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Effect of interstitial boron and hydrogenation on the magnetocaloric properties of $La_{0.8}Ce_{0.2}Fe_{11.4}Si_{1.6}$ compound

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Abstract

This study explores how boron doping influences hydrogen absorption and magnetocaloric properties in the $La_{0.8}Ce_{0.2}Fe_{11.4}Si_{1.6}$ (LCFS) compound. While hydrogenation can adjust the Curie temperature (T_C) in magnetocaloric materials, its influence on hysteresis loss remains a challenge. To address this, we synthesized a series of hydride $La_{0.8}Ce_{0.2}Fe_{11.4}Si_{1.6}B_xH_y$ compounds by exposure to the $La_{0.8}Ce_{0.2}Fe_{11.4}Si_{1.6}B_x$ (LCFSB) alloys and analyzed their structure. X-ray diffraction confirmed phase composition, revealing that boron and hydrogen co-doping tunes T_C between 174 and 329 K. The addition of boron and hydrogen significantly diminished the itinerant electron metamagnetic (IEM) transition and increased the slope of the critical field, H_C, while reducing magnetic hysteresis. This preserves a high maximum entropy change, ΔS_M with maximum values of 21.8, 12.6, and 12.1 kg^{-1} K^{-1} under 0–5 T for different compositions. The corresponding effective refrigerant capacity, RCP_{eff} values are 121.3, 154 and 81.2 J kg^{-1} respectively. It was found that the inclusion of boron in the LCFS compound enhanced the absorption of hydrogen. Further, the evaluation of dehydrogenation dynamics revealed that the B doping significantly enhanced the stability of hydrogen and the stable temperature was increased to 250 °C for B doped samples. Finally, these findings demonstrate that boron doping optimizes hydrogen absorption, improves thermal stability, and enhances magnetocaloric performance by mitigating hysteresis losses.

Keywords Magnetocaloric effect · Curie temperature · Itinerant electron metamagnetic (IEM) transition · Magnetic hysteresis · Magnetic entropy change

1 Introduction

In recent years, studies on near room temperature magnetic refrigeration have seen a significant upsurge [1–4]. This cutting-edge cooling technology is designed to supplant conventional refrigeration methods that rely on gas-compression and expansion, and it is particularly noteworthy due to its significant economic advantages. Magnetic refrigeration is a phenomenon that occurs when a magnetic moment system interacts with an external magnetic field, so as to result in either cooling or heating of the system and is directly based on magnetocaloric effect (MCE) [5]. The LCFS material system is low-cost to produce and, as shown earlier, has a significantly high MCE [6–8]. However, a first order itinerant electron metamagnetic (IEM) transition in this material system has been shown to occur at 174 K [7], 177 K [8], and 186 K [9]. It is associated with a large amount of magnetic hysteresis, leading to hysteresis loss which is disadvantageous to the refrigerant capacity. Hence, it is essential to significantly minimize the magnetic hysteresis

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