Determination of Contaminants in Rare Earth Materials by Prompt Gamma Activation Analysis (PGAA)*

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Prompt gamma activation analysis (PGAA) has been used to detect and quantify impurities in rare earth (RE) oxides. The analytical results are discussed with respect to the importance of having a thorough identification and understanding of contaminant elements in these compounds regarding the function of the materials in their various applications. Also, the importance of using PGAA to analyze materials in support of other physico-chemical studies of the materials is discussed, including the study of extremely low concentrations of ions – such as the rare earth ions themselves – in bulk material matrices.

The rare earth (RE) elements consist of those elements located in the 4*f* block of elements in the Periodic Table. Both the metals and their compounds are useful for an extremely wide variety of applications in chemistry and materials science, including applications that are dependent on both the metals' chemical and physical properties and their ability to form compounds and complexes. Their uses include hydrogen storage ("hydrogen sponges"), alloys, electronics, glass, ceramic pigments, and special alloys. The rare earth compounds, with the elements exhibiting several oxidation states, find uses as catalysts, phosphors, laser materials, and other materials that make use of their magnetic properties. Europium, for example, is used in conjunction with yttrium as color television phosphors[1,2] and as a dopant activator in nanoparticles for potential use in biochip-based analyses.[3] Europium chelates, cryptates, and other complexes with organic molecules have had their fluorescence properties exploited for use in distance measurements in biomolecules,[4] protein array applications,[5] fluoroimmunoassays,[6] and protein-protein interaction studies.[7] Materials science applications of europium also include silica-based matrix materials that make use of the fluorescent properties of europium(III) ions.[8] Other applications of rare earth metal ions include the use of samarium for crystal lattice structural studies,[9] yttrium and other rare earth ions for the syntheses of ferrite materials for use in recording media and microwave devices,[10,11] and divalent samarium in organic and polymer syntheses.[12] The use of the luminescent properties of rare earth metal ions is also incorporated into other devices such as chemical sensors, waveguides, and lasers.[13,14]

Neutron induced Prompt Gamma Activation Analysis (PGAA) is a non-destructive, self-calibrating, radioanalytical method capable of simultaneously identifying nearly the entire Periodic Table. It exploits the prompt capture gamma rays themselves, while Neutron Activation Analysis (NAA) utilizes the delayed gamma rays from the radioactive daughter nucleus. PGAA is thus able to detect every element in the Periodic Table from hydrogen through uranium. The method has been applied to materials science, chemistry, geology, mining, archaeology, environment, food analysis, medicine and other areas. Development of high flux neutron generators and a new analytical PGAA database make it possible to apply PGAA/NAA techniques without requiring a nuclear reactor. The nuclear reactions to form the gamma ray lines are independent of the physical form of the sample being analyzed, thus allowing the elemental composition of solids, liquids, and gases to be obtained. Also, the technique allows for the non-destructive analyses of samples with no prior chemical or other type of physical or experimental preparation.

The present report describes the application of PGAA to the analysis and determination of contaminants in rare earth oxides of europium, erbium, gadolinium and other rare earth metal ion-based materials for which total characterization data, including that of trace contaminants, are often required. The technique also is discussed with respect to its use in monitoring trace amounts of elements used in the syntheses and processing of other materials that use such rare earths as precursor materials or as the desired final product.

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