Spectrally tunable Ce^{3+}, Sm^{3+} doped phosphates for adaptive plant growth LEDs illumination

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Modern agriculture faces increasing challenges caused by multiple factors such as climate changes, limited arable land and restricted freshwater resources [1, 2]. To address this factors, alternative farming strategies e. g. indoor or greenhouse planting are becoming essential. As these environments rely on fully controlled growth conditions, precise control of illumination is required to provide optimized condition for plant's growth, blooming and fruiting [2]. Since photosynthesis is a fundamental physiological process for plant organism providing essential biochemical energy, the emitted light must match the photosynthetic action spectrum, which represents the combined effective absorption of all photosynthetic plant pigments participating in that process. In particular, blue light (430-470 nm) and red light (640-670 nm) are important, as they matches the absorption band of chlorophylls [1].

In this study, the $Ca_2Sr(PO_4)_2$ phosphor co-doped with Ce^{3+} and Sm^{3+} is proposed as a candidate material to meet these agricultural lighting requirements. The structural and spectroscopic properties analysis were performed including XRD analysis, emission, excitation and luminescence decay time. The excitation spectrum of the co-doped phosphor exhibits a broad band centered at around 320 nm, corresponding to 4f → 5d transition of Ce^{3+}, and narrow excitation lines with the most intense at around 403 nm, attributed to the $^6H_{5/2} \rightarrow {}^6P_{3/2}$ transition of Sm^{3+} ions. The material demonstrates excitation-dependent emission behavior. Under 266 nm excitation, the emission spectrum is dominated by a broad Ce^{3+} band with a maximum around 380 nm, accompanied by four weaker Sm^{3+} characteristic bands at around 562 nm, 646 nm, 708 nm, and 790 nm, corresponding to the transitions from $^4G_{5/2}$ excited level to ^6H_J levels respectively (J = 5/2, 7/2, 9/2, 11/2, 13/2). In contrast, under 360 nm excitation emission is characterized by inverted blue-to-red intensity ratio. The Ce^{3+} broad band is weaker with maximum at around 410 nm, while Sm^{3+} emission become dominant and possess fine structure, as a result of Sm^{3+} multiple occupation sites in the crystal structure. Finally, the potential applicability of the Ce^{3+}, Sm^{3+} co-doped phosphor in agricultural lighting systems is evaluated.

[1] Khan S. U., Alam O., Gul S., Li S., Fan Y., Saud S., Fahad S., Lu K., Ur Rahman T., Hemat M. and Nawaz T. (2025) Discover Sustainability, 6, 1284, 1–14.
[2] Wang L., Norford L., Arkin A., Niu G., Valle de Souza S., Zahid A., Shih P. M., Piette M. A. and Ganapathysubramanian B. (2025) npj Science of Plants, 1, 5, 1–11.

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