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I, Ahamed Milhan Ajward , hereby submit this original work as part of the requirements for the degree of Doctor of Philosophy in Physics.

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Linear and non-linear optical properties of OMBD grown PTCDA and Alq3 films

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Linear and non-linear optical properties of OMBD grown PTCDA and Alq3 films

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by

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Abstract

In this thesis, linear and non-linear optical properties of perylene-3,4,9,10-tetracarboxylic-3,4,9,10-dianhydride (PTCDA) and of tris(8-hydroxyquinolinato)aluminum (Alq3) films have been investigated using various experimental methods. The films were grown using the technique of organic molecular beam deposition (OMBD).

The dispersion of the in-plane and normal refractive index in PTCDA waveguides has been studied using the *m*-line technique. The PTCDA waveguides were grown on Pyrex substrates. TE and TM mode coupling at excitation wavelengths ranging from 633 to 910 nm has been accomplished using a Rutile prism. The derived refractive index values are in good agreement with existing ellipsometric data, which emphasizes the high structural quality of our waveguides.

The nonlinear absorption (two-photon absorption) of PTCDA and Alq3 films has been investigated using the z-scan technique. The films were grown on Pyrex substrates and a high repetition rate (80 MHz) laser was used as excitation source. Various methods have been utilized to minimize laser induced damaging of the soft organic films and to improve the signal-to-noise ratio. In addition, nonlinear fluorescence (two-photon induced fluorescence) measurements have been performed on Alq3 films to further investigate nonlinear absorption processes in this material.

The singlet-singlet annihilation (nonlinear bimolecular quenching) of excitons in disordered quasi-amorphous Alq3 films has been investigated using both time-resolved and continuous wave (cw) spectroscopic techniques at temperatures ranging from 15 K to 300 K. A

significant decrease of the PL efficiency with increasing exciton density (excitation intensity), especially at low temperatures, has been observed which is attributed to bimolecular quenching of excitons that are funneled into low-energy traps. This effect is different from the known diffusion based singlet-singlet annihilation in Alq3. To explain both the intensity and temperature dependence of the quenching phenomena a simple model has been developed and used to analyze and to simulate the complex experimental observations.

To investigate the possible influence of the degree of disorder on the bimolecular quenching of trapped excitons, PL efficiency experiments have been performed on Alq3 films that have been grown at different growth conditions. The investigations include films with varying thickness, films that were grown at various growth rates and on different substrates as well as annealed Alq3 films. Changes of bimolecular annihilation effects due to these modifications have been qualitatively explained.

To my parents

Ikram

and

Hidaya Ajward

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Table of contents

List of Figures

List of Tables

Chapter 1

1 Introduction

Since the development of the first organic electroluminescent diode by Tang et al. in 1987[1] luminescent devices based on organic materials have become one of the most promising technologies which might eventually replace their inorganic counterparts (LCD). OLED displays are very attractive because they are slimmer, faster, energy efficient, flexible, durable, and can be fabricated at cheaper production costs[2] when compared with other display technologies. In addition OLED displays have a larger viewing angle and put less stress on the eyes of the viewer because of the better contrast, color and brightness [2]. While there are so many advantages of this technology, short life span [3], and highly susceptible to water damage [4] are some of the major disadvantages. These days OLEDs based on small molecules are used in all sorts of commercial display applications and different thermal deposition techniques are used to fabricate these devices[5]. The first monochrome OLED display was produced by Pioneer cooperation in 1997 [6]. In 2003 both Sanyo and Kodak introduced the first color Active-Matrix OLED (AMOLED) display products [7]. Also in 2008 Sony produces the first color AMOLED TV[8].

Although the OLED display technologies have evolved quickly the quantum efficiencies of the OLED devices are relatively small namely about 1.4%[9]. Since the photoluminescence (PL) efficiencies are around 30%[9], there is huge possibility to improve the electroluminescence (EL) efficiencies of these devices. In order to improve both EL and PL efficiencies of these OLED devices, the dynamics of the luminescence emission has been studied for past few decades. The EL efficiency of an OLED (see Figure 1.2) is spin dependent because the electron and hole may recombine as a singlet or as a triplet. Statistically 25% of the excitons are singlets and 75% are