



Innovative surface modification of TiH₂ to fabricate aluminum foam with enhanced mechanical properties



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ABSTRACT

In this paper, an innovative modification method for TiH₂ foaming agent was presented and Boron phenolic resin (BPR)-TiH₂ foaming agent was successfully prepared for the first time. The result shows that the BPR-TiH₂ foaming agent has an excellent slow-release property which can last longer than 120 s. And Al foam with uniform pore dispersion and high compressive strength was also successfully prepared by melt foaming method using BPR-TiH₂ as foaming agent. What's more, Al foam prepared with BPR-TiH₂ foaming agent (BPR-TiH₂ Al foam) was better than Al foam prepared with TiH₂ foaming agent in terms of compressive strength and energy absorption, the compressive strength and energy absorption of Al foam prepared with BPR-TiH₂ foaming agent are 4.6 MPa and 3.15×10^6 J/m³ (compression strain was 55%), which are 324% and 123% higher than that of TiH₂ foaming agent respectively, due to the uniform pore dispersion.

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1. Introduction

The lightweight structure, high energy absorption capacity and large specific surface area make aluminum foam widely applied in many industrial areas, such as construction, automobile, aerospace, etc. Nowadays, melt foaming method is the primary method for the fabrication of Al foam in industrial production, because of its low cost, simple operation and manageable [1–4]. However, the decomposition temperature of TiH₂ foaming agent is low and the slow-release time is less than 10 s in foaming test [1–3], which is harmful to the uniform pore dispersion, mechanical properties and energy absorption characteristic of Al foam. Therefore, it is necessary to improve the slow-release property of TiH₂ foaming agent.

Nowadays, many researches have been conducted to improve the thermal properties of TiH₂ foaming agent. Ma et al. [5–7] indicated that the surface oxidation treatment of TiH₂ could prevent it from decomposing at low temperatures, but the decrease of H content in TiH₂ may degrade the blowing capacity of TiH₂. Abolfazl et al. [8] treated TiH₂ by electroplating nickel-plating, Ni layer prevent TiH₂ from pyrolysing in the early stages because Ni layer has a high-temperature mechanism. Nevertheless, the Ni layer is unstable and the electroless nickel-plating is very complicated and hard

to control. Fang et al. [9–11] confirmed that TiH₂ coated with SiO₂/Al₂O₃ could prolong slow-release time effectively, but the process of coating SiO₂/Al₂O₃ is complex and difficult to control. In general, the methods mentioned above exist some problems, such as the decrease of blowing capacity, complexity and uncontrollability, especially, the improvement of the decomposition characteristics of TiH₂ is very limited. Therefore, it has a practical significance to develop a new route to improve the decomposition properties of TiH₂ effectively.

Boron phenolic resin (BPR) is a kind of modified phenolic resin having many superior properties, for instance, thermal stability, heat insulation property, thermal oxidation resistance and fire resistance and so on. As a consequence, BPR was considered to be a preferred ablative resistance and fire retardant material in the thermal protection system [12–15]. Over the past decade, great attention has been paid to the synthesis and properties of BPR, whereas the application of BPR was not fully studied. Therefore, we prepared BPR-TiH₂ foaming agent, with long sustain-release time, for the first time, and studied its thermal properties. Meanwhile, Al foam which used the modified BPR-TiH₂ as foaming agent was also successfully prepared and its compressive property and energy absorption capacity were investigated.

2. Experiments

Boron phenolic resin (BPR)-TiH₂ foaming agent was prepared using BPR (Bengbu Tianyu, 99.7 wt% in purity), TiH₂ powders

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(Changsha Tianjiu, 99.7 wt% in purity, $\leq 35 \mu\text{m}$ in average) and alcohol (Chengdu Kelong, 99.7 wt% in purity) by a Physical adsorption method. First of all, 20 g TiH_2 powders were added to an alcohol solution (100 g/L raw BPR), then stirred it for 1 h with a magnetic stirrer. After that, TiH_2 powders were dried in a drying cabinet at 80°C and ground in a mortar. Finally, TiH_2 was cured at 120°C for 1 h and then cured at 180°C for 30 min in a muffle furnace. In order to test the modifying performance of BPR- TiH_2 , the Al foam was prepared with 1% TiH_2 or BPR- TiH_2 as foaming agent, 2% calcium as tackifier, by a melt foaming method at 700°C .

The surface structure of TiH_2 powders before and after modified by BPR was investigated by Scanning Electron Microscopy (SEM, XL30SFEG) equipped with an Energy-Dispersive Spectrometer (EDS). The Fourier Transform Infrared (FTIR, Nicolet iS10) spectroscopy was used to determine the bonding changing of BPR- TiH_2 powders, and BPR- TiH_2 powders were heat treated for 10 min. Pyrolysis properties of TiH_2 and BPR- TiH_2 were tested by Differential Scanning Calorimetry (DSC, STA449F3) from room temperature to 1000°C at a heating rate of $10^\circ\text{C}/\text{min}$ under argon

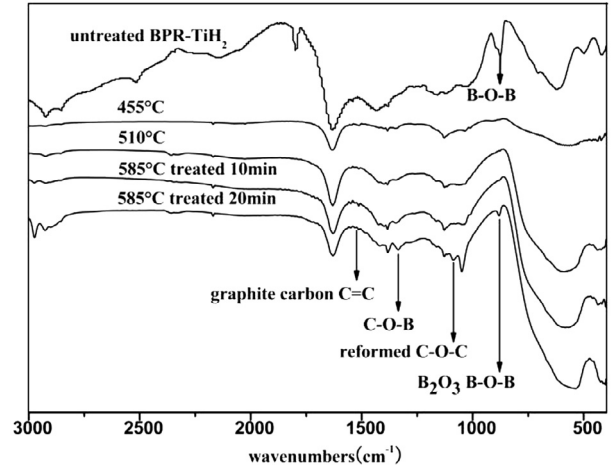


Fig. 3. FTIR of heat treated BPR- TiH_2 .

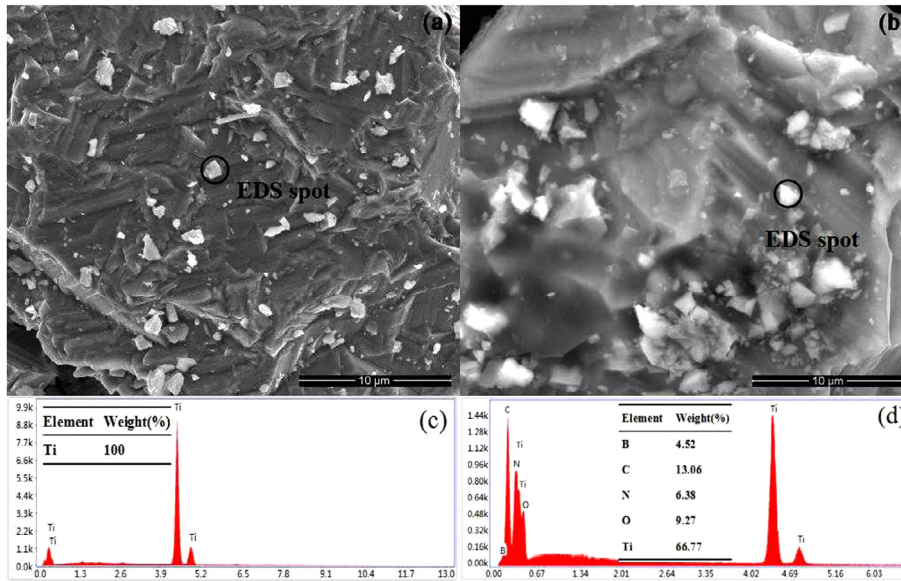


Fig. 1. SEM and EDS images of TiH_2 powders before and after modified by BPR: (a) SEM of TiH_2 ; (b) SEM of BPR- TiH_2 ; (c) EDS of TiH_2 ; (d) EDS of BPR- TiH_2 .

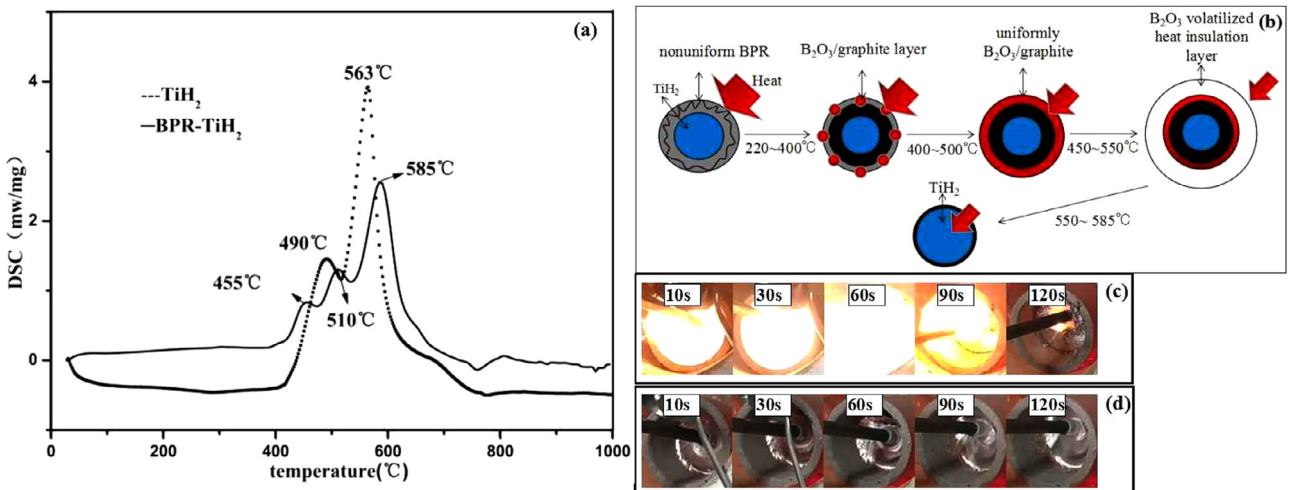


Fig. 2. DSC curves and illustration of BPR- TiH_2 and TiH_2 and their foaming process: (a) DSC curves of TiH_2 and BPR- TiH_2 ; (b) pyrolysis process illustration of BPR- TiH_2 ; (c) process of TiH_2 adding into Al melt; (d) process of BPR- TiH_2 adding into Al melt.

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