United States Patent Office

3,795,541
Patented Mar. 5, 1974

3,795,541

FERROMAGNETIC MATERIAL

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No Drawing. Filed Nov. 26, 1971, Ser. No. 202,604
Int. Cl. C04b *35/00*
U.S. Cl. 117—235 3 Claims

ABSTRACT OF THE DISCLOSURE

A room temperature stable ferromagnetic permanent magnet material with a large Faraday rotation and having a Curie temperature in the region of substantially 180–220° C. of a mutual solid solution having atomic proportions indicated by the formula:

$$Mn_{.8-1.0}Al_{1.3-1.6}Ge_{.8-1.0}O_{0.05-.3}$$

In the film form, the magnetization is normal to the film plane.

FIELD OF THE INVENTION

This invention relates to ferromagnetic films in general, and ferromagnetic films in particular of the general formula MnAlGe, and in particular MnAlGe films of non-stoichiometric composition and having low Curie point temperatures concurrent with high specific Faraday rotation.

PRIOR ART

Ferromagnetic materials utilizing the constituents Mn-Al-Ge are known in the prior art, as illustrated in U.S. Pat. No. 3,065,071, and discussed in the publication "Manganese Aluminum Germanium Films for Magneto-Optic Applications," by R. C. Sherwood, E. A. Nesbit, J. H. Wernick, D. D. Bacon, A. J. Kurtzig and R. Wolfe, J. Appl. Phys., 42, 1704 (1971). The above patent is directed toward compositions of the general formula $Mn_{.8-1.2}Al_{.8-1.2}Ge_{.8-1.2}$, given in atomic proportions. It is noted in the above patents that departures from the basic compositions disclosed results in excessive deficiencies in magnetic properties when the limits of the above formula are exceeded.

However, for various applications the properties sought cannot be met within the compositions known in the prior art. Thus, the prior art MnAlGe films disclosed while sufficient for permanent magnets as disclosed in the above patent, do not have the properties desired for many potential memory uses.

Potential memory use compositions preferably have room temperature stability, and indeed should be stable over a wide temperature range in air. Further, these films should have a relatively low Curie point, which is also controllable as desired. Further, these films should have a high specific Faraday rotation, be easy to manufacture, and have a sufficient coercivity. The remanent Faraday rotations should also be close to that of saturation. Prior art films have not achieved this.

Thus, it is an object of this invention to provide a ferromagnetic material of a mutual solid solution structure that is stable at room temperature and to approximately 400° C.

A further object is to maintain the Curie point of this material preferably between 180° and 220° C., for use in potential memory applications.

Still another object of this invention is the ability to make an easily manufactured film by a variety of techniques, the film being stable in air and having the above properties. Further, control of Curie points should be easily obtainable.

Still another object is to maintain adequate magnetization and coercivity of the film.

Still another object is a magnetic memory structure employing the ferromagnetic compositions of this invention.

SUMMARY OF THE INVENTION

These and other objects of the invention are met by the solid solution consisting essentially of the following materials having atomic proportions indicated by the formula:

$$Mn_{.8-1.0}Al_{1.3-1.6}Ge_{.8-1.0}$$

Alternatively, oxygen may be added to the extent between 0.05–.3 in atomic proportion, for increased stability of the composition. The properties of these compositions and preferred embodiments are disclosed in the following general description.

GENERAL DESCRIPTION

We have found a range of room temperature stable materials having a large Faraday rotation with a magnetization normal to the film plane and a Curie temperature between 180–220° C. Stochiometric MnAlGe, known in the art, has a high Curie temperature of approximately 245° C. Stoichiometric thin films of this material have been prepared in the prior art by DC sputter deposition and by vacuum evaporation.

We have prepared however, non-stoichiometric films of MnAlGe which allow greater control and give the unexpected result of room temperature stability, indeed, stability from room temperature to 400° C., and a lower and controllable Curie point. These non-stochiometric films may be produced by RF or DC sputtering, or from vacuum deposition techniques, all of these techniques known in the art. The substrate during such deposition techniques is essentially maintained in a temperature range of 25–420° C., while a deposition rate is maintained in the range between 2–10 A. per second in a preferred embodiment. In this manner, films having a composition of $Mn_{.8-1.0}Al_{1.3-1.6}Ge_{.8-1.0}$, and optionally, containing oxygen 0.05–.3 are produced. These films have a Curie point between 180–220° C., polar Faraday rotations at room temperature of between $.75-.9\times10^5$ deg./cm., a remanence of greater than .98 of saturation and coercivity of approximately 1500 oersteds. The saturation magnetization may be varied between approximately 3000–3600 gauss.

While prior art disclosures of a magnetic composition of $Mn_{.8-1.2}Al_{.8-1.2}Ge_{.8-1.2}$ noted that departures from the basic ternary composition result in excess deficiencies in magnetic properties when the above is exceeded, we have found that exceeding these limits results in an unusual and unexpected result of room temperature stability and Curie point control between 180° and 220° C. while maintaining the fundamental magnetic properties of the material in a form suitable for magnetic storage devices.

Example I

The composition $Mn_{1.0}Al_{1.6}Ge_{1.0}$, in the form of a film varying from 500–10,000 A., upon a nonmagnetic substrate, exhibited a Curie point of 180° C., a specific Faraday rotation of $.75\times10^5$ deg./cm. coercivity of 1500 oersteds and a saturation magnetization near bulk, or approximately 3000 gauss, the last three values measured at room temperature. The Faraday rotation above and those in the following examples are for wavelengths in the visible and near infrared regions.

Example II

The composition $Mn_{1.0}Al_{1.3}Ge_{1.0}$ exhibited a Curie point of 220° C. with a specific Faraday rotation of

$.9\times10^5$ deg./cm., coercivity at 1500 oersteds, and a saturation magnetization of approximately 3600 gauss.

Example III

The addition of between 0.05 and .3 oxygen in atomic proportion, resulting in the formula

$$Mn_{.8-1.0}Al_{1.3-1.6}Ge_{.8-1.0}O_{0.05-.3}$$

was added to improve the chemical stability of the material with no detrimental effect of the magnetic properties as listed above for $Mn_{.8-1.0}Al_{1.3-1.6}Ge_{.8-1.0}$.

Example IV

The addition of 0.2 oxygen was preferred for room temperature stability, resulting in a formula in atomic proportions of $Mn_{1.0}Al_{1.3}Ge_{1.0}O_{.2}$, having a Curie point of 220° C., and otherwise similar to the similar composition above without oxygen.

Still more generally, we have found that:

Example V

As the aluminum amount increases, the Curie point decreases, but there is a limit to the non-magnetic additions as noted above as affecting the magnetic properties and stability and crystal structure of the compositions.

Example VI

As manganese increases, so does it become necessary to increase the germanium content, and this in turn increases the Curie temperature close to the bulk value.

Consequently, the ranges described above appear optimum for the purposes intended.

Thus, we have found it possible to control the Curie point of these materials between 180–220° C., in a room temperature stable material optionally including oxygen as a constituent as desired. The Curie point, specific Faraday rotation, coercivity, saturation magnetization and other properties are all desirable for storage applications. The magnetization is normal to the film plane, as noted when grown by DC or RF sputtering or by vacuum deposition techniques.

Thus, what has been disclosed is a MnAlGe composition having a lower Curie point between the range of 180–220° C. that is stable between room temperature and substantially 400° C., can be manufactured by a variety of techniques, is stable in air, and has the ease of composition control allowing ease of Curie point control. Further, adequate magnetization and coercivity is achievable for storage applications.

While these representations appear as molecular formmulas, the subscripts should be considered to be atomic ratios and not as representing an absolute number of atoms. Thus, the representations $Mn_{.8}Al_{1.3}Ge_{1.0}$ designates a composition having the given atomic proportions of each constituent and not a molecule deficient in atoms.

These magnetic films are particularly useful for data storage applications, such as in a beam addressable file wherein a polarized beam of light is directed toward the magnetic media and the degree of rotation of the polarization of the beam from the area addressed indicates the state of magnetization of that area. The Faraday effect in transmission, or Kerr effect in reflection, may be used. Beam addressable file configurations are known in the art. For such a memory application, a film of MnAlGe in the preferred proportions listed above is deposited upon a non-magnetic substrate. The substrate may be transparent as may be the film, for the particular wavelength used, or it may be opaque for reflection techniques. Thus, the substrate may typically be of aluminum or other metals, of a ceramic, or glass. Film thickness is between 500–10,000 A. The film substrate structure may be in disk form, strip form, drum form or other forms known in the art. Film deposition is by methods known in the art and previously discussed.

Various other modifications as to this composition and use are apparent to those skilled in the art.

What is claimed is:

1. A ferromagnetic composition having a Curie temperature between substantially 180°–220° C. of a solid solution having atomic proportions indicated by the formula:

$$Mn_{.8-1.0}Al_{1.3-1.6}Ge_{.8-1.0}O_{.05-.3}$$

2. A ferromagnetic composition having a Curie temperature of substantially 220° C. of a solid solution having atomic proportions indicated by the formula:

$$Mn_{1.0}Al_{1.3}Ge_{1.0}O_{.2}$$

3. A data storage medium comprising a magnetic film upon a non-magnetic substrate, the magnetic film consisting essentially of a solid solution having atomic proportions indicated by the formula:

$$Mn_{.8-1.0}Al_{1.3-1.6}Ge_{.8-1.0}O_{.05-.3}$$

References Cited

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U.S. Cl. X.R.

252—62.51