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Photodegradation of 8-hydroxyquinoline aluminum

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Abstract

The photodegradation of 8-hydroxyquinoline aluminum (Alq_3) films under UV irradiation was studied by means of X-ray photoelectron spectroscopy, nano-second fluorescence spectrophotometer, and photoluminescence spectra. Degradation in photoluminescent properties was significant in an air environment. These results indicated that water and oxygen participate in the photodegradation processes of Alq_3. Quartz glass, metal Al and Ag substrates influenced the degradation in photoluminescent properties of Alq_3, but no changes in the absorption and PL spectra, and fluorescence decays of the irradiated Alq_3 were observed.

Keywords: Photoluminescence; X-ray photoelectron spectroscopy

1. Introduction

8-hydroxyquinoline aluminum (Alq_3) has been shown to be one of the most promising materials for the fabrication of low molecular weight organic light-emitting diodes (LEDs) [1]. A distinct limitation in these devices has been the introduction of atomic species in the final product due to the water that is followed in its formation, and hydrolysis of the surface. Among these species, water and particularly 8-hydroxyquinoline could act as efficient photoluminescence (PL) quenchers, which dissociate excitons and hence decrease the PL efficiency [2]. Metal-induced luminescence quenching of organic materials has been reported by many groups. This is strongly related to metallic clustering, band bending at the metal/organic interface, metal diffusion into organic films, and the reactivity of metals with organic materials [3]. However, there is no report on the interaction between metallic substrates and the photodegradation of Alq_3.

In this paper, we report the photodegradation of Alq_3 on quarzt glass, Al and Ag substrates.

2. Experimental

Evaporation of Al, Ag, and Alq_3 thin films was carried out in a vacuum chamber with a base pressure 5×10^{-5} Torr. Al and Ag films of 100 nm in thickness were first evaporated on a quartz glass substrate, then a layer of Alq_3 (~15 nm) was grown. In order to investigate the fluorescent degradation, the Alq_3 thin films were irradiated using an 8 W ultraviolet lamp at 365 nm in air and moisture environments.

3. Results and discussion

Fig. 1 shows XPS Al (2p) spectra of unirradiated and irradiated Alq_3 films on quartz glass, Al and Ag substrates. The XPS Al (2p) spectrum of as-deposited Alq_3 on the quartz glass shows a peak at 73.8 eV. The Al (2p) spectrum of Alq_3/Al sample shifts to lower binding energies and reaches an intermediate value (74 eV) between that of clean Al metal (72.8 eV) and Al_2O_3 (75 eV), but the spectrum of Alq_3/Ag sample is split into two peaks at 73.5 eV and 74 eV. Previous studies of the interaction between aluminum and conjugated polymers have reported the formation of covalent Al-C bonds and a reduction in the π conjugation of organic polymer [4]. When the Alq_3 molecule was deposited onto Al or Ag, the interaction between Al (or Ag) atoms and Alq_3 molecules may happen, leading to the formation of novel complexes [5]. The Al (2p) spectrum of the irradiated Alq_3/quartz glass sample shows two new shoulders around 72.9 eV and 74.3 eV besides the one at 73.8 eV, while the peaks of Al (2p) decrease in intensity. This result indicated that irradiated Alq_3 provides two new states of aluminum, corresponding to the two-photodegradation products containing Al^{3+} [2]. The Al (2p) spectrum of the irradiated Alq_3/Al sample shows only a peak at 73.4 eV. However, for the irradiated

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Alq_3/Ag sample, the peak positions of the Al (2p) are found to be at 73.5 eV with two shoulders at 72.9 eV and 74 eV, which are comparable to that of the irradiated Alq_3/quartz sample.

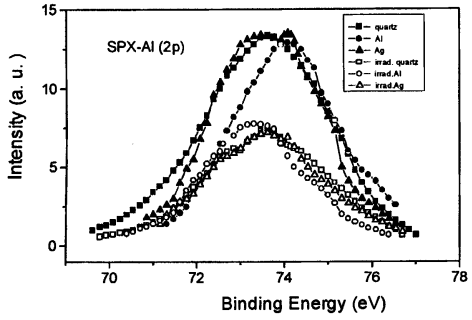

Fig. 1 XPS Al (2p) spectra of unirradiated and irradiated Alq_3 films on quartz glass, Al, and Ag substrates [illumination time is 30 h].

Fig. 2 exhibits fluorescent decadent curves of Alq_3 films on quartz glass, Al and Ag substrates before and after UV irradiation. The initial PL decay of Alq_3/quartz glass sample is nonexponential, but the PL decays of the Alq_3/Al (or Alq_3/Ag) samples are rapid due to the formation of novel Al-Alq_3 (or Ag-Alq_3) complexes when Alq_3 was evaporated on Al (or Ag) substrates. The PL decadent curves of the irradiated films on quartz glass are rapid with the irradiated times. This result further indicated that a chemical reaction occurred for Alq_3 and the quenchers formed during UV-light irradiation in the presence of moisture and oxygen. Extension irradiated times could induce increasing of the quenchers and, therefore, lead to the quickening of fluorescent decays. The effect of metal Al and Ag substrates on PL decadent curves of the irradiated Alq_3 films is not remarkable.

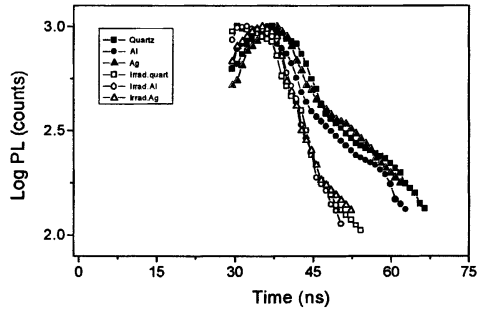

Fig. 2. Fluorescent decadent curves of Alq_3 films on quartz glass, Al, and Ag substrates before and after UV irradiation [illumination time is 30 h].

Fig. 3 shows photoluminescence intensity decays of Alq_3 films on quartz glass, Al, and Ag substrates during UV irradiation. The shape and emission peak of the absorption and PL spectra of Alq_3 films before and after UV irradiation are identical, but the PL intensities decrease with increasing illumination time. This result indicated that no change was observed for fluorescent center before and after UV irradiation, and the fluorescent center was Alq_3. However, there is a photo-induced quench center, which leads to the decrease of the PL intensities. PL intensity decay of Alq_3 films on Al (or Ag) substrates has a similar decay law as that on the quartz glass. However, as compared with PL degradation of Alq_3 films on the quartz glass, Al and Ag substrates change the PL decay law.

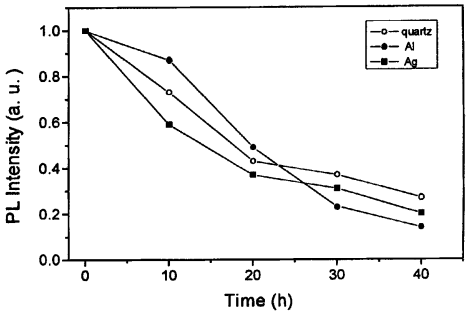

Fig.3 Photoluminescence intensity decays of Alq_3 films on quartz glass, Al, and Ag during UV irradiation.

4. Conclusion

We described the photodegradation of Alq_3 thin films in air and moisture environments by the irradiation of UV-light. With the help of the XPS, nano-second fluorescence spectrophotometer, and PL spectra, we studied the effect of metallic substrates on the photodegradation of Alq_3 films. Experimental results indicated that the LEDs made of Alq_3 may be degraded under an air and moisture environment by its instability and the oxygen and moisture-sensitive electroluminescent materials can be degraded by their reaction with water and oxygen. This photodegradation of EL materials may seriously affect the performance of light-emitting devices. Therefor, it is important to keep the device from the oxygen in air and moisture not only for protection of the easily oxidizable metal electrode but also for protection against photo- and chemical degradation, resulting in enhancement of the lifetime of LEDs.

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