Nanoparticulate Barrier Films and Gas Permeation Measurement Techniques for Thin Film Solar and Display Applications

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1. Introduction

The performance of flexible devices like OLEDs and solar cells are very sensitive to moisture because water and oxygen molecules seep past the protective plastic layer over time and degrades the organic materials which form the core of these products. It is well known that thin barrier oxide film coated plastic films have defects (pinholes, cracks, grain boundaries), which vastly affect the performance of barrier films. The currently available multi-layer barrier technologies are focusing on decoupling these defects by using organic/inorganic multi-layers which create a tortuous path for moisture and oxygen diffusion. In contrast, IMRE has taken an innovative approach to resolving the 'pore effect' by literally plugging the defects in the barrier oxide films using nanoparticles. The nanoparticles used in the barrier stack have a dual function - not only sealing the defects but also reacts with moisture and oxygen. The result is an achievement of moisture barrier performance of better than 10^{-6}g/m^2/day which surpasses the ideal requirements needed for flexible organic device substrate.

2. Nanoparticulate Barrier Stack and Results

Nanoparticulate barrier stacks consist of at least two barrier oxide layers and two defects sealing layers. The defects sealing layer consist of different types of nanoparticles that plugs the defects in the barrier oxide films. This also reduces the number of barrier layers needed in the construction of the barrier stack. Figure 1A shows the IMRE's typical multilayer barrier stack with a barrier oxide and a nanoparticulate sealing layers.

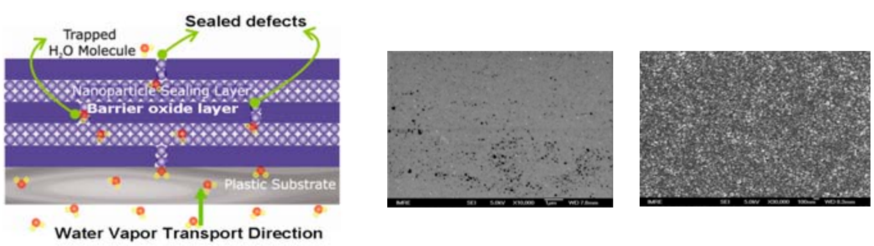

Figure 1. ***IMRE's barrier substrate technology 'plugs the gaps' in technology – (A) Conceptual Barrier Stack, (B) SEM picture (x 10K) of Barrier oxide with pinholes, (C) SEM image (x10K) of defects sealed- barrier oxide film***

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The nanoparticles used in the barrier film have a dual function - not only sealing the defects but also actively reacting with and retaining moisture and oxygen. The SEM images of indium tin oxide surface show the pinholes (figure 1A) and pinholes-sealed with nanoparticles (figure 1B). Therefore, moisture barrier performance is significantly increased up to 10^{-6}g/m^2/day, which surpasses the ideal requirements needed for flexible organic device substrate. The barrier film also has a lag time of more than 2300 hours at 60°C and 90% relative humidity. Calcium test results (figure 2) shown that there was no calcium degradation observed up to 2300 hours (the time it takes for the moisture to pass through the barrier film under those conditions) and quantitative WVTR properties measured as 2 x 10^{-4}g/m^2/day @ 80°C and 90% RH.

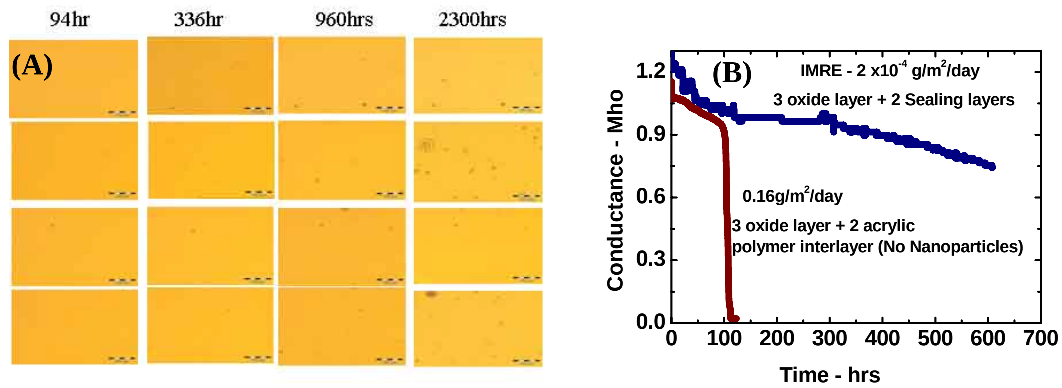

***Figure 2** (A) Microscopic images of calcium sensor at different time intervals at 60°C and 90% RH; (B) Water vapor transport rates for conventional and nanoparticulate barrier stacks*

3. Summary

It has been successfully resolved the 'pore effect issue' in multi-layered barrier stacks and developed ultra high barrier plastic substrates (barrier properties < 10-6 g/m2/day) for high barrier applications. Our calcium test results show that there is no calcium oxidation up to 2300hrs at 80°C and 90% relative humidity. The mechanical, optical and barrier properties have been successfully tested as per the industry standards and reported. In addition, a highly sensitive water vapor permeation measurement technique for organic light emitting display applications is demonstrated. Calcium is used as a sensor to detect the water vapors. Electrical properties of the calcium sensor are measured to monitor the calcium degradation. The water vapor permeation mechanism in various encapsulated organic light emitting devices and degradation phenomenon were investigated.