection of the barrier films to the Ca sensors whereby a water-vapor transmission rate on the order of 10^{-6} $g/m^2/day$ can be inferred.

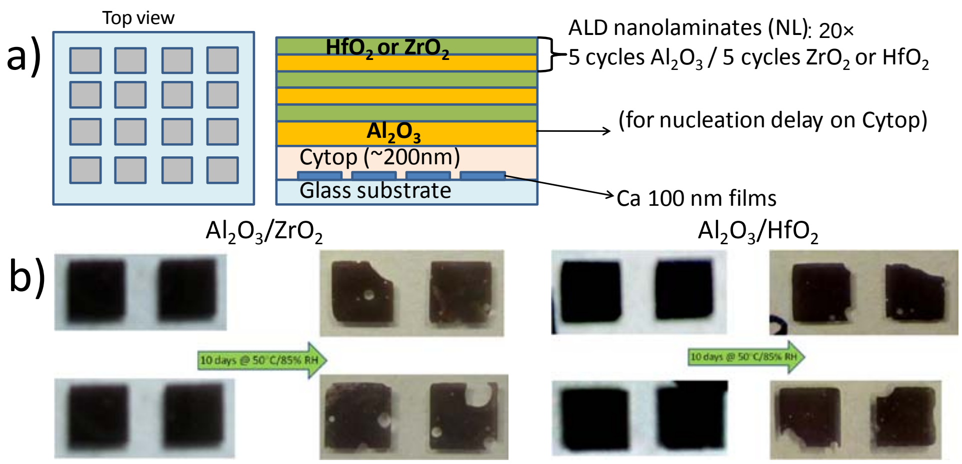

Fig.2 a) Schematics of sample geometry used for Ca tests. b) Images of Ca samples before and after exposure to an atmosphere having 85% relative humidity at 50 °C.

Future Work:

The Kippelen and Graham group's will optimize most the promising nanolaminate/polymer barrier system and implement barriers onto PEN substrates while addressing particle and surface defect generation. They will optimize barrier films for optical transmission and ultrabarrier performance using MOCON and Ca testing at 85 °C/85%RH. In addition, they will investigate methods for improving the mechanical properties of the barrier layers. They will engage other BAPVC members and industry to develop a strategy to test and implement barrier films using spatial ALD methods in Year 3.