Synthesis, Characterisation and Property Evaluation of excess and deficient MgO in $MgO.Al_2O_3$ Spinel

Abstract

Refractory materials play a vital role in high-temperature industrial processes, especially in the steelmaking industry, where the durability and efficiency of steel ladles depend significantly on the performance of the refractory linings. Among various refractory compounds, magnesium aluminate spinel ($MgAl_2O_4$) stands out due to its high melting point, excellent chemical inertness, superior thermal shock resistance, and mechanical strength at elevated temperatures. These unique properties make spinel a promising candidate for applications demanding prolonged exposure to harsh environments. This research focuses on the synthesis, characterization, and property evaluation of magnesium aluminate spinels with excess and deficient MgO compositions. By tailoring the MgO content in the spinel structure, it is possible to influence key properties such as thermal stability, corrosion resistance, and mechanical integrity, thereby extending the lifespan of refractory linings in steel ladles and other high-temperature equipment. The spinel materials will be synthesized through both sol-gel and solid-state processing methods, allowing comparative analysis of the microstructure and property variations arising from different fabrication routes. The study will undertake comprehensive characterization to evaluate the thermal, mechanical, physical, and chemical properties of the synthesized spinel materials. Thermal stability and decomposition behavior will be assessed using Differential Thermal Analysis (DTA) and Thermogravimetric Analysis (TGA). Microstructural features will be explored through Scanning Electron Microscopy (SEM), Field Emission SEM (FESEM), and High-Resolution Transmission Electron Microscopy (HRTEM), providing insights into particle morphology, grain boundaries, and phase distribution. Bond characteristics will be determined using Fourier Transform Infrared Spectroscopy (FTIR), while X-Ray Diffraction (XRD) will facilitate phase identification and crystal structure analysis. Mechanical properties, including the strength of the compacted mass, will be tested to gauge the material's capability to withstand mechanical stresses during service. High-temperature performance parameters such as softening temperature and refractoriness will also be measured to ensure suitability for demanding applications in steelmaking and related industries. The outcomes of this research are expected to contribute to the development of high-performance refractory spinel materials with optimized MgO compositions, enhancing their resistance to corrosion and thermal degradation. This, in turn, can lead to increased efficiency, reduced maintenance costs, and improved sustainability in steel production processes. Moreover, the findings will provide valuable insights for the design and fabrication of advanced ceramic materials with tailored properties for broader high-temperature applications. Through systematic synthesis and rigorous evaluation, this work aims to bridge existing knowledge gaps in the field of spinel refractories, offering practical solutions for industries where material performance at extreme conditions is crucial.

Keywords: Spinel, Morphology, Thermal analysis, Phase analysis, Crystallisation.