Hydrogen Storage in LaNi5 and TiFe Powders: A Literature Review

## Introduction

Hydrogen storage in LaNi5 and TiFe powders represents a pivotal area of research within the realm of sustainable energy solutions. These intermetallic compounds are particularly significant due to their capacity to absorb and release hydrogen efficiently, which is crucial for applications ranging from fuel cells to portable power systems. This literature review aims to explore recent studies on the hydrogen storage capabilities of LaNi5 and TiFe, focusing on thermodiffusion phenomena and technical properties that influence their performance. Understanding the intricate mechanisms of hydrogen absorption and desorption in these materials can lead to advancements in energy storage technologies, enhancing their practical utility. Furthermore, evaluating the mechanical and thermal properties of these powders under operational conditions will provide insights into their durability and efficiency, guiding future innovations in hydrogen storage systems.

## Hydrogen Storage Capabilities

Recent studies have significantly advanced our understanding of the hydrogen storage capabilities of LaNi5 and TiFe powders, highlighting their potential for energy applications. According to Liu et al., TiFe alloys, including TiFeH2, demonstrate effective hydrogen storage characteristics, making them suitable for use in various applications, such as submarine hydrogen tanks and fuel cell systems (Liu et al., 2023). Additionally, research by Lin et al. indicates that the particle size and porosity of LaNi5 significantly impact its hydrogen absorption performance, with smaller particles and higher porosity enhancing the absorption reaction due to increased surface area and thermal diffusion (Lin et al., 2019). The integration of rare earth elements such as La and Ce with TiFe has been shown to improve hydrogen absorption rates and storage capacity, as demonstrated by Alam et al., who explored mechanical milling techniques to enhance these properties (Alam et al., 2024). These findings underscore the technological advancements in optimizing LaNi5 and TiFe powders for efficient hydrogen storage, paving the way for their broader application in sustainable energy systems.

The hydrogen absorption and desorption properties of LaNi5 and TiFe powders exhibit distinct differences that influence their respective efficiencies and capacities. LaNi5 is characterized by its rapid hydrogen absorption kinetics, which is facilitated by its single-phase structure and high surface activity, allowing it to store hydrogen at pressures as low as 2 MPa (Jurczyk & Nowak, 2021). In contrast, TiFe powders require an activation process to achieve optimal hydrogen absorption, yet they offer the advantage of greater hydrogen storage capacity under higher pressures, making them suitable for applications requiring robust energy storage (Liu et al., 2023). Furthermore, recent research suggests that the incorporation of rare earth elements, such as lanthanum in TiFe alloys, can enhance hydrogen absorption rates and improve overall storage efficiency, thereby bridging some performance gaps between these materials (Alam et al., 2024). This comparative analysis underscores the importance of material choice and modification in optimizing hydrogen storage systems for various technological applications.

## Thermal Diffusivity

Thermodiffusion plays a crucial role in the hydrogen storage performance of LaNi5 and TiFe powders, primarily by influencing the kinetics of hydrogen absorption and desorption. According to Lin et al., the particle size and porosity of LaNi5 are integral factors that enhance its thermal diffusion capabilities, thereby facilitating more efficient hydrogen absorption (Lin et al., 2019). The thermal properties of these materials are vital as they determine the rate at which hydrogen can be absorbed and released, impacting the overall efficiency of the storage system. Additionally, Liu et al. highlight that modifications in thermal conductivity can lead to improved hydrogen uptake, especially in TiFe alloys, which often require an activation process to optimize their hydrogen storage potential (Liu et al., 2023). Understanding these thermal characteristics is essential for developing advanced hydrogen storage systems that meet the demands of various energy applications, ensuring both efficiency and reliability.

Recent experimental investigations into the thermal diffusivity of LaNi5 and TiFe powders have provided valuable insights into their practical applications for hydrogen storage. For instance, Lin et al. have demonstrated that the thermal diffusion properties of LaNi5 are significantly influenced by particle size and porosity, enhancing hydrogen absorption efficiency through improved heat transfer (Lin et al., 2019). Similarly, research conducted by Liu et al. highlights the importance of optimizing thermal conductivity in TiFe alloys, which can enhance hydrogen uptake by improving the kinetics of hydrogen absorption and desorption processes (Liu et al., 2023). These findings suggest that manipulating thermal properties could be a strategic approach to maximizing the efficiency of hydrogen storage systems, particularly in applications where rapid hydrogen uptake and release are critical. Consequently, such advancements in understanding thermal diffusivity may lead to the development of more reliable and efficient hydrogen storage solutions, meeting the increasing demands of sustainable energy technologies.

## Mechanical Properties

The mechanical properties of LaNi5 and TiFe powders are critical in determining their effectiveness and reliability for hydrogen storage applications. Structural stability is a pivotal factor, as these materials must withstand cyclic hydrogen absorption and desorption without significant degradation. According to Jurczyk and Nowak, the mechanical alloying of TiFe with LaNi5 enhances durability, suggesting that alloying techniques can improve the structural integrity of hydrogen storage materials (Jurczyk & Nowak, 2021). Furthermore, Łodziana notes that the surface properties and exposure of La in LaNi5 contribute to its mechanical stability, impacting the compound's overall hydrogen storage performance (Łodziana, 2021). Understanding these mechanical characteristics is essential for optimizing the design and application of LaNi5 and TiFe powders, ensuring they can maintain performance under various operational conditions over extended periods.

## Conclusion

This literature review has provided an in-depth examination of the hydrogen storage capabilities, thermal diffusivity, and mechanical properties of LaNi5 and TiFe powders. The studies reviewed highlight the distinct advantages of these materials, such as LaNi5's rapid hydrogen absorption kinetics and TiFe's significant storage capacity under high-pressure conditions, making them suitable for diverse energy applications. The role of thermodiffusion is pivotal in optimizing hydrogen absorption and release, with particle size and porosity being key factors affecting thermal properties. Additionally, the mechanical integrity of these powders is essential for their long-term reliability, with alloying techniques showing promise in enhancing structural stability. Future research should focus on refining these materials' properties through innovative engineering approaches to maximize their potential in sustainable energy systems, addressing challenges such as degradation and efficiency under varying operational conditions.