P06

異常ネルンスト効果を有する新規熱電材料 Fe_3Al の電磁浮遊法による作製

Preparation of new thermoelectric material Fe_3Al with anomalous Nernst effect by electromagnetic levitation method

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1. Introduction

Thermoelectric conversion is one of the essential technologies for reducing CO_2 emissions through the effective use of waste heat energy[1)]. To increase the efficiency of this thermoelectric conversion technology, materials that exhibit the anomalous Nernst effect are attracting attention[1)]. Because the electric current generates to perpendicular to temperature gradient by the spontaneous magnetization of this type of materials, it is expected to design the compact module structure, to reduce cost, and durability[1)]. Fe_3Al has been reported as a thermoelectric material for the above, which also enables reduction in the use of rare and toxic elements[1)]. In previous studies, Fe_3Al has been fabricated by the CZ method[1)]. For controlling the morphology of the material and the phase selection, the solidification kinetic should be understand. In this research, we focused on the relation between supercooling and microstructure, and the phase selection using an electromagnetic levitation.

2. Experiment

Fe and Al samples of about 1 g in mass were independently levitated using an electromagnetic levitator, and then melted to produce the liquid alloy without container under Ar gas atmosphere. After the complete melting, the levitated sample are cooled by He gas blowing to solidify. The temperature of the samples was measured with a two-color radiation thermometer, which was calibrated by Wien's approximation using the liquidus temperature. The prepared samples were analyzed for formations by X-ray diffraction (XRD).

3. Results and discussion

The temperature history of the electromagnetically levitated Fe-Al sample is shown in **Figure. 1**. The starting materials, Fe and Al, reached a melting point of about 1500°C in the levitated state and completely melted. Subsequent solidification by cooling with He gas at under supercooling ($\Delta T > 150$ K).

The XRD analysis results of the prepared Fe-Al sample are shown in **Figure. 2**. The diffraction patterns of Fe_3Al and FeAl were confirmed. Although α-Fe is expected to be first phase to solidified in the equilibrium, no diffraction pattern of α-Fe, has been found in the obtained sample.

A stereo microscopic photograph of a sample cross section is shown in **Figure. 3**. It was found that the sample had a polycrystalline, and that the crystal domain became larger toward the inside of the sample. It was found that a large crystal domain with a maximum width of about 2 mm was formed near the inner of the sample. Therefore, SEM-EDS analysis was performed at the outer (A) and inner (B) of the sample. The results of the EDS analysis are shown in **Table 1**. Although the grain size at outer (A) and inner (B) parts of the sample are different, it is tuned out that the sample composition is almost uniform: Fe : Al = 79.6(± 0.5) : 20.4(± 0.5) at% at the outer (A) and Fe : Al = 80.1(± 0.6) : 19.9(± 0.6) at% at the inner (B).

These results suggest that the FeAl phase is directly solidified from the undercooled liquid Fe-Al under high supercooling ($\Delta T > 150$ K). Due to the rapid solidification, the compositional separation could be weakened. The monotonous temperature decreases after the recalesce infer the lack of the secondary phase transition would also suggest the FeAl phase formed at a time directly from the liquid. However, the XRD analysis results suggest that Fe_3Al phase formed in some parts of the sample.

Table 1. EDS analysis results at two locations on the sample cross section.

Left : outer (A) (N = 6), Right : inner (B) (N = 5)

Chemical element	Atom%
Fe	79.6 ± 0.5 %
Al	20.4 ± 0.5 %

Chemical element	Atom%
Fe	80.1 ± 0.6 %
Al	19.9 ± 0.6 %

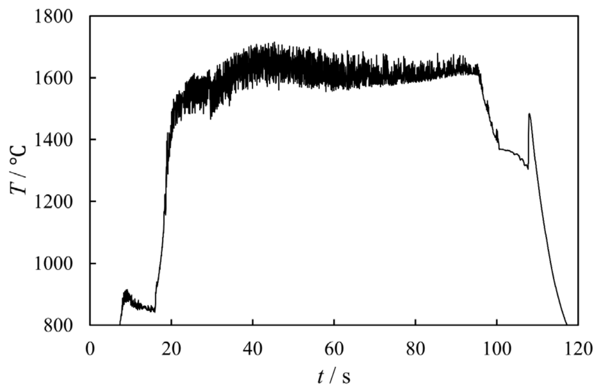

Figure 1. An example of temperature history of Fe-Al sample.

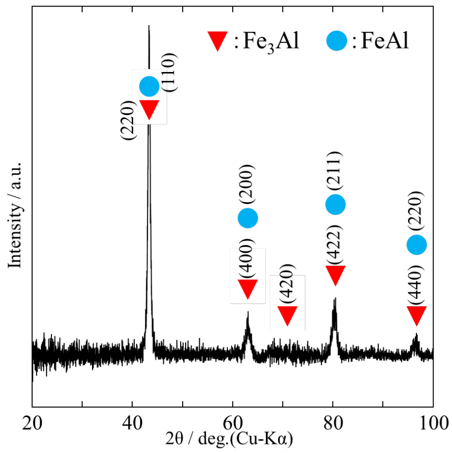

Figure 2. XRD analysis result of Fe-Al sample.

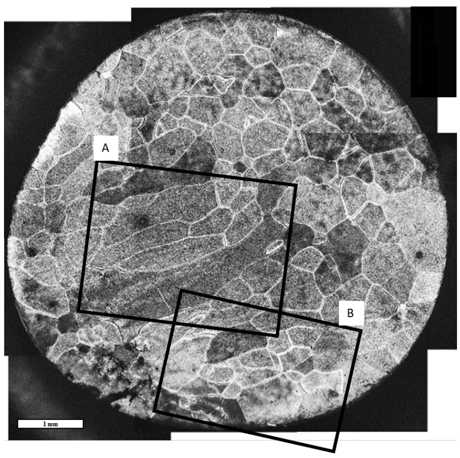

Figure 3. A stereo microscopic photograph.

References

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