Comparative Example 6

In a comparative example 6, a magnetic material was created likewise the example 1 except that it had a composition formula of $Gd_{85}Y_{15}$. As to the magnetic material, the temperature dependence of a magnetization curve was measured. Table 3 shows a result of measurement.

TABLE 1

	T_{peak} (K)	ΔS_{max} (J/kg · K)	½ ΔS_{max} Temperature Range (K)
Comparative Example 1: Gd	295.4	3.58	29.5
Comparative Example 3: $Gd_{70}(Y_{28.5}Zr_{1.5})$	218.9	2.62	40.6
Example 1: $Gd_{99.8}Zr_{0.2}$	293.5	3.31	31.9
Example 3: $Gd_{98.5}Zr_{1.5}$	289.2	3.30	33.5
Example 4: $Gd_{97}Zr_3$	284.4	3.14	35.1
Example 5: $Gd_{93}(Y_{5.5}Zr_{1.5})$	276.3	3.39	34.5
Example 7: $Gd_{93}(Y_4Zr_3)$	275.5	3.20	35.1
Example 8: $Gd_{85}(Y_{12}Zr_3)$	258.0	3.02	36.2

TABLE 2

	T_C (K)	T_{SR} (K)	$T_C - T_{SR}$ (K)
Comparative Example 1: Gd	294.0	230.0	64.0
Comparative Example 2: $Gd_{90}Y_{10}$	274.0	251.0	23.0
Comparative Example 4: $Gd_{97}Y_3$	288.2	239.0	49.2
Comparative Example 5: $Gd_{93}Y_7$	281.1	248.0	33.1
Example 1: $Gd_{99.8}Zr_{0.2}$	293.2	231.5	61.7
Example 2: $Gd_{99.5}Zr_{0.5}$	292.5	234.0	58.5
Example 3: $Gd_{98.5}Zr_{1.5}$	288.0	242.0	46.0
Example 4: $Gd_{97}Zr_3$	283.5	252.0	31.5

TABLE 3

	T_C (K)	T_{SR} (K)	$T_C - T_{SR}$ (K)	Difference from $T_C - T_{SR}$ of Gd (K)
Comparative Example 4: $Gd_{97}Y_3$	288.2	239.0	49.2	14.8
Example 9: $Gd_{97}(Y_{1.5}Zr_{1.5})$	285.0	243.1	42.0	22
Example 4: $Gd_{97}Zr_3$	283.5	252.0	31.5	32.5
Comparative Example 5: $Gd_{93}Y_7$	281.1	248.0	33.1	30.9
Example 5: $Gd_{93}(Y_{5.5}Zr_{1.5})$	277.5	252.2	25.3	38.7
Example 7: $Gd_{93}(Y_4Zr_3)$	275.0	253.0	22.0	42
Comparative Example 6: $Gd_{85}Y_{15}$	261.0	244.0	17.0	47
Example 6: $Gd_{85}(Y_{13.5}Zr_{1.5})$	258.0	245.0	13.0	51

FIG. **6** is a view showing the temperature dependence of the amounts of change of magnetic entropy $|\Delta S|$ of the example 3 and the comparative example 1. As shown in FIG. **6**, it can be found that a peak appears to each of the amounts of change of the magnetic entropy ΔS. Then, it can be found that the peak is changed to a shape having a tail extending to a low temperature side by adding Zr. As a result, as shown in Table 1, the temperature range of $1/2\Delta S_{max}$ of the example 3 becomes larger than that of the comparative example 1.

FIG. **7** is a view showing the temperature dependence of magnetization curves of the example 3 and the comparative example 1. As shown in FIG. **7**, two peculiar points T_c and T_{SR} exist in each of the magnetization curves. In the comparative example 1, T_c due to the ferromagnetic transition is T_c=294K, and T_{SR} due to the spin realignment is T_{SR}=230K. In the example 3, the temperature interval between the two peculiar points is small as shown by T_c=288K and T_{SR}=242K.

As described in the embodiments, it is considered that the close temperature interval of T_c and T_{SR} found in FIG. **7** contributes to the difference between the shapes of the peaks found in FIG. **6** and to the expansion of the temperature range of $1/2\Delta S_{max}$ in the example 3.

FIG. **8** is a view showing the Zr concentration dependence of T_c and T_{SR} determined from the temperature dependence of the magnetization curves of the examples 1 to 4 and the comparative example 1. As described above, it is found that the case, in which Zr is added in a larger amount, has a larger amount of change of T_c and T_{SR} than the case, in which Zr is not added to Gd, that is, has a smaller temperature interval between T_c and T_{SR}.

As shown in Table 1, the temperature range of $1/2\Delta S_{max}$ is more expanded in the examples 1, 3, and 4 in which Zr is added than in the comparative example 1. In contrast, ΔS_{max} exhibits a maximum value in the comparative example 1. When a magnetic refrigeration is executed using the magnetic material, since not only the magnitude of the amount of change of the magnetic entropy ΔS but also the temperature range in which the amount of change of the magnetic entropy ΔS appears, i.e., an effective temperature range are important factors, it can be said that the examples are also effective magnetic materials for magnetic refrigeration.

As shown in Table 2, it is admitted that the temperature interval (T_c–T_{SR}) between T_c and T_{SR} is more reduced by a decrease of T_c and an increase of T_{SR} in the examples 1 to 4, in which Zr is added, than in the comparative example 1. Note that the temperature interval between T_c and T_{SR} can be reduced even in the comparative example 2, 4, 5 in which only Y is added to Gd, the effect thereof is smaller than the case in which Gd is replaced with Zr as shown in Table 2.

When Gd is replaced by Y in the range of 0 to 10 at %, T_c is decreased about 1.8K and T_{SR} is increased about 2.4K each 1 at %. In contrast, when Gd is replaced by Zr, T_c is decreased about 3.6K and T_{SR} is increased about 7.9 K each 1 at % so that Zr can change the magnetic transition temperature more than Y.

Further, even if Gd is replaced by a combination of Y and Zr, the temperature interval between T_c and T_{SR} can be reduced and the temperature range showing $1/2\Delta S_{max}$ can be increased. As shown in Table 3 as to the examples 5 to 9, when Gd is replaced by the combination of Zr and Y, the temperature interval between T_c and T_{SR} can be reduced and a wide temperature range showing $1/2\Delta S_{max}$ can be obtained by a smaller replace amount of them to the Gd element as compared with the case in which only Y is added.

In addition, T_c and T_{SR} can be obtained in a wider temperature range by combining Zr and Y as compared with the case of adding only Zr. As a result, T_c and T_{SR} can be more easily designed.

When Gd is replaced by the combination of Zr and Y, the total replace amount of Gd is 7 at %, T_c is 277.5K, and T_{SR} is 252.2K as in the example 5. In the replacement of only Y, this change approximately corresponds to the comparative example 2 in which Gd of 10 at % is replaced. However, replacement of Gd in an excessively large total amount is not appropriate because the amplitude of ΔS itself is decreased as shown in Table 1 and the comparative example 3.

As described above, the effect of the present invention is confirmed by the examples.

What is claimed is:

1. A magnetic refrigeration apparatus comprising:

an AMR bed filled with a first magnetic material;

a magnetic field generation device configured to apply and remove a magnetic field to and from the first magnetic material;

a low temperature side heat exchanging unit configured to receive coldness from the AMR bed;