Flexible Ultra-high Gas Barrier Substrate for Organic Electronics

Min Yan, Ahmet Gün Erlat, Ri-an Zhao, Brian Scherer, Cheryl Jones, David J. Smith, Paul A. McConnelee, Thomas Feist, Anil Duggal

General Electric Global Research Center, Schenectady, New York, USA

Abstract

The use of plastic substrates enables new applications, such as flexible display devices, and other flexible electronic devices, using low cost, roll-to-roll (R2R) fabrication technologies. One of the limitations of polymeric substrate in these applications is that oxygen and moisture rapidly diffuse through the material and subsequently degrade the electro-optical devices. GE Global Research (GEGR) has developed a plastic substrate technology comprised of a superior high-heat polycarbonate (LEXAN®) substrate film and a unique transparent coating package that provides the ultra-high barrier (UHB) to moisture and oxygen, chemical resistance to solvents used in device fabrications, and a high performance transparent conductor. This article describes the coating solutions for polycarbonate (LEXAN®) films and its compatibility with OLED device fabrication processes.

1. Introduction

GE has developed and evaluated a plastic substrate technology comprised of a superior GE Advanced Materials high-heat (HH) polycarbonate substrate film and a unique transparent coating package that provides the ultra-high barrier (UHB) to moisture and oxygen, chemical resistance, and conductivity functionality required for successful flexible display manufacturing. This article provides an update of the UHB coating, presents a comprehensive evaluation of the fully integrated plastic substrate properties, and provides an update on its OLED fabrication compatibility.

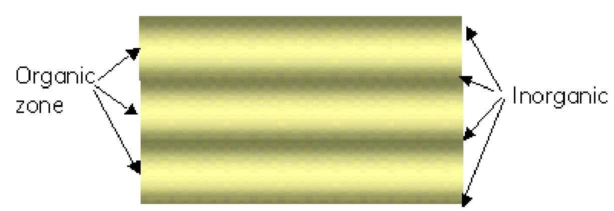
2. High-Heat LEXAN Polycarbonate Film

Substrate Development efforts at GE have been based on a high temperature polycarbonate film provided by GE Advanced Materials (GEAM). During this time, GEAM and others have developed new materials potentially suitable for display applications. Therefore, in this program, GE will develop the R2R UHB process on GEAM high-temperature plastics. This will ensure the compatibility and flexibility of the R2R equipment and process that will be developed in this program.

Transmittance	~90%
Glass Transition Temperature	~240C
Surface Roughness	Ra=0.5nm, Rp<10nm
Retardation	<5nm
Dimensional Stability	25 ppm/hr at 200C

3. Ultra-High Moisture Barrier (UHB)

GERC developed a novel graded UHB coating technology. The graded UHB consists of inorganic silicone oxynitride and organic silicone oxycarbide zones with non-discrete interfaces forming a highly robust structure. The silicon oxynitride is one of the most commonly used inorganic barrier materials. The organic silicon oxycarbide zones are used primarily to decouple pinhole defects in individual inorganic zones to further reduce water vapor transmission. This graded barrier structure has demonstrated a water vapor transmission rate (WVTR) in the mid 10-6 g/m2/day range, approaching the barrier performances requirement for OLED fabrication on plastic substrate.



The graded structure has unique advantages over multilayered barriers. First, continuous transition of the coating composition eliminates the possibility of delamination of the layers, since there is no discrete interface between different materials. Under the cross-sectional XPS analysis of the graded barrier coating, it clearly shows the transitional zones within the coating, where the composition of the coating changes monotonically from silicon oxynitride to silicon oxycarbide and vice versa. In contrast, for multilayered barrier structures, where the discrete interface exists between the layers, coefficient of thermal expansion (CTE) mismatch between two different materials can cause delamination of the layers, especially during the thermal cycles in display manufacturing processes.

4. UHB LEXAN® Film Performance

A comprehensive evaluation was carried out on the plastic OLED substrate. WVTR test was measured using improved Ca corrosion test, ITO sheet resistance was measured using 4-probe method, optical transparency was measured using UV-VIS spectrometer, adhesion was measured using ASTM3359 method, dimensional stability was measured using thermal mechanical analysis, and surface roughness was studied using optical profilometry. Chemical resistance, mechanical flexibility and thermo-mechanical stability were validated with both visual inspection and Ca corrosion test.

	USDC Specifications	GEGR Performance
WVTR	10^{-6}g/m^2/day	low 10^{-5}~mid 10^{-6}
Chemical Resistance	acid, solvent, alkali	Pass
Electrical Conductivity	<40 ohmn/sq	40.3 ohmn/sq
Optical Transparency	>80%	82%
Mechanical Flexiblity	bend around 1" radius	Pass
Thermo-Mechanical Stability	200C for 1 hour	Pass
Adhesion	>4B	4B
Dimension Stability	<20ppm/hr at 150C	4ppm/hr
Average Surface Roughness	<5nm	0.6nm

5. Next Step

OLED display technology offers the potential to enable low cost, highly functional electronic devices that are area-scalable and mechanically flexible. To achieve this potential, it is crucial to develop viable R2R process methods and equipment that are capable of manufacturing coated plastic substrates in mass quantity. To be successful, the R2R plastic substrate must ultimately enable a lower OLED system cost than achievable with display quality glass. Through a detailed understanding of the materials, process, and infrastructure needed to create a R2R plastic substrate, GE will demonstrate compatibility of its R2R substrate with the economic needs of the OLED display industry.