Synthesis and characterization of optical properties of europium (III) complex with 4,4,4-trifluoro-1-phenyl-1,3-butanedione and 1,10-Phenanthroline

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Abstract: *Luminescent thermally stable lanthanide complex has been synthesized and characterized and its photo physical properties like excitation and luminescence spectra were investigated. Origin of photoluminescence in this complex is radiative transitions of the lanthanide ion which is excited via intersystem crossing from the excited organic ligands. Light emitting devices using this rare-earth complex tris (4, 4, 4-trifluoro-1-phenyl-1, 3-butanedionate) (1, 10-Phenanthroline) europium (III) as emissive layer emitted sharp red light with a peak wavelength at 612nm. In this device the hole transport layer is obtained using a thin film of N, N-diphenyl-N, N'-bis(3-methylphenyl)-1,1'-biphenyl-4,4'-diamine (TPD), LiF as hole blocking layer and tri(8-hydroxyquinoline aluminum)(AlQ_3)as the electron transporting layer.*

Keywords: Lanthanide complexes; Electro luminescence; Sharp emission; organic ligand; Spectroscopic properties.

Introduction

OLEDs using 8-hydroxyquinoline aluminum (Alq_3) as the emitting layer was reported to emit green light in 1987 [1]. Since then in the last years, electroluminescence (EL) from organic thin films has become a matter of great interest because of its potential to enable low-cost, full color, flat panel displays and other emissive devices [2]. In these systems, energy released by recombination of injected holes and electrons excites molecules in an emitting layer and results in luminescence. Europium(III)-β-diketonates complexes have been applied by several researchers as emitting materials in red-emitting EL devices with sharp spectra [3-8]. The 4f—4f luminescence intensity in these compounds is the result of a balance between strong absorption by the ligands, ligand-rare earth ion energy transfer rates, non-radiative decays and radiative emission rates involved. In the present paper, a red Eu complex was synthesized, characterized and spectroscopic properties of the complex tris(4, 4, 4-trifluoro-1-phenyl-1,3-butanedionate) (1,10-phenanthroline) europium (III) were investigated. In addition, Eu complex was used to fabricate light emitting devices and their electroluminescence (EL) properties were studied and comparative study was done with other red light emitting materials present.

Experimental

Synthesis of Eu complex and device fabrication

The europium(III)chloride and the organic ligands 4, 4, 4-trifluoro-1-phenyl-1, 3-butanedione and 1,10-phenanthroline were purchased from Fluka. The europium complex was synthesized by mixing 4, 4, 4-trifluoro-1-phenyl-1,3-butanedione solution and 1,10-phenanthroline solution drop wise with constant stirring. The pH of solution was adjusted from acidic to and aqueous solution of europium chloride was added drop wise with constant stirring till metal complex was precipitated out. Digested the precipitates at room temperature, filtered and dried in a vacuum at 80ºC over P_2O_5 under reduced pressure. The C, H, N analysis data of complex indicated the formula Eu $(btfa)_3$.phen. The proposed formula was also consistent with the IR spectra of the complex. The EL devices were fabricated using conventional vacuum vapor deposition technique. The ITO coated glass was patterned and then ultrasonically cleaned in isopropanol and trichloroethylene in sequence. The hole transporting layer (HTL), emitting layer (EML), electron transporting layer (ETL) and electron injecting layer (EIL) used in the multilayer device were composed of N, N′-diphenyl-N, N′-bis(3-methylphenyl)-1,1′-biphenyl-4,4′-diamine (TPD), Eu$(btfa)_3$.phen and tris-8-hydroquinolinato aluminum (Alq_3) and LiF respectively. These organic compounds were successively thermally evaporated onto ITO at room temp. at rates in the range of 1-3 Aº/sec below a pressure of 2.0×10^{-6} Torr. Finally, aluminum cathode was vacuum deposited at higher rates (about 6-8 Aº/sec) at the same pressure. Elemental Analysis i. e. C, H, N analysis of complex was done by Elemental Analyzer Perkin Elmer 2400 CHN. Perkin Elmer 2000 FTIR was used to take IR spectra in KBr pallets. The excitation and emission spectra of complex were recorded in THF solution using spectrophotometer Horiba Jobin YVON Fluolog Model No FL 3-11. The Electroluminescence and Photoluminescence spectra were recorded on a High-Resolution USB Fiber Optic spectrometer Model No HR2000 purchased from Ocean Optics Inc. For V-I Keithley 2400 electrometer was used.

Result and discussion

The IR vibrational spectra provided evidence that the metal ion is coordinated to the ligands via the C=O group and N atoms. The excitation and emission spectra of the Eu^{3+} ion in Eu $(btfa)_3$.phen complex were shown in Fig. 1. The excitation spectra evidenced an efficient

ligand to metal energy transfer, since the most intense feature was a broad band corresponding to transitions populating ligand-centered excited states. The luminescent spectrum of europium complex upon ligand excitation was shown in Fig. 1. Characteristic red luminescence of the Eu^{3+} ion can be observed at 612nm ($^5D_0 \rightarrow {}^7F_2$) in emission spectra. Therefore, the Eu^{3+} ion is excited via energy transfer from the initially excited organic ligand. The excitation energy is transferred from the triplet state of the ligand to the nearest lower resonance level of the Eu^{3+} ion. The electroluminescent performance of europium complex was investigated by fabrication of light emitting devices using complex as emissive layer. The electroluminescence and photoluminescence spectrum were similar to indicating that emission originated from complex. The color of emitted light was red from the multilayered electroluminescent devices. The current voltage characteristics were shown in Figure 3 showing the turn on voltage was about 5V. Color C.I.E. Coordinates x = 0.624, y = 0.342

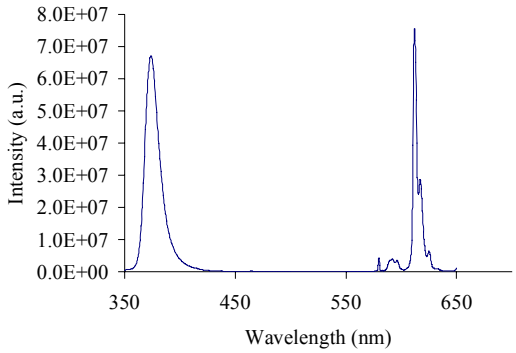

Figure 1. Excitation and Emission spectra of complex in THF solvent

Conclusion

A soluble europium complex with was synthesized. Red light emitting devices had been fabricated utilizing the complex as an emissive material. An efficient organic electroluminescent material $Eu(btfa)_3$.phen with narrow emission bands at 612nm($^5D_0 \rightarrow {}^7F_2$) originating from the Eu^{3+} ion transitions was synthesized and characterized using different spectroscopy techniques. The excitation and emission peaks of the complex were 376nm and 612nm respectively. The complex was employed as an emitting layer in light emitting devices and the properties of the device using complex like electroluminescence (EL), current-voltage graph (I-V) were investigated. The photoluminescence (PL) and electroluminescence (EL) spectra exhibited similar pattern having peak at 612nm. We found that the complex is an excellent red light emitting material to be used in electroluminescent application for full color display.

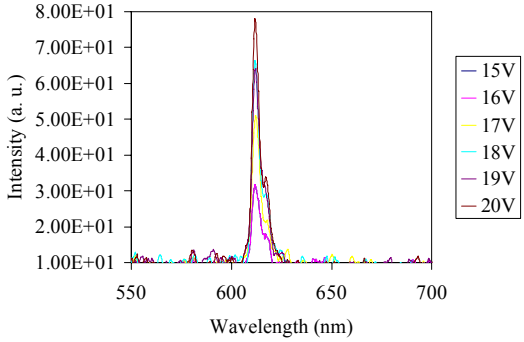

Fig. 2. EL at different values of voltages for the device

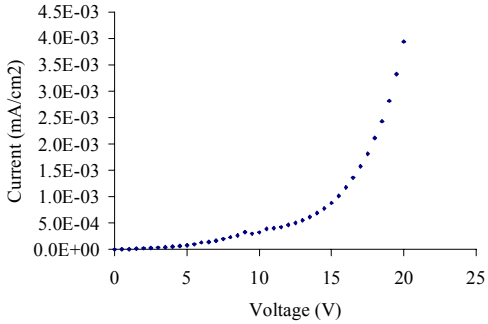

Fig. 3. Current-voltage curve of the device

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