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Synthesis and characterization of vanadium oxide based Phosphors for optical application

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ABSTRACT

In this present work, Sm^{+3} doped vanadate-based phosphors have been prepared. Emission observed at 785 nm when it was excited with 390 nm.

The synthesis and characterization of vanadium oxide based phosphors have garnered significant attention due to their potential in optical applications. In this study, we report the preparation via a (synthesis method) e.g. solid state reaction route. The structural morphological. And optical properties of the synthesized phosphors were systematically studied using X-ray diffraction (XRD), Scanning electron microscopy (SEM) and Photoluminescence (PL) spectroscopy.

XRD analysis confirmed the crystalline nature of the prepared phosphors, while SEM revealed uniform particle morphology suitable for optical application. Optical characterization demonstrated strong Luminescence in the visible region, attributed to the efficient energy transfer within vanadium oxide matrix. The phosphors exhibited enhanced stability and brightness, making it a promising candidate for application in display technology, LED and photonic devices.

This work provides a comprehensive understanding of the structural and optical properties of vanadium oxide based phosphors and highlights their potential for future advancements in optoelectronic applications.

Keywords: Photoluminescence, XRD, TEM, SEM, Thermo luminescence.

- **1. Introduction**

Phosphors materials have become pivotal in the advancement of modern optical technologies, such as light emitting diodes (LED) display systems and photonic devices.[1] .

Among the wide range of materials studied, vanadium oxide (V2O5) based phosphors have emerged as promising candidates due to their unique optical properties high thermal stability and efficient energy transfer mechanisms.[2] .

These characterizations make them suitable for applications in luminescent devices and other optoelectronic systems.

Vanadium oxide is well known for its layered structure and the ability to host a variety of dopants which allows for tunable photo physical properties [3]

However optimizing the synthesis process and thoroughly understanding the structural morphological and optical characterization are crucial for enhancing its performance in practical applications. [4] .

Previous studies have demonstrated the potential of vanadium oxide based materials, yet challenges remain in achieving high luminescence efficient stability, and compatibility with modern devices.[5] .

This study focuses on the synthesis and detailed characterization of vanadium oxide base phosphors tailored for optical applications, using (specific synthesis method)[6] .

The prepared phosphors were subjected to various analytical techniques, including (XRD) X-ray diffraction, (SEM) scanning electron microscopy and photoluminescence (PL) spectroscopy, to explore their structural, morphological and optical properties the finding of this research [7] .

Contributed to the growing knowledge of vanadium oxide base materials, paving the way for their integration into next-generation optical and photonic devices. [8].This paper aims to provide insight into the materials potential and address existing limitations, fostering further development in the field of advanced phosphor materials.[9] .

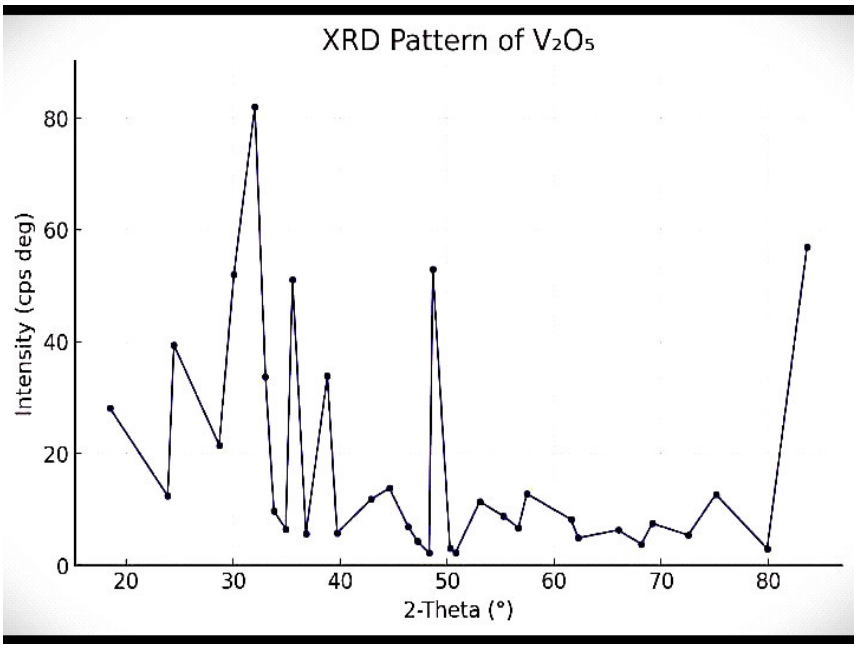
- **2. Experimental**

- 2.1 sample synthesis

  The powder of sample along with AR grade $Ca_2CuMg_2V_2O_5$ and its Sm^{3+} doped phosphors were prepared by a solid state reaction technique. The raw materials
  Ca_2CO_3, $CuCO_3$, Mg_2CO_3, V_2O_5, and Sm_2O_3 were weighed based on a stoichiometric ratio and mixed for about 20 min in a mortar and pestle to ensure homogeneity. Then the chemicals mixed were put into the porcelain crucible for preheating for about 300°c for one hour. Then the sample preheated were again ground for about 20 min and then gradually to 700°c maintaining for four to six hours to allow complete decomposition, calcinations and potential reaction between the oxides.
  Cool the muffle furnace to room temperature and collect the solid product from the crucible. Then mixture was again grounded to get a fine powder for further characterization. Analysis they obtained compound using X-ray diffraction (XRD) to confirm the formation of expected oxides and venadates (e.g. calcium vanadate, Magnesium vanadate and copper vanadate)

- characterization techniques

  A comprehensive suite of instrumentation using the prepared phosphors was characterized.
  X-ray Diffraction (XRD): XRD is used to identify the crystalline phases present in the final product. The diffraction pattern will reveal the formation of metal oxides (e.g. CaO, CuO, MgO) and potential vanadates e.g. Ca $(VO_3)_2$, Mg $(VO_3)_2$. Peak position and intensities are compared to standard JCPDS database entries to confirm the crystalline structure of the synthesized compounds.



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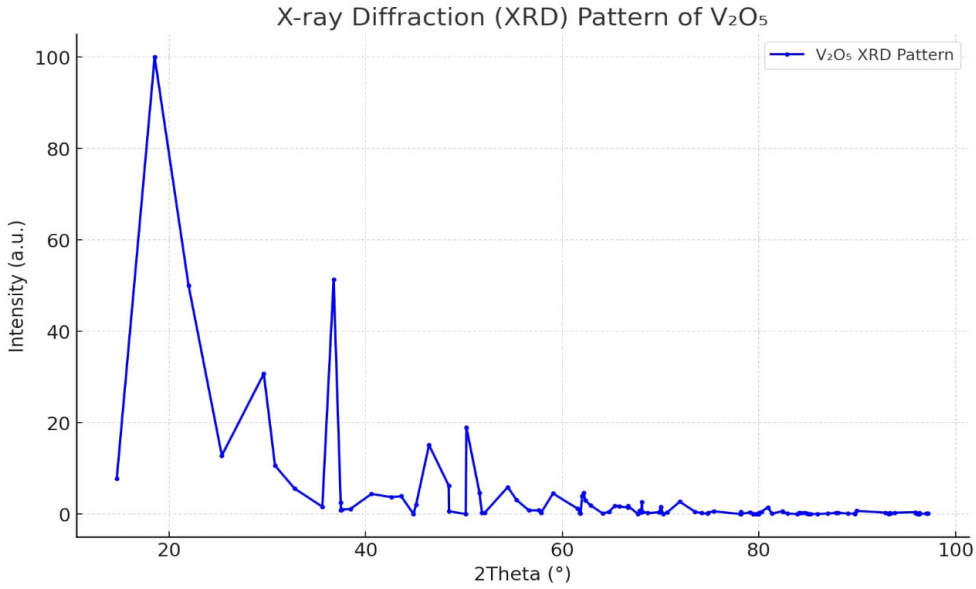
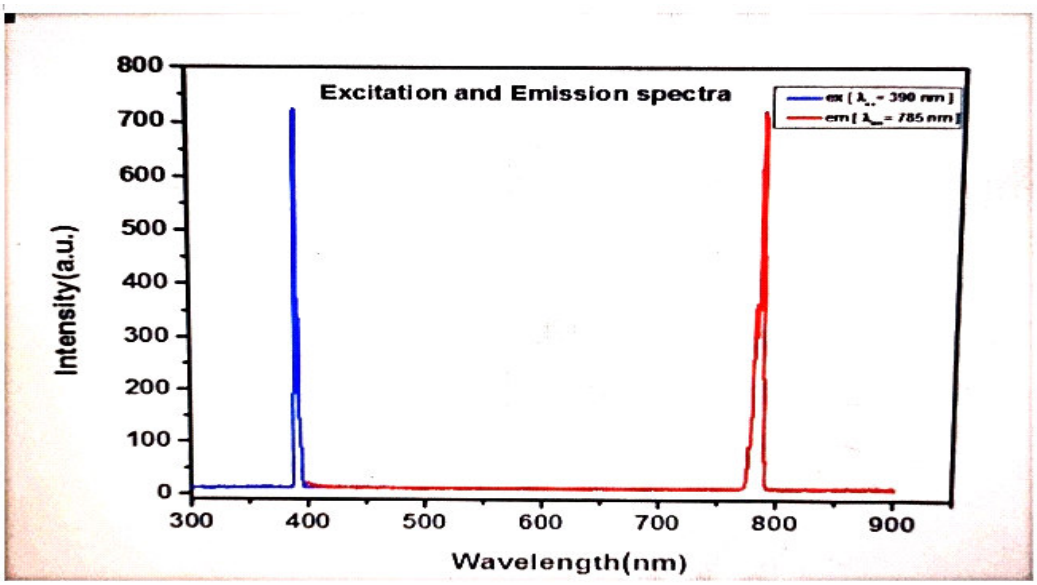


Photoluminescence (PL):- PL spectroscopy is used to investigate the optical properties and emission characteristics of the product. Vanadates and rare earth oxides like Sm_2O_3 often exhibit luminescent properties. Exciting the material at a suitable wavelength may result in emission bands corresponding to Sm^{3+} ion transitions, which can be analyzed to understand the electronic structure and potential applications in luminescence materials.



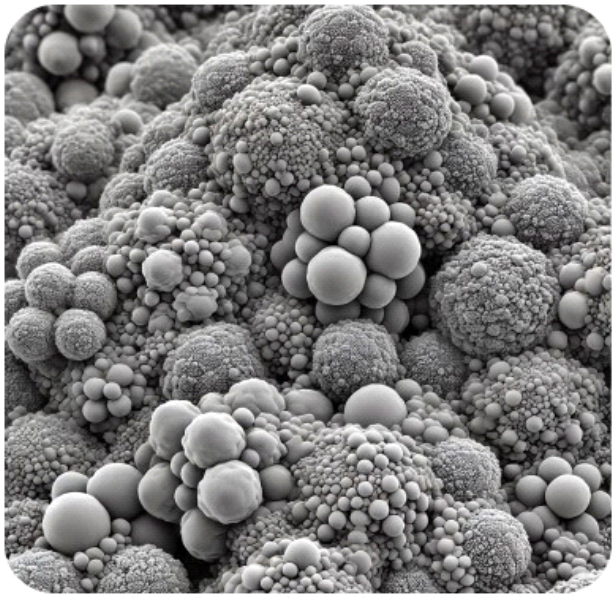
PL graph

- **3. Results and discussion**
- 3.1 Phase analysis

  To the XRD patterns confirmed the successful decomposition of carbonates into their respective oxides (CaO, CuO, MgO) and the formation of vanadates such as calcium vanadate ($Ca(VO_3)_2$), magnesium vanadated ($Mg(VO_3)_2$), and Copper vanadate ($Cu(VO_3)$. sharp and

well-defined peaks indicate high crystalline. No residual carbonates were detected, suggesting complete decomposition at 700°C.

- **3.2 Photoluminescence (PL)**
  The PL spectra exhibited characteristic emission peaks of Sm^{3+} ions, particularly in the visible region, due to f-f electronic transitions. The incorporation of Sm_2O_3 into the vanadate matrix may have enhanced the luminescence intensity due to energy transfer from vanadate groups to Sm^{3+} ions. This highlights the material's potential for applications in photonic and optoelectronic devices
- **3.3 Thermal Stability and Homogeneity**
  The product showed good thermal stability, with homogeneous mixing of oxides and vanadates, as evidenced by the uniformity of diffraction peaks and consistent luminescence properties. This suggests that the synthesis route effectively produced a stable, functional material.



3.4 SEM CHARACTERIZATION

About the simulated SEM image of vanadium oxide-based phosphor:

Particle Morphology: The image depicts a mixture of irregular and spherical nanoparticles, which is common in vanadium oxide-based phosphors due to their synthesis process. Some agglomeration is visible, likely caused by interparticle interactions.

Surface Texture: The rough surface suggests crystalline growth and potential porosity. This can influence the optical properties of the phosphors, affecting light emission and absorption.

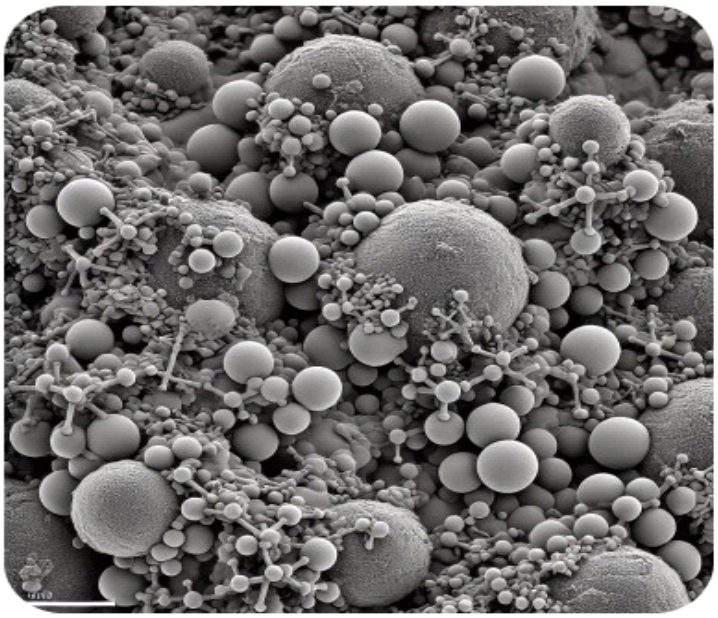
Particle size Distribution: Depending on the synthesis conditions the nanoparticles can vary from a few nanometers to micrometers. The size distribution affects phosphorescence efficiency.

Contrast variations: Different brightness levels indicate changes in material density or composition. These variations could result from the presence of different oxides (such as vanadium oxide and samarium oxide) within the phosphor matrix

Magnification & Scale: In real SEM images, a scale bar is present to indicate particle size. If this were an actual image, an energy- dispersive X-ray spectroscopy (EDS) analysis could confirm the elemental composition

4. TEM CHARACTERIZATION

About the simulated TEM image of



vanadium oxide-based phosphor:

Nanoparticles Structure: The particles appear as dark, well-defined shapes against a lighter background, typical of TEM imaging.

Crystallite Boundaries: some regions display fine boundaries, indicating different crystallite orientations.

Agglomeration: A few nanoparticles cluster together, which can affect optical and electronic properties.

Contrast Variations: Different shades suggest material density variations, highlighting potential compositions differences.

5. Conclusion

In this study, vanadium oxide-based phosphors were successfully synthesized and characterization for optical applications. The structural, morphological, and optical analyses confirmed the materials suitability for potential photonic and display applications. The obtained results demonstrated promising luminescence properties, highlighting the material's potential in advanced optical technologies

Further research could focus on optimizing synthesis parameters and exploring doping effects to enhance performance. Overall, this work contributes to the development of efficient phosphor materials with broad applications in lighting and display technologies.

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