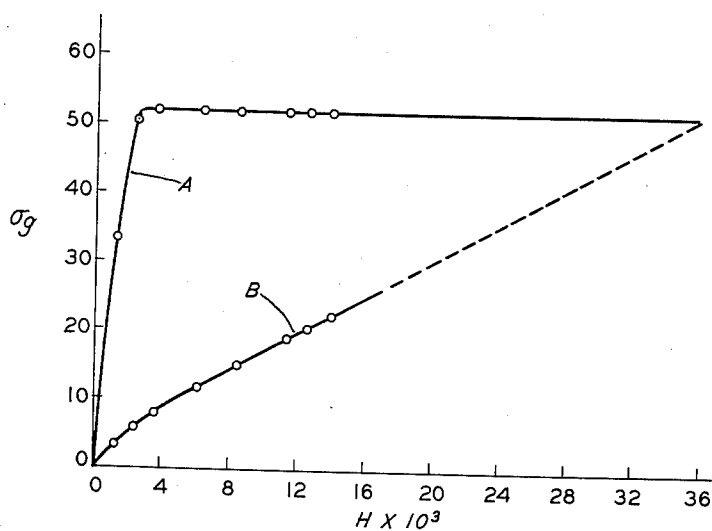


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J. H. WERNICK
FERROMAGNETIC MATERIAL

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FERROMAGNETIC MATERIAL

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4 Claims. (Cl. 75-134)

This invention relates to a new ferromagnetic composition. This composition, essentially the ternary compound, MnAlGe, is especially effective for use in permanent magnets.

It has been found that a new and novel composition, MnAlGe, provides unexpected and significant magnetic properties. Specifically, this material exhibits a high degree of crystalline anisotropy, a high coercive force and an impressive saturation moment. Such properties are especially suitable for a permanent magnet material.

Crystals of MnAlGe, easily obtainable from a stoichiometric melt, have a tetragonal structure belonging to the space group $D_{4h}^{7-}P4/nmm$. The easy magnetization axis is the *c*-axis.

To measure the magnetic properties of this material a sample was prepared as follows:

Lumps of each constituent approximately 1/4" in size were mixed in the following proportions: 18.31 gms. Mn, 8.993 gms. Al and 24.20 gms. Ge and were placed in a quartz crucible and heated in an argon atmosphere in an induction furnace to approximately 1200° C. The melt was allowed to cool to room temperature. The resulting ingot was a single phase ternary compound showing the crystal habit referred to above. The melting point of the compound was approximately 800° C. It was found that the crystal form and resulting composition were essentially unaffected by the cooling rate. Quenching the melt in water produced essentially the same crystal habit.

The ingot obtained was then milled in a ball mill to an average particle size of approximately 400 microns. These particles were dropped into a quarter inch capsule containing molten paraffin and were then ferromagnetically aligned with a field of 3,000 gauss. The capsule was allowed to cool until the paraffin solidified and the coercive force of the resulting sample was measured. The particles were found aligned in the field and the easy axis of magnetization (the *c*-axis) was parallel to the field direction. The observed coercive force was 2,200 oersteds. The following specific characteristics were found:

Table I

Saturation magnetization ($4\pi M_s$)	3600 gauss.
Anisotropy constant K_1	$5.3 \cdot 10^6$ ergs% cm. ³
Maximum calculated coercive force	36,00 oersteds.
Observed coercive force from above sample)	2,200 oersteds.
Estimate of the maximum theoretical energy product	$>7.10^6$ gauss-oersteds.

The anisotropy constant was calculated from an extrapolation of the data appearing in the figure.

The figure is a plot σ_g , the magnetization in gauss per gram vs. *H*, the applied field in oersteds.

Referring to the figure, curve A shows the magnetization curve for a single crystal with the field *H* along the *c*-axis, the easy direction of magnetization. Curve B shows the magnetization curve for the crystal aligned with the field *H* perpendicular to the easy direction. Curve B, extrapolated to intersect curve A gives a crystalline anisotropy field or maximum theoretical coercive force of 36,000 oersteds and a saturation magnetization $4\pi M_s=3600$ gauss. The anisotropy constant is calculated using the formula:

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$$H = \frac{2K_1}{M_s} \quad (1)$$

where *H* is the anisotropy field (oersteds), M_s is the saturation moment, and K_1 is the first anisotropy constant in ergs/cm.³. The saturation moment is obtained from the relation:

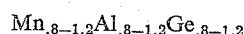
$$B-H=4\pi M_s \quad (2)$$

where *B-H* is the saturation magnetization in the easy direction.

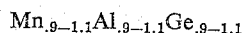
Whereas the observed coercive force for the sample measured was 2200 gauss, higher coercive forces may be obtained by using smaller magnetic particles and ferromagnetically aligning them in stronger fields.

Various modifications in the molecular composition MnAlGe can be tolerated without a significant departure in useful magnetic properties of the material. A 10 atomic percent deficiency in manganese was found to produce only a 5% reduction in saturation magnetization and, assuming a nearly linear function, a 20% variation in atomic proportion of Mn results in a 10% reduction in saturation magnetization. Excesses in manganese were found to exhibit a similar effect. Variations in atomic percentages of aluminum and germanium produced essentially the same departures in optimum magnetic properties as those observed with modifications in manganese content.

Thus, a composition can be established which includes such variations in composition and still affords substantial magnetic properties. Departures from the basic ternary composition result in excessive deficiencies in magnetic properties when they exceed the following limits:



For many purposes more preferred limits are represented by:



While these representations appear as molecular formulas, the subscripts should be considered to be atomic ratios and not as representing an absolute number of atoms. Thus, the representations $Mn_8Al_8Ge_{1.0}$ designates a composition having the given atomic proportions of each constituent and not a molecule deficient in atoms. Based on weight percentage composition of each constituent in the above ranges of atomic proportions, the composition is expressed as:

	Pecent
50 Mn -----	26.6-44.7
Al -----	12.5-24.3
Ge -----	37.5-57.3

and preferably:

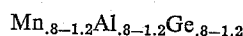
	Precent
55 Mn -----	31.1-39.7
Al -----	15.1-20.6
Ge -----	42.6-51.6

To the extent that the composition departs from the ternary compound MnAlGe, the composition may be considered a mutual solid solution.

Various other modifications in this novel composition will become apparent to those skilled in the art. All such variations which basically rely on the composition set forth herein are considered within the scope of the appended claims.

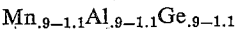
What is claimed is:

1. A ferromagnetic composition consisting essentially of a mutual solid solution having atomic proportions indicated by the formula:



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2. A ferromagnetic composition consisting essentially of a mutual solid solution having atomic proportions indicated by the formula:



3. A ferromagnetic composition consisting essentially of by weight:

	Percent
Manganese -----	26.6-44.7
Aluminum -----	12.5-24.3
Germanium -----	37.5-57.3

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4. A ferromagnetic composition consisting essentially of by weight:

	Percent
Manganese -----	31.1-39.7
Aluminum -----	15.1-20.6
Germanium -----	42.6-51.6

References Cited in the file of this patent

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