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MECHANIC PROPERTIES AND MAGNETOCALORIC EFFECTS OF BONDED $La_{0.9}Ce_{0.1}Fe_{11.7-x}Mn_xSi_{1.3}H_{1.8}$

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The bonded $La_{0.9}Ce_{0.1}Fe_{11.7-x}Mn_xSi_{1.3}H_{1.8}$ materials have been prepared by powder metallurgy. The bonded materials, which have better mechanical properties and good magnetocaloric effects, can be more effectively utilized in the magnetic refrigerator.

Keywords: magnetic materials, magnetocaloric effect, powder

I. Introduction

La(Fe,Si)$_{13}$-based alloys have attracted much attention due to their low costs and non-toxic of raw material, and large MCEs compared to other magnetic refrigeration materials such as Gd-Si-Ge[1] and Mn-Fe-P-As[2] compounds.

However, La(Fe,Si)$_{13}$-based alloys are very brittle and not easy shapable. Generally, the mechanical properties of materials getting worse, even becomes powder after hydrogenation. In present work, the bonded $La_{0.9}Ce_{0.1}Fe_{11.7-x}Mn_xSi_{1.3}H_{1.8}$ (x=0.27, 0.29, 0.31, 0.33) are prepared and the mechanical properties and magnetocaloric effects have been investigated.

II. Experimental details

The hydrogen concentration y of $La_{0.9}Ce_{0.1}Fe_{11.7-x}Mn_xSi_{1.3}H_y$ was measured to be ~1.8 by oxygen and nitrogen hydrogen analyzer (LECO ONH-836). The hydride powder was mixed with an epoxy resin adhesive in a proper proportion. Then the mixed powder was pressed into cylindrical pieces of φ10 ×10mm. The crystal structure was measured by X-ray diffraction (XRD), the phase structure of bonded $La_{0.9}Ce_{0.1}Fe_{11.7-x}Mn_xSi_{1.3}H_{1.8}$ is $NaZn_{13}$-type cubic structure with a minor amount of α-Fe as impurity phase. The compression tests were performed by a universal material testing machine. The magnetic properties were measured by vibrating-sample magnetometer (VSM, Lakeshore 7407).

III. Results and Interpretation

Figure 1 shows the compressive stress-strain curve for bonded $La_{0.9}Ce_{0.1}Fe_{11.41}Mn_{0.29}Si_{1.3}H_{1.8}$. The $La_{0.9}Ce_{0.1}Fe_{11.41}Mn_{0.29}Si_{1.3}$ becomes powder after hydrogenation, so the bulk $LaFe_{10.99}Co_{0.91}Si_{1.1}B_{0.2}$, which has been tested in a reciprocating magnetic refrigerator and shows good mechanical and magnetocaloric properties,[3] is used for the compression tests and compared with bonded material. The compressive strength of bulk $LaFe_{10.99}Co_{0.91}Si_{1.1}B_{0.2}$ is about 290 Mpa, and the stress-strain curves drops sharply without further plastic deformation, indicating the characteristic of brittleness for bulk $LaFe_{10.99}Co_{0.91}Si_{1.1}B_{0.2}$. For the bonded $La_{0.9}Ce_{0.1}Fe_{11.41}Mn_{0.29}Si_{1.3}H_{1.8}$, its compressive strength is 332 Mpa, 15% higher than that of bulk $LaFe_{10.99}Co_{0.91}Si_{1.1}B_{0.2}$ compound. Besides, the stress-strain curves of bonded $La_{0.9}Ce_{0.1}Fe_{11.41}Mn_{0.29}Si_{1.3}H_{1.8}$ shows a short yield stage before the maximum compressive strength, this may be the bonded material is porous architecture and thus a strain could be observed due to the densification under stress.

The embedded graph of figure 1 exhibits magnetization isotherms of bonded $La_{0.9}Ce_{0.1}Fe_{11.41}Mn_{0.29}Si_{1.3}H_{1.8}$ near T_C. Studies show that $LaFe_{11.7}Si_{1.3}$ compound exhibits a very large magnetic hysteresis loss of 41 J/kg[4], which would strongly reduce the effective refrigeration capacity. The magnetic hysteresis of bonded $La_{0.9}Ce_{0.1}Fe_{11.41}Mn_{0.29}Si_{1.3}H_{1.8}$ is very small and the value is about 2 J/kg. The reasons could be: (1) the introduction Mn and H atoms weaken the nature of first-order magnetic transition,[4,5] and (2) the internal strain and grain boundaries are partially removed by introducing porosity in bonded materials.[6]

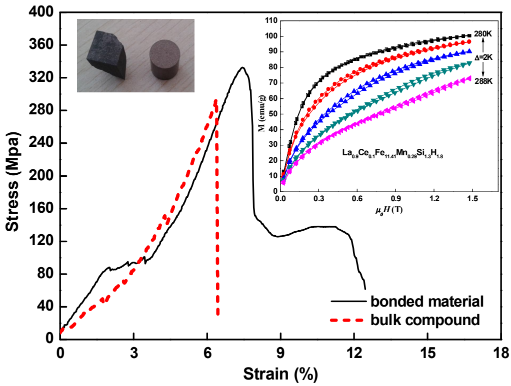

Fig. 1 Compressive stress-strain curves for bonded $La_{0.9}Ce_{0.1}Fe_{11.41}Mn_{0.29}Si_{1.3}H_{1.8}$ in comparison with that of bulk $LaFe_{10.99}Co_{0.91}Si_{1.1}B_{0.2}$; embedded graph is magnetization isotherms of bonded $La_{0.9}Ce_{0.1}Fe_{11.41}Mn_{0.29}Si_{1.3}H_{1.8}$ near T_c

Figure 2 shows the MCEs of bonded $La_{0.9}Ce_{0.1}Fe_{11.7-x}Mn_xSi_{1.3}H_{1.8}$ including (a) isothermal magnetic entropy change (ΔS) and (b) adiabatic temperature change (ΔT_{ad}) under magnetic field change from 0 to 1.5T. For comparison, the MCEs of bulk $LaFe_{10.99}Co_{0.91}Si_{1.1}B_{0.2}$is also included in Fig. 2. With increasing Mn content, the ΔS of bonded $La_{0.9}Ce_{0.1}Fe_{11.7-x}Mn_xSi_{1.3}H_{1.8}$ slightly decreases from 7.7 (x=0.27) to 7.1 J/kgK (x=0.33), but still remains a relatively higher value (> 7 J/kgK) than that of $LaFe_{10.99}Co_{0.91}Si_{1.1}$ (about 5.1 J/kgK at 293K). TheΔT_{ad} of bonded $La_{0.9}Ce_{0.1}Fe_{11.7-x}Mn_xSi_{1.3}H_{1.8}$ is obtained through a direct method for measuring. The results show that with increasing Mn content, the T_C of bonded materials linearly decreases from 287 to 275 K, while the ΔT_{ad} for bonded materials have hardly any change. The ΔT_{ad} of bonded $La_{0.9}Ce_{0.1}Fe_{11.7-x}Mn_xSi_{1.3}H_{1.8}$ (≥2.6 K) is about 17% larger than that of $LaFe_{10.99}Co_{0.91}Si_{1.1}$ (2.2 K at 293 K). Thus, the bonded materials also exhibit good MCEs in a temperature range from ~275 to ~290 K.

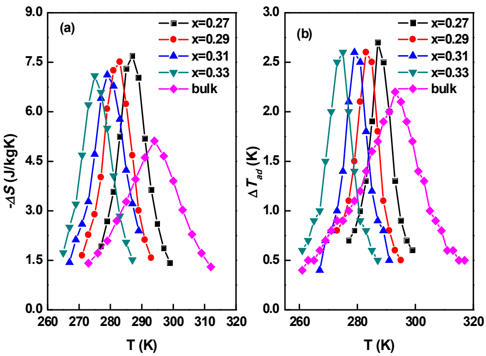

Fig.2 magnetocaloric effects of bonded $La_{0.9}Ce_{0.1}Fe_{11.7-x}Mn_xSi_{1.3}H_{1.8}$ in comparison with those of $LaFe_{10.99}Co_{0.91}Si_{1.1}B_{0.2}$ compound under magnetic field change from 0 to 1.5T

IV. Conclusions

The bonded $La_{0.9}Ce_{0.1}Fe_{11.7-x}Mn_xSi_{1.3}H_{1.8}$materials have been prepared by powder metallurgy. And the bonded material exhibits a better compressive strength of 332 Mpa, about 15% higher than that of bulk $LaFe_{10.99}Co_{0.91}Si_{1.1}B_{0.2}$. And the magnetic hysteresis for the bonded material is very low. By adding Mn atoms, the Curie temperature T_c can be adjusted near the room temperature. With increasing Mn content, the maximal $\Delta S_m$of bonded materials slightly decreases, though, a relatively high value (>7 J/kgK) remains, while the ΔT_{ad} for bonded $La_{0.9}Ce_{0.1}Fe_{11.7-x}Mn_xSi_{1.3}H_{1.8}$ is also maintained a high value (≥2.6 K) compared with $LaFe_{10.99}Co_{0.91}Si_{1.1}B_{0.2}$ compound. Consequently, the bonded materials, which have better mechanical properties and good magnetocaloric effects, can be more effectively utilized in the magnetic refrigerator.

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Склеенные $La_{0.9}Ce_{0.1}Fe_{11.7-x}Mn_xSi_{1.3}H_{1.8}$ материалы были подготовлены методом порошковой металлургии. Склеенные материалы, которые имеют более высокие механические свойства и хорошие эффекты магнетокалорическим, могут быть более эффективно использованы в магнитном холодильнике.

Ключевые слова: магнитные материалы, магнитокалорический эффект, порошок.