



## Table of Contents

|                                                         | Page |
|---------------------------------------------------------|------|
| 1. Introduction                                         |      |
| 1.1. Introduction to Luminescence                       | 2    |
| 1.2. General Characteristics of Luminescence            | 3    |
| 1.2.1 Photoluminescence                                 | 4    |
| 1.3. Phosphor Configuration                             | 8    |
| 1.4. Lanthanides and Rare Earths                        | 10   |
| 1.5 Types of Dopants                                    | 15   |
| 1.6. Model of Luminescence Process to take place        | 16   |
| 1.6.1. Decay Process of Excited States                  | 17   |
| 1.7. Introduction to TL                                 | 19   |
| 1.7.1. Historical Background of Luminescence Phenomenon | 19   |
| 1.8. Theory of Thermally Stimulated Luminescence        | 23   |
| 1.8.1. Basic Phenomenon                                 | 23   |
| 1.8.2. Dynamics of Detrapping (Trap emptying process)   | 25   |
| 1.9. Mathematical Description                           | 26   |
| 1.9.1. First Order Kinetics                             | 26   |
| 1.9.2. Second Order Kinetics                            | 28   |
| 1.9.3. General Order Kinetics                           | 29   |
| 1.10. Determination of TSL Parameters                   | 30   |
| 1.11. Applications                                      | 32   |
| 1.11.1. TSL Dosimetry                                   | 32   |
| 1.11.2. Personnel Dosimetry                             | 33   |
| 1.11.3. Environmental Dosimetry                         | 33   |
| 1.11.4. Clinical Dosimetry                              | 34   |
| 1.11.5. High Dose                                       | 35   |
| 1.11.6. Retrospective Dosimetry                         | 35   |
| 1.11.7. Archeological Dating                            | 35   |
| 1.11.8. Other Applications                              | 36   |

|                                                                                                                                                                                                                              |    |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| 1.12. Phosphor Research: Past and Present                                                                                                                                                                                    | 38 |
| 1.12.1. Fluorescent Lamp Phosphors                                                                                                                                                                                           | 39 |
| 1.13. Scope and Objectives of Present Study                                                                                                                                                                                  | 41 |
| 1.14. References                                                                                                                                                                                                             | 44 |
| 2. Instrumentation, Synthesis and Fundamentals of Alkaline Earth Aluminates                                                                                                                                                  |    |
| 2.1. Introduction                                                                                                                                                                                                            | 49 |
| 2.2. Optical System of Spectrofluorophotometer                                                                                                                                                                               | 49 |
| 2.2.1. Measurement Procedure                                                                                                                                                                                                 | 57 |
| 2.3. Thermoluminescence (TL) Glow Curve Recorder                                                                                                                                                                             | 57 |
| 2.3.1. Procedure to Measure TL more accurately using NUCLEONIX<br>PC based TL Reader System                                                                                                                                  | 60 |
| 2.4. X-ray diffractometer (XRD)                                                                                                                                                                                              | 62 |
| 2.5. Brief introduction to alkaline earth aluminates                                                                                                                                                                         | 64 |
| 2.6. Synthesis Technique                                                                                                                                                                                                     | 70 |
| 2.6.1. Flow Chart of synthesis technique for $\text{Sr}_3\text{Al}_2\text{O}_6$ phosphor                                                                                                                                     | 72 |
| 2.7. References                                                                                                                                                                                                              | 73 |
| 3. Luminescence Characteristics of $\text{Sr}_3\text{Al}_2\text{O}_6:\text{Eu}^{3+}$ and $\text{Sr}_3\text{Al}_2\text{O}_6:\text{Eu}^{3+},\text{Dy}^{3+}$<br>phosphor                                                        | 76 |
| 3.1. Introduction                                                                                                                                                                                                            | 77 |
| 3.2. Experimental                                                                                                                                                                                                            | 81 |
| 3.3. Results and Discussion                                                                                                                                                                                                  | 82 |
| 3.3.1. X-ray diffraction (XRD) studies                                                                                                                                                                                       | 82 |
| 3.3.2. Photoluminescence (PL) characteristics                                                                                                                                                                                | 83 |
| 3.3.3. Thermally Stimulated Luminescence characteristics                                                                                                                                                                     | 93 |
| 3.4. References                                                                                                                                                                                                              | 96 |
| 4. Luminescence Characteristics of $\text{Sr}_3\text{Al}_2\text{O}_6:\text{Tb}^{3+}$ phosphor and Study of<br>Energy Transfer between $\text{Tb}^{3+}$ and $\text{Eu}^{3+}$ in the $\text{Sr}_3\text{Al}_2\text{O}_6$ System | 98 |
| 4.1. Introduction                                                                                                                                                                                                            | 99 |

|                                                                                                                                                                                            |     |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| 4.2. Experimental                                                                                                                                                                          | 100 |
| 4.2.1. Sample preparation                                                                                                                                                                  | 100 |
| 4.2.2. X-ray diffraction, Photoluminescence and Thermoluminescence Characterization                                                                                                        | 101 |
| 4.3. Result and Discussion                                                                                                                                                                 | 101 |
| 4.3.1. X-ray diffraction (XRD) studies                                                                                                                                                     | 101 |
| 4.3.2. Photoluminescence (PL) Characteristics                                                                                                                                              | 103 |
| 4.4. Thermoluminescence (TL) Characteristics                                                                                                                                               | 107 |
| 4.4.1. Separation of TL peaks by $T_{\text{stop}}$ -Method                                                                                                                                 | 107 |
| 4.4.2. Effect of different Terbium concentration on TL glow curve                                                                                                                          | 109 |
| 4.4.3. Fading Effect of $\text{Sr}_3\text{Al}_2\text{O}_6:\text{Tb}$ (1%) phosphor                                                                                                         | 111 |
| 4.4.4. Dose response of $\text{Sr}_3\text{Al}_2\text{O}_6:\text{Tb}$ (1%) phosphor                                                                                                         | 112 |
| 4.4.5. Measurements of reproducibility in TL readouts                                                                                                                                      | 113 |
| 4.4.6. Discussion of 350 °C TL peak                                                                                                                                                        | 114 |
| 4.5. Energy transfer between $\text{Tb}^{3+}$ and $\text{Eu}^{3+}$ in the $\text{Sr}_3\text{Al}_2\text{O}_6$ system                                                                        | 115 |
| 4.5.1. Photoluminescence emission spectra of $\text{Sr}_3\text{Al}_2\text{O}_6:\text{Tb}^{3+},\text{Eu}^{3+}$ phosphor                                                                     | 116 |
| 4.5.2. Photoluminescence excitation spectra of $\text{Sr}_3\text{Al}_2\text{O}_6:\text{Tb}^{3+},\text{Eu}^{3+}$ phosphor                                                                   | 119 |
| 4.5.3. Photoluminescence emission spectra of $\text{Sr}_3\text{Al}_2\text{O}_6:\text{Tb}^{3+},\text{Eu}^{3+}$ phosphor with varying concentration of $\text{Tb}^{3+}$ and $\text{Eu}^{3+}$ | 121 |
| 4.5.4. Thermoluminescence glow curve of $\text{Sr}_3\text{Al}_2\text{O}_6:\text{Tb}^{3+},\text{Eu}^{3+}$ phosphor                                                                          | 124 |
| 4.5.5. Thermoluminescence glow curve of $\text{Sr}_3\text{Al}_2\text{O}_6:\text{Tb}^{3+},\text{Eu}^{3+}$ phosphor with varying concentration of $\text{Tb}^{3+}$ and $\text{Eu}^{3+}$      | 126 |
| 4. 6. References                                                                                                                                                                           | 128 |
| 5. Luminescence Characteristics of Double Doped $\text{Sr}_3\text{Al}_2\text{O}_6$ Phosphor and Effect of Addition of Flux on $\text{Sr}_3\text{Al}_2\text{O}_6:\text{R.E.}^{3+}$ System   | 130 |

|                                                                                                                            |     |
|----------------------------------------------------------------------------------------------------------------------------|-----|
| 5.1. Introduction                                                                                                          | 131 |
| 5.2. Experimental                                                                                                          | 133 |
| 5.3. Results and Discussion                                                                                                | 134 |
| 5.3.1. Photoluminescence characteristics of $\text{Sr}_3\text{Al}_2\text{O}_6:\text{Eu}^{3+}, \text{Ce}^{3+}$              | 134 |
| 5.3.2. Photoluminescence of $\text{Sr}_3\text{Al}_2\text{O}_6:\text{Eu}, \text{Mg}$ Phosphor                               | 136 |
| 5.3.3. Photoluminescence of $\text{Sr}_3\text{Al}_2\text{O}_6:\text{Eu}^{3+}, \text{R.E.}^{3+}$                            | 137 |
| 5.3.4. Photoluminescence of $\text{Sr}_3\text{Al}_2\text{O}_6:\text{Tb}^{3+}, \text{Ce}^{3+}$ Phosphor                     | 138 |
| 5.3.5. Thermoluminescence of $\text{Sr}_3\text{Al}_2\text{O}_6:\text{Tb}, \text{Ce}$ Phosphor                              | 141 |
| 5.4. Effect of addition of Flux on the Luminescence Characteristics of $\text{Sr}_3\text{Al}_2\text{O}_6:\text{R.E.}^{3+}$ | 143 |
| 5.4.1. Photoluminescence of $\text{Sr}_3\text{Al}_2\text{O}_6:\text{Eu}^{3+}, \text{H}_3\text{BO}_3$                       | 144 |
| 5.4.2. Photoluminescence of $\text{Sr}_3\text{Al}_2\text{O}_6:\text{Eu}^{3+}, \text{Dy}^{3+}, \text{H}_3\text{BO}_3$       | 145 |
| 5.4.3. Photoluminescence of $\text{Sr}_3\text{Al}_2\text{O}_6:\text{Tb}, \text{R.E.}, \text{H}_3\text{BO}_3$               | 146 |
| 5.5. Low Temperature TL of $\text{Sr}_3\text{Al}_2\text{O}_6:\text{Eu}^{3+}$ (1%), $\text{X}^{3+}$ phosphors               | 150 |
| 5.6. References                                                                                                            | 154 |
| 6 Conclusions                                                                                                              | 157 |
| Scope and Future Work                                                                                                      | 161 |