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Optical Properties, Morphology and Long Time Degradation of Alq_3 Thin Films

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Introduction

Tris(8-hydroxyquinoline)aluminum (Alq_3) is a material widely applied in organic light emitting diodes (OLEDs) as an electron transporting layer and/or a highly efficient emitting layer of green light since the late 1980s [1]. Many studies in this field have been focused on the optimization of device performance [2], but in spite of the widespread use of Alq_3 in commercial OLEDs [3], there are still challenges to be addressed as large-scale manufacturing, efficiency and material lifetime [4]. Moreover, relatively few studies were devoted to the correlation between molecular structure and optical properties of Alq_3 amorphous films [5,6].

In order to better comprehend the microscopic properties of Alq_3 molecules, see Fig.1, and to find out practical ways to preserve longer their luminescence, systematic measurements of the optical properties were performed on several thin films of Alq_3 [7]. Mostly emission properties were measured, and in particular the decay of photoluminescence (PL). We had already found in a few films that the intensity of the peak values of PL up to 10,000 h could be described as the sum of four exponential decays which possess vastly different amplitudes, constant times and spectral features [8]. The measurements have been extended here up to 50,000 h, to establish whether the previous phenomenological Four Components Model (FCM) applies to all films of Alq_3 irrespectively of their origin and length of decay. Here we report the results of only two films, one measured after the evaporation, sample alq63-3, and the other one measured after being annealed in wet O_2 at 155 °C for 10 min, sample alq64-2 .

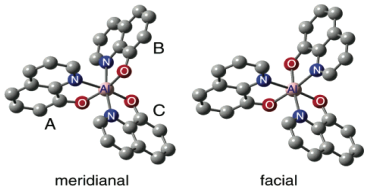

Figure 1. *Two isomeric forms of the Alq_3 molecule, meridianal and facial. Hydrogen atoms are omitted for clarity. In the facial isomer, the three ligands are equivalent, while they are different and labeled by A, B, and C in the meridianal isomer. Amorphous thin films are composed mainly by meridianal isomers.*

Experimental Results and Discussion

Figure 2 reports the bands of PL of the two samples measured every so often, and they display a decreasing of intensity and a blue shift.

Figure 3 displays in a semi-log representation the experimental peak intensity of the PL, it can be observed that the new measurements beyond 10,000 h follow a linear behavior as expected by the FCM. A complete best fit of the experimental data with this model is shown in Fig. 4, where also the components are reported for a full analysis, and the agreement is satisfactory. These results show that the process of annealing increases the amplitude of the component 4 at the expense of component 3, which has the consequence of increasing the lifetime of the film and its PL intensity.

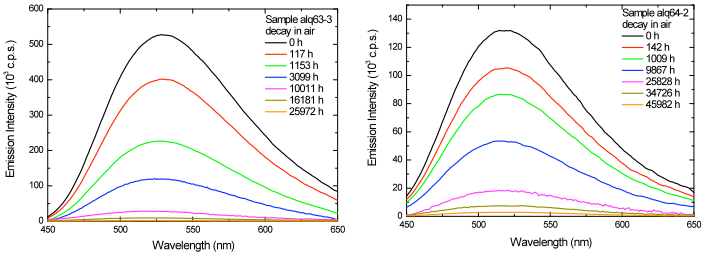

Figure 2. *Photoluminescence spectra of 45 nm thick films of Alq_3, sample alq63-3 (left) and sample alq64-2 (right), excited at 395 nm. The different curves were measured at successive times as indicated in the legend up to about 50,000 h after having moved the sample in open atmosphere from a dry box.*

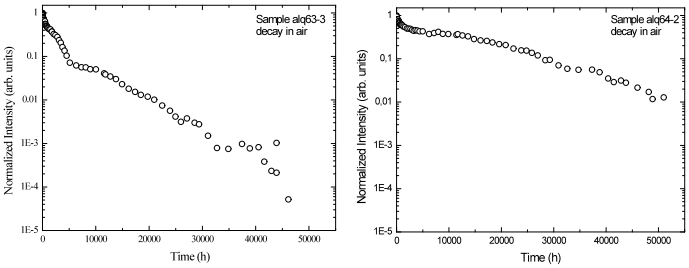

Figure 3. Emission decay of samples alq63-3 (left) and alq64-2 (right), in a semi-log representation, as a function of time up to 50,000 h. A linear behavior above 10,000 h is evident.

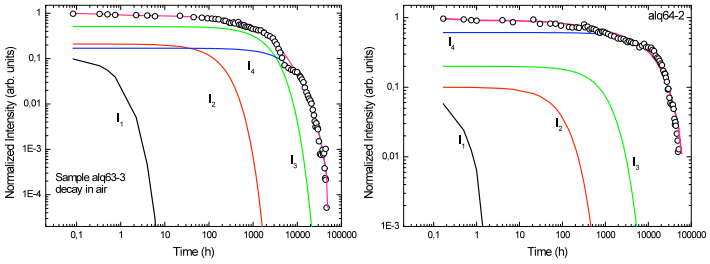

Figure 4. *Emission decay of samples alq63-3 (left) and alq64-2 (right), and FCM fit, pink line, in a log-log representation, as a function of time up to 50,000 h. The four components, full lines, are also reported.*

Conclusions

For the first time ever, PL measurements of Alq_3 thin films have been performed for as long as six years. The results obtained in this work have confirmed the phenomenological model known as FCM.

The FCM means that films of Alq_3 are not necessarily amorphous, as commonly described in the literature, but rather they are made up of four morphological aggregations where molecules pack each other in different ways [5], which have nothing to do with the well known crystalline phases [5,6,9]. Moreover, the four components explain plainly the blue shift of the PL band [10,11], and the many effects of annealing processes on the intensity and longevity of Alq_3 films [12,13], which have significant consequences also for OLEDs [14].

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