Synthesis of alumina aerogels using aluminum can precursors and recovered rare earth elements from fluorescent lamp waste for photonic applications.

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Thematic Area: Materials chemistry.

Keywords: Circular Economy, Rare Earth Elements, Alumina Aerogel

The circular economy, aligned with scientific advancements, opens new possibilities for exploiting resources by transforming waste into valuable new materials, devices, and sensors. With China holding approximately 50% of the world's reserves of rare earth elements (REEs), there is a significant monopoly on their export, impacting their global value. Consequently, alternative methods of obtaining REEs from non-primary sources are essential [1]. This project aims to synthesize a new luminescent material by reusing waste from fluorescent lamps, which contain a significant concentration of REEs [2]. The goal is to create an alumina aerogel matrix, made from recycled beverage aluminum cans, that incorporates REEs extracted from fluorescent lamps waste. To produce the aerogel, we employ an $AlCl_3$ precursor solution obtained by directly dissolving recycled aluminum cans in HCl, thus adhering to circular economy and green chemistry principles. This is followed by a gelation process using propylene oxide and supercritical drying with carbon dioxide (CO_2). To incorporate the rare earth elements from lamp waste into the aerogel, we select a fraction with the highest concentration of REEs, as identified by G. Belardi et al., who utilized sieving to remove contaminants such as potassium oxide (K_2O) and sodium oxide (Na_2O) [2]. Acid leaching, which involves submerging the waste powder in an acidic $AlCl_3$ solution, is employed to extract the REEs. By using our aluminum can-derived precursor in this process, we eliminate the need for a separate acidic solution, enhancing the process's environmental sustainability.

Different aerogel samples with varying amounts of lamp waste were synthesized and characterized by XRD, XRF, FTIR and photoluminescence measurements. Only the sample with the highest concentration of lamp waste exhibited characteristic terbium emission ($^5D_4 \rightarrow {}^7F_J$). The optimal emission results were achieved by exciting the host material, promoting energy transfer to Tb^{3+} and Eu^{3+} extracted from fluorescent lamp waste. The lack of emission in other samples can be correlated to FTIR results, which showed a broad band at ~3460 cm^{-1}, indicating the presence of OH bonds known to suppress REE luminescence. XRD indicated that alumina aerogels crystallize in boehmite structure and a REE crystal structure is formed in the as-synthesised aerogels only for the sample with highest concentration of lamp waste, further corroborating why this sample show optimum photoluminescence. This study demonstrates the potential for converting aluminum can and fluorescent lamps wastes into valuable photonic materials, paving the way for innovative applications in sensing, lighting, and other advanced technologies.

Acknowledgments: The authors thank the Brazilian agencies CAPES (grant 88887.906596/2023-00), CNPq (grant 407747/2022-2) , Sisfoton (grant CNPq 440217/2021-0) and FAPESP (Tematico Fapesp 2021/08111-2).

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