Near-Ultra-Violet (NUV) Excited Phosphors

NG Ka Man

A thesis submitted in partial fulfillment of the requirements
for the degree of
Master of Philosophy

Principal Supervisor: Prof. K W Cheah

Hong Kong Baptist University

Sept 2008
ABSTRACT

In this project, three phosphors (RGB: blue, green and red) excited by near UV-light are investigated. Those phosphors are specially selected for the use of producing white-light with a UV-based LED. The project aim is to obtain a mixture of RGB phosphors emitting white light with adjustable color-standardizing CIE coordinates and comparable intensity to the commercial fixed-cool-white-color product (Blue LED with YAG:Ce yellow phosphor). In order to achieve the aim, luminescence mechanism and characteristics of phosphors are studied.

For luminescence mechanism, general theories of energy transfer and absorption and emission processes in the rare earth ions were studied. The electronic transitions in a specific rare earth ion (Europium – Eu$^{2+}$ and Eu$^{3+}$), which was used as luminescence centers in our UV-excited phosphors, were focused. Then, phosphors with varies of doping Europium concentration in different hosts were synthesized for analysis. Optimization in synthesis process and conditions were done in advance. These included methods comparison, annealing temperature evaluation and study of grinding effect. After that, a detail study on optical properties among the phosphors was done according to series of measurement results – SEM photos, XRD patterns, PL and PLE spectrum and luminescence lifetime. Three RGB phosphors with intense emission in visible-light region were finally selected. A white light emitting LED with tunable CIE coordinates, especially in warm-white-color region, was successfully fabricated with the three RGB phosphors.
# Table of Contents

Declaration.....................................................................................................................i  
Abstract.........................................................................................................................ii  
Acknowledgements .....................................................................................................iii  
Table of Contents........................................................................................................iv  
List of Tables ............................................................................................................vii  
List of Figures ...........................................................................................................viii  
Chapter 1 Introduction...............................................................................................1  
Chapter 2 Basic Theory...............................................................................................2  
  2.1 Luminescence Mechanism ...............................................................................3  
  2.2 Luminescence Characteristics .................................................................3  
      2.2.1 Broadening of Spectrum .................................................................3  
      2.2.2 Stokes Shift ....................................................................................4  
      2.2.3 Lifetime ...........................................................................................5  
  2.3 Transition Criteria ...............................................................................6  
      2.3.1 Transition Probability .................................................................6  
      2.3.2 Selection Rule ................................................................................7  
  2.4 Influences on Optical Properties .........................................................8  
      2.4.1 Host Lattice Effect .................................................................8  
          2.4.1.1 Covalency .................................................................8  
          2.4.1.1 Crystal Field..............................................................8  
      2.4.2 Luminescence Center Effect ......................................................9  
          2.4.2.1 Electronic Transitions of Activator ....................................9  
          2.4.2.2 Activator Concentration Effect ......................................10
2.5 Transitions in Europium ions ................................................................. 11
   2.5.1 Eu\textsuperscript{2+} ions ........................................................................... 11
   2.5.2 Eu\textsuperscript{3+} ions ........................................................................... 12
Chapter 3 Sample Preparation ........................................................................... 13
   3.1 Phosphor Synthesis .................................................................................. 14
      3.1.1 Solid-state Method ........................................................................... 14
      3.1.2 Microwave Method .......................................................................... 17
      3.1.3 Synthesis Method Comparison ...................................................... 20
   3.2 Grinding ................................................................................................... 22
   3.3 White-light LED Fabrication ................................................................... 28
Chapter 4 Experiments ..................................................................................... 29
   4.1 Crystal Structure and Morphological Measurement ............................... 29
   4.2 Photoluminescence Emission (PL) Measurement ........................................ 30
   4.3 Photoluminescence Excitation (PLE) Measurement ............................... 32
   4.4 Lifetime Measurement ........................................................................... 34
   4.5 Brightness Measurement ........................................................................ 35
   4.6 Color Temperature and Color Rending Index (CRI) Measurement .......... 35
   4.7 Commission Internationale de l'Eclairage (CIE) Measurement .................. 35
Chapter 5 Results and Discussion .................................................................. 37
   5.1 Blue Phosphors ...................................................................................... 38
      5.1.1 Sr\textsubscript{4}Al\textsubscript{14}O\textsubscript{25}:Eu\textsuperscript{2+}, X\textsuperscript{2+} ................................................. 39
         5.1.1.1 Co-doping Materials (X) .......................................................... 41
         5.1.1.2 Effect of Co-doping Concentration ........................................ 42