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Synthesis and Characterization of Luminescent Eu(TTA)$_3$phen in a Poly(ethylene oxide) Matrix for Detecting Traces of Water

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The water vapor transmission rate (WVTR) is limited to 10^{-6} g/m^2/day for flexible organic light-emitting diodes. However, it is difficult to measure permeability as low as 10^{-6} g/m^2/day with current commercial testing methods. To address this need, a developed optochemical method which is extremely sensitive to oxygen or water shows promise. In this study, an Eu complex is synthesized and characterized as a fluorescent probe for detecting traces of water molecules. The Eu-complex film dispersed in poly(ethylene oxide) has strong red fluorescence that is easily quenched by a trace of water. Based on the photoluminescence spectra, the detection limit of the film to water appears to be below 1.0×10^{-9} g/cc. This suggests that the Eu-complex film can be used as a film sensor to measure WVTRs below 10^{-6} g/m^2/day.

Key words: Eu(TTA)$_3$phen, permeability, water sensor, optical sensor, WVTR

INTRODUCTION

Promising next-generation flexible electronics, such as flexible organic light-emitting diodes (OLEDs), thin-film solar cells, and flexible lighting, provide robust, lightweight, portable, and rollable display characteristics. However, a major obstacle to the use of this technology is the extraordinary sensitivity of organic-based active materials to water and oxygen molecules. The water vapor transmission rate (WVTR) should be under 1×10^{-6} g/m^2/day to maintain the characteristics of OLED displays which run over 10,000 h. However, current WVTR measuring technologies, such as the calcium test, are very sensitive to preparation and operation conditions, and it is difficult to get a reliable WVTR measurement below 1×10^{-4} g/m^2/day.[1,2] Despite the great deal of effort devoted to the development of water sensors, current technology still comes up short. A promising method is an optochemical method that has many advantages, including miniaturization, portability, and high sensitivity.[3–5]

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In this study, a film sensor composed of an Eu complex dispersed in a poly(ethylene oxide) (PEO) matrix was synthesized and characterized as a fluorescent probe for detecting trace amounts of water molecules. The sensor's optical properties, morphology, and water sensitivity were investigated and characterized using scanning electron microscopy (SEM), ellipsometry, ultraviolet–visible (UV–Vis) spectroscopy, and photoluminescence (PL) spectroscopy.

EXPERIMENTAL PROCEDURES

Synthesis of Eu(TTA)$_3$phen

The synthesis of Eu-complex europium oxide (Eu_2O_3, purity ≥99.9%), 1,10-phenanthroline (phen), poly(ethylene glycol)-block-poly(propylene glycol)-block-poly(ethylene glycol) (PEG, molecular weight 2000 Da), 2-thenoyltrifluoroacetone (TTA), and poly (ethylene oxide) (PEO, molecular weight 100,000) were purchased from Sigma Co. (USA, www.sigmaaldrich.com). All other reagents were of analytical grade and used as received. Triple-distilled water was used throughout the experiments. Europium chloride ($EuCl_3$) was prepared using a published