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Phosphate Phosphors for Solid-State Lighting

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Preface

The theme of luminescence and phosphors has assumed ever more significance in the overall scheme of scientific progress. This book is aimed at providing a sound introduction to the phosphate phosphor for undergraduate and postgraduate students. I hope that it will also be of value to teachers of these courses. The reader will find a fairly comprehensive bibliography for further investigation.

The luminescent materials known as phosphors convert energy into electromagnetic radiation, usually in the visible energy range. Phosphors are solid luminescent materials that emit photons when excited by an external energy source. Luminescence continues to play a major technological role for mankind. Solid-state luminescence is now set to significantly displace gas discharge luminescence in many areas, in much the same way as gas discharges have already displaced tungsten filament incandescence. Almost all modern phosphors are synthesized by solid-state reactions at high temperatures. Updated versions of these techniques are presented in this book along with other techniques such as sol–gel and combustion that have been developed over the past few decades. In the domain of lighting devices, from the first lamp made by Edison to the compact fluorescent lamp used everywhere today, progress and improvement are obvious. However, there is a need to continue research in this field because excitation sources have changed and it is known that a good phosphor for electronic or ultraviolet excitation is not necessarily a good choice for excitation in vacuum ultraviolet (VUV). Till date, in order to produce light with a fluorescent lamp it was necessary to put mercury inside the lamp to generate ultraviolet photons at $\lambda = 254$ nm. These would subsequently excite the phosphor-coated inner surface of the lamp. However, in the near future, it will be mandatory to replace/reduce the use of mercury in lighting devices, because mercury is very harmful for the environment.

The past few decades have seen spectacular developments in research on luminescence. There has been phenomenal growth in the subject and significant progress has been made. Rare earth ion-activated phosphors have numerous applications in the display, lighting, and medical industries. In recent years, the luminescent properties of phosphate materials have been widely investigated for their many advantages, such as excellent thermal and chemical stability, and the development of optical devices based on rare earth (RE) ion-doped materials has proven to be one of the most interesting fields of research. In this context, phosphates are investigated because of their low cost, their high stability for use in lamp applications, and their important crystallographic possibilities with regard to the accommodation of luminescent ions.

Phosphate structures are generally rigid, resistant to chemical attack, and (when anhydrous) insoluble and thermally stable. This leads to some applications as nuclear waste immobilization hosts or negative thermal expansion materials. Phosphate anions do not absorb significantly in the UV-visible region and so solid phosphates can also find use as optical materials such as glasses, phosphors, nonlinear media, and lasers. Solid phosphates constitute many minerals, notably apatites, which are also found in living organisms as rigid components such as bones and teeth.

Considerable improvement in the field of luminescent materials has been made by the introduction of rare earth ions as activators. These ions possess unique optical behavior when doped into materials and have paved the way for the development of optical amplifiers and phosphors. The optical value of these ions results from the electronic transitions occurring within the partially filled 4f energy shell of the lanthanide series. Rare earth-activated alkaline phosphate-based compounds are of interest due to their unusual stability and useful luminescent properties. They are used for different applications such as phosphors for lamps, color TV screens, long lasting devices, laser hosts, scintillators, and pigments.

The energy transfer phenomenon has been studied extensively in inorganic phosphors, crystals, solutions, and glasses. Hence, in order to contribute to such knowledge, an attempt has been made in this book to consider efficient phosphors based on rare earth-activated phosphates, to study their luminescence properties, and to explore potential new materials and applications. These phosphors are synthesized using low-cost and time-saving synthesis methods, such as wet chemical synthesis and combustion synthesis. One of the objectives of the book is to better understand the mechanism of energy transfer and photoluminescence behavior of some phosphate phosphors. Efforts have been made to identify new phosphate phosphors which could be used for solid state lighting and whose efficiency is either of the same order or better than that of commercial phosphors.

Phosphates are among the most important class of inorganic compounds. As its title indicates, this book is devoted specifically to phosphate phosphors. Each chapter consists of a short general introduction to a specific class, followed by some examples from the literature and by my own work. Solid-state lighting using light-emitting diodes (LED) and phosphor material to generate white light is the current research focus in the lighting industry. Solid-state lighting technology has several advantages over conventional fluorescent lamps, such as reduced power consumption, compactness, efficient light output, and longer lifetime. Solid- state lighting will have its impact in reducing global electricity consumption. White light-emitting diodes can save about 70 % in energy terms and do not require any harmful ingredients, in contrast to conventional light sources, such as incandescence light bulbs and luminescent tubes. White LEDs thus have a great potential to replace the latter and are considered to represent the next generation of solid-state lighting devices. Research on tricolor phosphors suitable for near-ultraviolet/ultraviolet excitation has attracted considerable attention because of their important applications in solid-state lighting. Simple syntheses from easily available starting materials of known phosphate phosphors used as lamp phosphors were also investigated. Possible future developments are pointed out. Studies of mixed cation phosphates are also described. Many mixed anion phosphates are known to chemists and geologists. However, no luminescence measurements are available on these halophosphate and orthophosphate materials.

I have provided the exact formulas for calculations and conditions required to make all of the phosphors known at the time of writing. Each formula is the result of many hours of experimentation to optimize the final phosphor composition. I have retained much of the material presented in the book because I believe one should know what the history of any given subject entails. The last part is organized in some cases with the structure of an academic paper, that is, with an experimental part and a results and discussion section. I think this is a good choice since not only "general" data are presented, but specific procedures to prepare the described compounds, adding to the "fundamental" knowledge are also presented. Hence, the present book is both a review of a specific theme and a preparative manual. I have enjoyed preparing this book and hope that you find reading it both profitable and enlightening.