

## **NOVEL PHASE CHANGE MAGNETIC MATERIAL**

[001] This invention relates to a novel material, in particular, a novel phase change magnetic material and methods of making the same. The invention also relates to the uses of the material in optical media, phase change random access memory (PCRAM) devices, magnetic random access memory (MRAM) devices, solid state memory devices, sensor devices, logical devices, cognitive devices, artificial neuron network, three level device, control device, SOC ( system on chip) device, and semiconductors.

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### **BACKGROUND OF THE INVENTION**

[002] Over the last three decades, materials for rewritable media have been receiving an increasing amount of interest in the scientific community and the industry. Since the discovery of chalcogenide film materials in 1968, materials have developed into a complex technology which find uses in many important applications, including electrical write and erase non-volatile memory devices, cognitive semiconductors, and rewritable optical discs.

[003] Recent research efforts have been focussed on the development of non-volatile phase change random access memory and rewritable discs with high storage capacities and fast read-write speeds. Examples of such rewritable media that are now widely in use include rewritable compact discs (CD-RW), rewritable digital video discs (DVD-RAM, DVD-RW, DVD+RW) and rewritable blue laser optical disc (Blu-ray, HD-DVD).

[004] Phase change media utilise phase change materials as recording media. The media is thermally written and optically read. Data is written and erased by inducing a change in phase of the material between crystalline phase and the amorphous phase. A laser beam is typically used to heat the material to bring about a change of phase. As each phase is associated with a different level of light reflectivity, namely, the crystalline phase is highly reflective, and the amorphous phase is lowly reflective, both lowly reflective

mark and highly reflective background spots can be formed on the material to represent computer-readable data bits.

**[005]** The use of rewritable material for optical discs was first reported  
5 in 1971 in which the recording media comprised chalcogenide phase-change  
composite material (Feinleib et al., Appl. Phys. Lett. Vol.18 (1971) pg. 254).  
Since then, many attempts have been made to provide new materials for  
rewritable media in response to the increase in computer data size and the  
corresponding increase in the demand for larger storage capacity and faster  
10 read-write speeds.

**[006]** For example, US Patent 5,709,978 discloses a phase change  
recording film for use in double sided optical discs in which the recording  
material comprises a phase change component such as Sb-Te-Ge and at least  
15 one lanthanide element and a transition metal. A high melting point component  
is precipitated in the recording film to coexist with a phase change component  
to prevent the recording film from flowing and segregating during recording and  
erasing.

**[007]** Another type of rewritable media that is widely in use is magneto-  
20 optical (MO) media (used for example in Mini Discs). MO media operates  
based on both magnetic and optical storage device principles: writing is carried  
out magnetically after thermal treatment, and reading is carried out optically.  
Typically, a focussed laser beam is applied onto one side of the media in order  
25 to heat the MO material to its Curie point or compensation temperature, and  
thus render it susceptible to a magnetic field. A magnetic head positioned on  
the opposite side of the disc is then operated to record digital data onto the  
disk by altering the magneto-optical polarity of the heated area.

**[008]** US Patent 6,132,524 discloses an example of a semiconductor  
30 magneto-optical material. The material comprises a semiconductor such as  
MsAs:GaAs in which fine magnetic particles are dispersed. The material  
exhibits magneto-optical effects at room temperature and can be used for

signal processing and the fabrication of optical isolators and integrated circuits.

[009] Composites comprising two or more kinds of material components and their use in recording media have been disclosed in US Patent 5,709,978. In carrying out the synthesis of the composites, material components of the composites are either combined and prepared from a simple mixture, or one material component is precipitated in the other material component. Such composites exhibit either magnetic or phase change properties individually, but is incapable of exhibiting both magnetic and phase change properties simultaneously.

[010] Several studies into materials for optical discs have been carried out. In a study of the erasing process in optical rewritable discs, Shi et al. discloses the use of phase change material  $\text{Ge}_2\text{Sb}_2\text{Te}_5$  in optical rewritable discs and the dynamic crystallisation behaviour in relation to the erasure of data on such discs (Jpn. J. Appl. Phys. Vol. 42, Part 1, No. 2B, pp 841-847, 2003).

[011] In another study, Sato et al. discloses a GaN-based ferromagnetic diluted magnetic semiconductor for semiconductor devices (Jpn. J. Appl. Phys. Vol. 40, Part 2, No. 5B, pp. L485-L487, 2001). In yet another study, Sun et al. (Appl. Phys. Lett. Vol. 82 No. 12 pp, 1902-1904, 2003. ) discloses the use of FePt magnetic films sputtered on Cu.

[012] Despite the developments that have taken place, limitations in current materials still exist. For example, the capacity and recording speed of rewritable optical media are presently limited by the laser diffraction limit and the crystallisation speed of the recording material. Therefore, continuing efforts are needed to provide new materials having new characteristics.

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[013] Accordingly, it is an object of the present invention to provide new materials that, for example, give rise to improved performance.

## **SUMMARY OF THE INVENTION**

**[014]** According to a first aspect of the present invention, there is provided a phase change magnetic composite material which comprises a phase change material component, and a ferromagnetic material component. This material has a crystalline phase associated therewith a first magnetic property and a first phase change material property. In addition, this material has an amorphous phase associated therewith a second magnetic property and a second phase change material property. The material of the invention has unique electrical, magnetic, thermal, crystallization and optical properties at different phases, such as fully crystalline states, amorphous, and partial crystalline phases. The material exhibits both magnetic effects and phase change effects and can be used in a wide range of applications. Examples of applications in which the material may be used include, but are not restricted to, optical media, phase change random access memory (PCRAM) devices, magnetic random access memory (MRAM) devices, solid state memory devices, sensor devices, logical devices, cognitive devices, artificial neuron network, three level devices, control devices, SOC devices and semiconductors.

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**[015]** According to another aspect of the invention, there is provided an optical recording medium for recording information, said medium comprising the phase change magnetic material of the invention. The invented material has different electrical, magnetic, and optical properties at different phase states, such as crystalline states, amorphous, and partial crystalline. The invention further relates to the uses of the phase change magnetic material in devices such as solid state memory devices, semiconductors, logical devices, magnetic random access memory, artificial neuron network, and phase change random access memory devices.

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**[016]** These aspects and other aspects of the invention will be more fully understood in view of the following description, drawings and non-limiting examples.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

**[017]** Figure 1 is a schematic diagram showing the synthesis of phase change magnetic material according to one embodiment of the present invention.

**[018]** Figure 2a shows graphical data characterising the magnetic properties of a conventional phase change material  $\text{Ge}_2\text{Sb}_2\text{Te}_5$ ; as can be seen from the figure, the material exhibits antimagnetic properties.

**[019]** Figure 2b shows graphical data characterising the magnetic properties of a phase change magnetic material,  $\text{Fe}_{4.4}\text{Ge}_{14.8}\text{Sb}_{34.2}\text{Te}_{46.6}$  according to one embodiment of the invention. Coercivity value  $H_c$  of 38 Oersteds is observed at zero magnetization.

**[020]** Figure 2c shows graphical data characterising the magnetic properties of phase change material of  $\text{GeTe}$ .

**[021]** Figure 2d show magnetic properties of phase change magnetic material of  $\text{Fe}_{4.6}\text{Pt}_{7.3}\text{Ge}_{59.5}\text{Te}_{28.6}$  according to the present invention.

**[022]** As shown in Figures 2(a-d), conventional phase change materials exhibits antimagnetic property while phase change magnetic material according to the present invention shows magnetic property.

**[023]** Figure 3a and 3b shows graphical data characterising the magnetic properties of the  $\text{Co}_{6.3}\text{Ge}_{31.1}\text{Sb}_{27.1}\text{Te}_{35.5}$  in the amorphous and crystalline state.

**[024]** Figure 4 is a microscope photograph of the material according to the invention at amorphous and crystalline phases as induced by a pulse laser. The photograph indicates that the phase change magnetic material has different optical properties in the amorphous and the crystalline phases, similar to phase change materials. The experiment also showed that between crystal and amorphous there are partial crystalline states meaning the crystalline fraction  $x$  is in the range,  $0 < x < 1$ .

**[025]** Figure 5 shows a table of data comparing the electrical resistivity of conventional phase change materials and the phase change magnetic material of the invention at amorphous and crystalline states. The data shows that phase change magnetic material according to the invention have similar electrical

properties to phase change materials.

[026] Figures 6a and 6b show XRD profiles characterising the crystal structure of 2 different phase change magnetic materials, namely,  $\text{Fe}_{4.4}\text{Ge}_{14.8}\text{Sb}_{34.2}\text{Te}_{46.6}$  and  $\text{Fe}_{4.6}\text{Pt}_{7.3}\text{Ge}_{59.5}\text{Te}_{28.6}$ .

5 [027] Figure 7a and 7b show schematic diagrams of a laser ablation system and a sputtering system, respectively, which can be used for synthesising the phase change magnetic material of the invention.

### DETAILED DESCRIPTION

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[028] The invention is based on the finding that phase change materials and magnetic materials can be used to form a homogeneous composite material that exhibits both phase change effects as well as magnetic effects. In the context of the present invention, a material is said to exhibit phase change  
15 effects if it shows changes in its physical properties when it undergoes a phase change. Examples of these physical properties include resistivity, absorption at different wavelength, optical constants, dispersion relation, dielectric constants, density, thermal conductivity, thermal diffusion coefficient, specific heat, active energy, lattice constant, crystallization temperature, glass temperature. Likewise,  
20 a material is said to exhibit magnetic effects if it is under a magnetic field.

[029] Without wishing to be bound by theory, the inventors presently believe that under appropriate growth conditions, phase change components and magnetic components can be combined such that the crystal structure of the  
25 resulting phase change magnetic material is altered: some of the atoms of the phase change material is replaced by the atoms of magnetic material in the crystal structure, so a new unit cell having a unique crystal structure is formed. In other words, atoms of magnetic material are made to replace the positions of some atoms of phase change material, without destroying crystal structure of  
30 phase change material. In this manner, phase change magnetic composite materials are able to exhibit both phase change effects due to similar crystal structure with phase change material, and magnetic effects due to magnetic atoms existing in the crystal structure.

[030] One advantage that is provided by the material of the invention is that each phase of the material is coupled to a unique set of phase change properties and magnetic properties. This means that when the material undergoes phase change from crystalline phase to amorphous phase, for instance, the material exhibits a corresponding change in both its phase change properties (e.g. optical reflectance, optical constants) and its magnetic properties (e.g. field strength). The benefit of dual property change can be harnessed for a wide variety of applications, such as sensing, data storage, logical, cognitive, control, SOC (system on chip) and semiconductor applications. For recording applications for instance, this property enables the readout signal from the contribution of both the optical reflectance change, polarization, frequency and magnetic change to be detected at the same time and at the same point, thereby increasing the recording density and data transfer rate in recording media utilising the material of the invention. In sensing applications, this property enables sensing measurements to be highly accurate for electric, thermal, optical, magnetic, magneto-optical, thermal-electric, electric-optical and their combination.

[031] Phase change properties exhibited by the phase change magnetic material (hereinafter referred to as "PCM material") of the present invention include the properties of high electrical resistivity, low thermal conductivity, and low light reflectivity in the amorphous phase, and low electrical resistivity, high thermal conductivity and high light reflectivity in the crystalline phase. The physical parameters such as resistivity, reflectivity, absorption, optical constants, refraction index and absorption coefficient, dielectric constants, density, thermal conductivity, thermal diffusion coefficient, specific heat, active energy, and so on are different at partial crystalline states ranging from those at the amorphous state to those at the crystalline state. These properties are similar to those exhibited by known phase change materials and are thus presently known as phase change effects.

[032] Magnetic properties (hereinafter used interchangeably with the

term "magnetic effects") exhibited by the material include having paramagnetic properties in the amorphous (disordered) phase and magnetic properties in the crystalline (ordered) phase. Magnetic effects also include changes of magnetic properties such as the saturation magnetization  $M_s$ , coercive field  $H_c$ , anisotropy field  $H_k$ , uniaxial anisotropy constant  $K_u$ , squareness, remanence magnetization  $M_r$ , saturation induction  $B_s$ , Curie temperature  $T_c$ , compensation temperature and so on. These properties are similar to those exhibited by magnetic materials and are thus presently known as magnetic effects.

10       **[033]**     The phase change magnetic composite material of the invention comprises two main components, namely a phase change component and a magnetic component.

15       **[034]**     The phase change component comprises any type of phase change material. It is preferable in some embodiments that the phase change material exhibits phase change (i.e. it may melt) at a temperature above standard room temperature (i.e. 25° Celsius), or more preferably, at an elevated temperature of more than a hundred, or more than several hundred degrees Celsius. The elevated temperature can be brought about by any suitable focussed laser beam or any electric current or heating device. For recording purposes, the phase change material preferably changes from the crystalline phase to the amorphous phase upon heating and subsequent cooling, and does not regain the crystalline conformation. In this manner, the amorphous marks in combination with the crystalline areas may be used to represent data. It is possible to also use phase change materials in which phase change occurs at 25 temperatures higher than the temperatures that can be provided by standard laser equipment. If used, such materials require higher operating power in order to induce the phase change. On the other hand, phase change materials such as paraffin wax and polyimides (e.g. polymeric organic substances) which are 30 used for thermal insulation of buildings, for example, are not considered to be suitable for use in the invention due to the relatively low phase change temperature.

[035] In one embodiment, the phase change component is selected from an element from any of the Groups IIIB, IVB, VB and VIB of the Periodic Table. In some embodiments, preferred elements are selected from, but are not restricted to, the chalcogen elements Te, S, Po and Se, as well as other  
5 elements such as P, As, Sb, Bi, Ge, Sn, Pb, Ga, In, and Ti.

[036] In a presently preferred embodiment, the phase change component comprises a chalcogenide alloy. Examples of suitable secondary, ternary and quaternary chalcogenide alloy systems include, but are not limited  
10 to, Ge-Te, Sb-Te, Ge-Sb, Sn-Te, Sb-Se, In-Se, Ge-Sb-Te, Pt-Ge-Te, In-Sb-Te, As-Sb-Te, As-Ge-Te, Se-Sb-Te, Sn-Te-Se, Ge-Te-Sn, Sb-Se-Bi, Ga-Te-Se, In-Se-Ti, Ge-Te-Ti, Ge-Te-Sn-O, Ge-Te-Sn-Au, Ge-Te-Sn-Pd, Ag-In-Sb-Te and mixtures thereof. Presently preferred quaternary systems include Ge-Sb-Te-X and In-Sb-Te-X wherein X is a transition metal such as Au, Pd, Ir, Ru, Re, Mo,  
15 Ta, Zr and La. Each element in these presently preferred alloy systems can be present in any suitable atomic percentage. Some examples of presently preferred alloy compositions include, but are not limited to,  $\text{Ge}_2\text{Sb}_2\text{Te}_5$ ,  $\text{GeSb}_2\text{Te}_4$ ,  $\text{GeSb}_3\text{Te}_4$ ,  $\text{GeSb}_4\text{Te}_7$ ,  $\text{In}_3\text{SbTe}_2$ ,  $\text{Ag}_5\text{In}_5\text{Sb}_{60}\text{Te}_{30}$ ,  $\text{Sb}_2\text{Te}_3$ ,  $\text{Sb}_{70}\text{Te}_{30}$ , GeTe, GeSb,  $\text{Sb}_2\text{Se}_3$ ,  $\text{Sb}_2\text{Te}_3$ -GeTe, for instance.

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[037] The second component present in the phase change magnetic material of the invention is a ferromagnetic component. The term "ferromagnetic component" refers to materials having a large and positive susceptibility to an external magnetic field. Typically, such materials have unpaired electrons whose  
25 spins results in a net magnetic moment to be generated in each atom of the ferromagnetic material. The electron spins of the atoms are aligned in microscopic regions known as domains. In these domains, large numbers of atoms (typically about  $10^{12}$  to  $10^{15}$ ) are aligned in parallel so that the magnetic force within the domain is strong. When a ferromagnetic material is in the  
30 unmagnetized state, the domains are nearly randomly organized and the net magnetic field for the part as a whole is zero. When the ferromagnetic material is brought within the influence of a magnetic field, the domains become aligned with the magnetic field, thereby producing a strong magnetic field within that part

of the material.

[038] In one embodiment, the ferromagnetic component that is used in the present invention is selected from, but not limited to, the elements iron, nickel, and cobalt. Further examples include ferromagnetic alloys comprising at least one ferromagnetic component, such as such iron, nickel, and cobalt. Examples of ferromagnetic alloys comprising at least one ferromagnetic component includes FePt, CoPt, PdCo, TbFeCo, GdFeCo, CoCrPtB, and CoCrPtTa, to name only a few.

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[039] When the material of the invention is used in a conventional recording medium such as compact discs, digital video disc, and magnetic media systems, the proportion of each of the phase change component and the magnetic component is selected such that the resulting material possesses characteristics or exhibits properties that are desirable in conventional phase change media, conventional magnetic media and as well as conventional magneto-optical media, so that the medium is able to function according to the requirements of standard reading and recording equipment. To achieve this purpose, the components of the phase change magnetic material can be selected such that the composite material exhibits at least one physical state selected from a crystalline state, an amorphous state and a partial crystalline state. The components of the phase change magnetic material can also be selected such that the composite material exhibits different electrical, magnetic, thermal, crystallization, and optical properties at each of said at least one physical state.

[040] Desirable characteristics in a phase change optical media includes different refractive indexes for the crystalline and amorphous phases (for optical contrast), low melting point (for low laser power), high crystallization speed and good amorphous stability. Desirable characteristics in a magnetic media includes perpendicular magnetic anisotropy (for facilitating perpendicular magnetic recording), small grain size, high perpendicular coercivity, high perpendicular anisotropy, high squareness, proper saturation magnetization. Desirable

characteristics in a magneto-optical media includes an amorphous structure (for smooth surface and domain's boundaries to decrease system's noise), suitable Curie temperature (for media stability and low laser power), rapid drop of coercivity near the Curie temperature (for sharp recording threshold),  
5 perpendicular magnetic anisotropy, chemical stability (for constant material's properties under repeated heating-cooling) and high coercivity at room temperature (for media stability, accidental data loss prevention). Accordingly, in one embodiment, the components of the material are selected to achieve at least one of the above properties.

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[041] In one embodiment, the phase change component and ferromagnetic component are present in a proportion such that the resulting phase change material has a crystalline phase associated therewith a first magnetic property and a first phase change property, and an amorphous phase  
15 associated therewith a second magnetic property and a second phase change property. The proportion of each component present in the material should enable the second set of magnetic and phase change properties to be distinct and different from the first set properties, thereby enabling these properties to be used for representing recorded information on the material.

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[042] In some embodiments, the resistivity  $\rho$  of said material is generally in the range of  $1 \times 10^{-3} \Omega \text{cm} < \rho < 1 \times 10^3 \Omega \text{cm}$ , or  $0.1 \Omega \text{cm} < \rho < 10 \Omega \text{cm}$  at amorphous state and in the range of  $1 \times 10^{-4} \Omega \text{cm} < \rho < 1 \times 10^{-1} \Omega \text{cm}$ , or  $1 \times 10^{-7} \Omega \text{cm} < \rho < 1 \times 10^{-2} \Omega \text{cm}$  at crystalline state. The resistivity difference of said material  
25 between the amorphous phase and the crystalline phase by at least about a factor of 2 to  $10^6$ . In other preferred embodiments, the coercivity of the material in the crystalline phase is at least about 1 Oersted, or in some cases, at least about 40 Oersteds.

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[043] In a further embodiment, the phase change magnetic material has a crystal structure that is at least substantially similar to the phase change material component. In this embodiment, the atoms of magnetic materials replace the position of some atoms of phase change materials without

destroying crystal structure of phase change materials. As the atoms of magnetic elements or materials replace the positions of some atoms of phase change material to form a new unit cell with unique crystal structure under appropriate growth conditions and the replacement is in a certain range of replacement, these materials exhibit both phase change effect and magnetic effect.

**[044]** In a further embodiment, the phase change magnetic material has a composition of formula (I):

10  $A_x B_y$

wherein

A denotes the ferromagnetic component;

B denotes the phase change component;

x denotes the total atomic percentage of A, wherein  $1\% \leq x \leq 50\%$ , and

15 y denotes the total atomic percentage of B, wherein  $50\% \leq y \leq 99\%$ .

**[045]** In one presently preferred embodiment, the phase change magnetic material as defined in formula (I) has a ferromagnetic component A selected from any of the elements Co, Fe Ni and the alloy FePt, and a phase change component B selected from Sb, Te, GeTe, Sb<sub>2</sub>Te<sub>3</sub>, GeSb, Sb<sub>70</sub>Te<sub>30</sub>, InSbTe, Ag-In-Sb-Te and Ge-Sb-Te. The chemical formula of composite materials having the formula (I) may be selected from one of the following simplified chemical formula: Fe(Sb<sub>2</sub>Te<sub>3</sub>), Co(Sb<sub>2</sub>Te<sub>3</sub>), Ni(Sb<sub>2</sub>Te<sub>3</sub>), FeGeSb, CoGeSb, NiGeSb, Fe(Sb<sub>70</sub>Te<sub>30</sub>), Co(Sb<sub>70</sub>Te<sub>30</sub>), Ni(Sb<sub>70</sub>Te<sub>30</sub>), FeInSbTe, CoInSbTe, and NiInSbTe. Illustrative examples include, but are not limited to, Co<sub>6.3</sub> Ge<sub>31.1</sub> Sb<sub>27.1</sub> Te<sub>35.5</sub>, Co<sub>3.6</sub> Ge<sub>20.8</sub> Sb<sub>30.5</sub> Te<sub>44.9</sub>, Co<sub>2.8</sub> Ge<sub>17.9</sub> Sb<sub>31.9</sub> Te<sub>47.1</sub>, Co<sub>6.1</sub> Ge<sub>14.3</sub> Sb<sub>33</sub> Te<sub>46.5</sub>, Co<sub>3.0</sub> Ge<sub>18.5</sub> Sb<sub>30.1</sub> Te<sub>48.2</sub>, Co<sub>5.0</sub> Ge<sub>16.9</sub> Sb<sub>31.6</sub> Te<sub>46.5</sub>, Co<sub>1.5</sub> Ge<sub>17.3</sub> Sb<sub>32.9</sub> Te<sub>48.3</sub>, Co<sub>5.4</sub> Ge<sub>17.2</sub> Sb<sub>30.5</sub> Te<sub>46.9</sub>, Co<sub>2.0</sub> Ge<sub>17.7</sub> Sb<sub>32.5</sub> Te<sub>47.8</sub>, Co<sub>5.8</sub> Ge<sub>17.1</sub> Sb<sub>32.3</sub> Te<sub>44.8</sub>, Co<sub>4.6</sub> Ge<sub>14.9</sub> Sb<sub>33.4</sub> Te<sub>47.1</sub>, Co<sub>10.1</sub> Ge<sub>14.4</sub> Sb<sub>34.6</sub> Te<sub>40.9</sub>, Co<sub>26.1</sub> Ge<sub>17.2</sub> Sb<sub>22.1</sub> Te<sub>34.6</sub>, Co<sub>5.6</sub> Ge<sub>15.8</sub> Sb<sub>33.6</sub> Te<sub>45</sub>, Fe<sub>20.2</sub> Ge<sub>21.5</sub> Sb<sub>16.9</sub> Te<sub>41.4</sub>, Fe<sub>9.2</sub> Ge<sub>16.3</sub> Sb<sub>27.4</sub> Te<sub>47.2</sub>, Fe<sub>4.7</sub> Ge<sub>18.5</sub> Sb<sub>28.1</sub> Te<sub>48.6</sub>, Fe<sub>4.4</sub> Ge<sub>14.8</sub> Sb<sub>34.2</sub> Te<sub>46.6</sub>, Fe<sub>11.1</sub> Ge<sub>16</sub> Sb<sub>25.9</sub> Te<sub>47.1</sub>, Fe<sub>1.0</sub> Ge<sub>15.7</sub> Sb<sub>35.2</sub> Te<sub>48.2</sub>, Fe<sub>7.2</sub> Ge<sub>14.7</sub> Sb<sub>32.9</sub> Te<sub>45.2</sub>, Fe<sub>28.2</sub> Pt<sub>32.4</sub> Ge<sub>30.0</sub> Te<sub>9.3</sub>, Fe<sub>4.1</sub> Pt<sub>4.2</sub> Ge<sub>64.5</sub> Te<sub>27.1</sub>, Fe<sub>2.1</sub> Pt<sub>5.5</sub> Ge<sub>63.9</sub> Te<sub>28.4</sub>, Fe<sub>1.1</sub> Pt<sub>2.7</sub> Ge<sub>64.3</sub> Te<sub>31.9</sub>,

Fe<sub>4.6</sub> Pt<sub>7.3</sub> Ge<sub>59.5</sub> Te<sub>28.6</sub>, Fe<sub>5.0</sub> Pt<sub>6.8</sub> Ge<sub>59.6</sub> Te<sub>28.6</sub>, Fe<sub>1.1</sub> Pt<sub>1.1</sub> Ge<sub>50.4</sub> Te<sub>31.1</sub>, Fe<sub>4.8</sub> Pt<sub>4.6</sub> Ge<sub>58.2</sub> Te<sub>32.4</sub>, and Fe<sub>1.2</sub> Pt<sub>2.5</sub> Ge<sub>54.2</sub> Te<sub>41.9</sub>, Fe<sub>1.0</sub> Pt<sub>2.0</sub> Ge<sub>62.1</sub> Te<sub>34.9</sub>.

[046] In a further embodiment, the phase change magnetic material has  
5 a composition of formula (II):



wherein

A denotes a ferromagnetic component;

B denotes a phase change component;

10 C denotes a manganese compound component;

x denotes the total atomic percentage of A, wherein  $1\% \leq x \leq 40\%$ , y denotes the total atomic percentage of B, wherein  $40\% \leq y \leq 98\%$ , and z denotes the total atomic percentage of C, wherein  $1\% \leq z \leq 20\%$ .

15 [047] In one presently preferred embodiment, the phase change magnetic material as defined in formula (II) has a ferromagnetic component A selected from any of the elements Co, Fe Ni and the alloy Fe-Pt, and a phase change component B selected from Sb, Te, GeTe, Sb<sub>2</sub>Te<sub>3</sub>, GeSb, Sb<sub>70</sub>Te<sub>30</sub>, InSbTe, Ag-In-Sb-Te and Ge-Sb-Te. The third component C is selected from  
20 MnAs, MnGa, MnSb, and MnAl. Components A and B of presently preferred composite materials having the formula (II) are presently preferably combined to form one of the following compounds: Fe(Sb<sub>2</sub>Te<sub>3</sub>), Co(Sb<sub>2</sub>Te<sub>3</sub>), Ni(Sb<sub>2</sub>Te<sub>3</sub>), FeGeSb, CoGeSb, NiGeSb, Fe(Sb<sub>70</sub>Te<sub>30</sub>), Co(Sb<sub>70</sub>Te<sub>30</sub>), Ni(Sb<sub>70</sub>Te<sub>30</sub>), FeInSbTe, CoInSbTe, and NiInSbTe. Illustrative examples include, but are not  
25 limited to, Co<sub>6.3</sub> Ge<sub>31.1</sub> Sb<sub>27.1</sub>Te<sub>35.5</sub>, Co<sub>3.6</sub> Ge<sub>20.8</sub> Sb<sub>30.5</sub>Te<sub>44.9</sub>, Co<sub>2.8</sub> Ge<sub>17.9</sub> Sb<sub>31.9</sub>Te<sub>47.1</sub>, Co<sub>6.1</sub> Ge<sub>14.3</sub> Sb<sub>33</sub>Te<sub>46.5</sub>, Co<sub>3.0</sub> Ge<sub>18.5</sub> Sb<sub>30.1</sub> Te<sub>48.2</sub>, Co<sub>5.0</sub> Ge<sub>16.9</sub> Sb<sub>31.6</sub>Te<sub>46.5</sub>, Co<sub>1.5</sub> Ge<sub>17.3</sub> Sb<sub>32.9</sub>Te<sub>48.3</sub>, Co<sub>5.4</sub> Ge<sub>17.2</sub> Sb<sub>30.5</sub>Te<sub>46.9</sub>, Co<sub>2.0</sub> Ge<sub>17.7</sub> Sb<sub>32.5</sub>Te<sub>47.8</sub>, Co<sub>5.8</sub> Ge<sub>17.1</sub> Sb<sub>32.3</sub>Te<sub>44.8</sub>, Co<sub>4.6</sub> Ge<sub>14.9</sub> Sb<sub>33.4</sub>Te<sub>47.1</sub>, Co<sub>10.1</sub> Ge<sub>14.4</sub>Sb<sub>34.6</sub>Te<sub>40.9</sub>, Co<sub>26.1</sub> Ge<sub>17.2</sub> Sb<sub>22.1</sub>Te<sub>34.6</sub>, Co<sub>5.6</sub>Ge<sub>15.8</sub>Sb<sub>33.6</sub>Te<sub>45</sub>, Fe<sub>20.2</sub> Ge<sub>21.5</sub> Sb<sub>16.9</sub> Te<sub>41.4</sub>, Fe<sub>9.2</sub> Ge<sub>16.3</sub> Sb<sub>27.4</sub> Te<sub>47.2</sub>, Fe<sub>4.7</sub> Ge<sub>18.5</sub> Sb<sub>28.1</sub> Te<sub>48.6</sub>, Fe<sub>4.4</sub> Ge<sub>14.8</sub> Sb<sub>34.2</sub> Te<sub>46.6</sub>, Fe<sub>11.1</sub> Ge<sub>16</sub> Sb<sub>25.9</sub> Te<sub>47.1</sub>, Fe<sub>1.0</sub> Ge<sub>15.7</sub> Sb<sub>35.2</sub> Te<sub>48.2</sub>, Fe<sub>7.2</sub> Ge<sub>14.7</sub> Sb<sub>32.9</sub> Te<sub>45.2</sub>, Fe<sub>28.2</sub> Pt<sub>32.4</sub> Ge<sub>30.0</sub> Te<sub>9.3</sub>, Fe<sub>4.1</sub> Pt<sub>4.2</sub> Ge<sub>64.5</sub> Te<sub>27.1</sub>, Fe<sub>2.1</sub> Pt<sub>5.5</sub> Ge<sub>63.9</sub> Te<sub>28.4</sub>, Fe<sub>1.1</sub> Pt<sub>2.7</sub> Ge<sub>64.3</sub> Te<sub>31.9</sub>, Fe<sub>4.6</sub> Pt<sub>7.3</sub> Ge<sub>59.5</sub> Te<sub>28.6</sub>, Fe<sub>5.0</sub> Pt<sub>6.8</sub> Ge<sub>59.6</sub> Te<sub>28.6</sub>, Fe<sub>1.1</sub> Pt<sub>1.1</sub>

Ge<sub>50.4</sub> Te<sub>31.1</sub>, Fe<sub>4.8</sub> Pt<sub>4.6</sub> Ge<sub>58.2</sub> Te<sub>32.4</sub>, Fe<sub>1.2</sub> Pt<sub>2.5</sub> Ge<sub>54.2</sub> Te<sub>41.9</sub>, and Fe<sub>1.0</sub>Pt<sub>2.0</sub>Ge<sub>62.1</sub>Te<sub>34.9</sub>.

**[048]** It would be understood by a person skilled in the art that the phase  
5 change magnetic material of the invention can be used in conjunction with any  
suitable type of secondary material known in the art which aids in the optical  
media, phase change random access memory (PCRAM) devices, magnetic  
random access memory (MRAM) devices, solid state memory devices, sensor  
10 devices, logical devices, cognitive devices, artificial neuron network, and  
semiconductors of the material of the invention. Secondary materials include  
dyes for improving reflectivity, sacrificial coatings for preventing moisture  
degradation, for example.

**[049]** In order for both phase change effects and magnetic effects to be  
15 exhibited in the material, the phase change component and the ferromagnetic  
component may be present in the material according to a suitable ratio which  
allows the atoms of the magnetic material to replace the atoms of the phase  
change material without resulting in any substantial change in the crystal  
structure of the phase change material. Many methods are suitable for the  
20 synthesis of the phase change magnetic material of the invention. Examples of  
methods which enable a homogeneous composite material to be formed and  
can thus be used herein, include laser ablation, sputtering, ion plating, chemical  
vapor deposition (CVD), plasma enhanced chemical vapor, metal organic  
chemical vapor deposition, spin coating, molecular beam epitaxy (MBE), top-  
25 seeded solution growth, thermal pressing, vacuum melting, and conventional  
crystal growth.

**[050]** In one embodiment, the material of the invention is synthesized by  
laser ablation or by laser synthesis. Preferably, the material is synthesised via  
30 laser synthesis. In the context of the present invention, the method of synthesis  
involving dual-beam laser ablation of different targets for synthesizing new  
materials within the overlapping plasma area is included in the term "laser  
synthesis". Laser synthesis is carried out by laser pulses from an excimer laser

used to heat precursor component materials that are mounted onto rotating mounts. By positioning the mounts such that the plumes emitted from the precursors overlap at least partially, a substrate can be positioned within this overlapping region so that a homogeneous film can be formed thereon. This  
5 procedure is described, for example, by Song et al. (Appl. Phys. A. Vol. 79 p 1349-1352, 2004).

**[051]** In another aspect, the invention relates to an optical recording medium for recording information, comprising a phase change magnetic  
10 material, said material comprising a phase change component and a ferromagnetic component, wherein said material exhibits both magnetic effect and phase change effect. The design of an optical disc as such and method of manufacturing an optical disc are known to the person of average skill in the art and described for example, in US Patent 6,469,977. Actual implementations of  
15 such an optical disc include CD-RW, DVD-RAM, DVD-RW, DVD+RW, Blu-ray, HD-DVD. Next generation products of optical discs including discs with holography recording, near field optical recording, multi layer optical recording and multi-level recording have been the subject of intense research in recent years. Other uses of the phase change magnetic material according to the  
20 invention include the use in phase change random access memory (PCRAM) devices, magnetic random access memory (MRAM) devices, solid state memory devices, sensor devices, logical devices, cognitive devices, three level device, control device, and semiconductors.

25 **[052]** In actual use, an information recording medium which has a recording layer comprising the material of the invention is provided with the phase change magnetic material in either crystalline phase or in amorphous phase. During recording procedure, a laser selectively heats areas of a recording track present in the optical disc above the phase change magnetic  
30 material's melting point or crystallization temperature. The material is melted and subsequently 'frozen' by quickly cooling the layer or is crystallized. The reflectance of the amorphous areas is much different with that of the crystalline areas which, during readout, gives rise to a signal similar to that produced from

the pits and lands of a ROM type disc. The change in optical reflectance can be used to represent stored data on the recording medium. A new overwriting signal can be recorded by erasing an existing recorded signal, using by modulating the laser output of the recording laser beam. During overwrite, some amorphous areas along the track are returned to the crystalline phase by annealing below the melting point with the use of a focussed laser beam, the material is locally heated to a temperature of approximately between the melting point and crystallisation temperature for a certain retention time in order to carry out re-crystallisation. Similarly, some crystalline areas are converted to the amorphous phase by heating above the melting point, then quenching as described above. This process can be repeated several thousand times per disc. For rewritable optical media, the background is in some cases preferably crystalline. The media using phase change magnetic material of the invention can also be made to be written once. For write once media or so-called "recordable media", the background of the disc can be either crystalline or amorphous.

**[053]** At the same time, when the material is reversibly changed between amorphous and crystalline states, the magnetic properties of the material of the invention is correspondingly changed because of the structural change. Thus, this structural change can be detected by measuring the readout signal associated with the change in magnetic properties. Finally, the readout signal from the contribution of both the optical reflectance change and magnetic change is detected at the same time and at the same point. The recording density and data transfer rate will be increased. For conventional phase change media, only the optical reflectance change from the material can be detected. For the material of the invention, both the optical reflectance change and magnetic change can be detected at the same time and at the same point (location). The recording density and data transfer rate will be increased.

**[054]** In utilising the magnetic properties of the material, conventional methods used for reading and writing magneto-optical discs can be carried out. For example, during reading, a laser projects a beam on the disk and the changes in the polarisation of reflected light is interpreted as binary data. The

reflected light varies according to the magnetic data stored on the disc. The changes in light polarization occur due to the presence of a magnetic field on the surface of the disk (the Kerr effect). If a beam of polarized light is shone on the surface, the light polarization of the reflected beam will change slightly (typically  
5 less than  $1^\circ$ ), provided it is reflected from a magnetized surface. If the magnetization is reversed, the change in polarization (the Kerr angle) is reversed as well. The magnetized areas - pits - cannot be seen in regular light, but only in polarized light. The change in direction of magnetization can be associated with numbers 0 or 1, thus allowing the storage of binary data. During recording, the  
10 light becomes stronger so it can heat the material up to the Curie point or compensation temperature in a single spot. This allows an electromagnet positioned on the opposite side of the disc to change the local magnetic polarization, and the polarization is retained when temperature drops. This fact that the material's coercivity drops at higher temperatures allows thermally-  
15 assisted magnetic recording to be carried out with relatively weak magnetic fields.

[055] At the same time, when light polarization of the material changes because of the magnetization reversal, the structure the invented material is  
20 reversibly changed between amorphous and crystalline states, this change can be detected and a reflectance change is observed from the readout signal because of structural change. Finally, the combined readout signal from the contribution of both the light polarization change and optical reflectance change is detected at the same time and at the same point/location. The recording  
25 density and data transfer rate will be increased as a result. For conventional magneto-optical medium, only the light polarization change by magnetic reverse can be detected. For the material of the invention, both the light polarization change and optical reflectance change will be detected at the same time and at the same point. The recording density and data transfer rate is consequently  
30 increased.

**EXAMPLE 1: Laser synthesis****Synthesis procedure**

[056] The schematic diagram of our laser synthesis system is shown in following Figure 7(a). The synthesis was carried out in chamber 8. A KrF excimer laser beam from the laser 10 was split into two beams via splitter 12, and were focused onto two rotating targets 14 with two focus lenses 16, 18 and with the aid of two reflectors 30. Two overlapping plumes were produced on substrate 20, respectively. The laser fluence on each target is between 0.5 and 6 J/cm<sup>2</sup>. The targets were mounted at 45° with respect to the laser beams. Facing the targets at a distance of 2 to 8 cm, substrate 20 was mounted on a two-inch stainless steel holder 22 by silver paste. The two mirrors is to reflect the splitted laser onto the focussing lens. A background pressure of 2X10<sup>-6</sup> Torr was achieved with a turbomolecular pump (not indicated). The growth temperature was between room temperature and 900 °C. The synthesized materials were typically grown for 12000 pulses at a repetition rate of 10 Hz. After laser synthesis, the materials were cooled to room temperature.

[057] In the context of the present invention, the method of synthesis involving dual-beam laser ablation of different targets for synthesizing new materials within the overlapping plasma area is termed "laser synthesis". In this method, the components including atoms, molecules, electrons, ions and clusters for material synthesis are highly energetic evaporants generated by laser ablation. The use of short laser pulses for ablation is more likely to achieve congruent ablation to preserve stoichiometry during mass transfer from target to substrate, which makes composition of new material easily controlled. Since laser interaction with gas-phase species is relative weak, many kinds of reactive gases can be input for material synthesis. It is flexible in tuning synthesized elements and composition by varying target, laser fluence and input gas as well as substrate position within the overlapping plasma area. A preferred single crystal substrate can be chosen to lead to crystal growth of new materials. It can also heat the substrate to high temperature to provide an appropriate environment for new material synthesis. The method is inexpensive, simple and

fast to synthesize new materials.

[058] According to the above experimental conditions, one target was selected from Fe, Co, FePt and another target was selected from  $\text{Ge}_2\text{Sb}_2\text{Te}_5$  and GeTe. Three groups of phase change magnetic materials were synthesized. They comprised Co-Ge-Sb-Te, Fe-Ge-Sb-Te and Fe-Pt-Ge-Te systems. The composition of the materials produced were analysed by X-ray photoelectron spectroscopy (XPS). The crystal structures were analyzed by XRD. The magnetic, electrical and optical properties were all tested.

10

[059] As shown in Figures 2a to 2d, a conventional phase change material such as  $\text{Ge}_2\text{Sb}_2\text{Te}_5$  and GeTe exhibits antimagnetic property while phase change magnetic materials of the invention show magnetic property. In comparison, as shown in Figure 3a and 3b, the phase change magnetic material at crystalline state exhibits stronger magnetic property than the phase change magnetic material at amorphous state. This indicates that magnetic properties of phase change magnetic material vary with a state change of phase change magnetic material.

[060] Figure 4 is a microscope photo showing contrast change between amorphous and crystalline phases induced by a pulse laser for the phase change magnetic material according to one embodiment of the present invention. It indicates that the phase change magnetic material has different optical properties between amorphous and crystalline phases, which is similar with phase change material.

[061] Figure 5 shows a table of data comparing the electrical resistivity of conventional phase change material and the phase change magnetic material according to one embodiment of the present invention at amorphous and crystalline states. It indicates both the phase change material and the phase change magnetic material exhibit relatively large differences in electric properties between amorphous state and crystalline state. This means that phase change magnetic material has a similar electric property with conventional phase change

material.

[062] In summary, phase change magnetic materials of the invention not only display characteristics of conventional phase change materials, but also magnetic properties and characteristics of magnetic semiconductor materials.

[063] Figure 6a shows the XRD profile characterising the crystal structure of a sample  $\text{Fe}_{4.4}\text{Ge}_{14.8}\text{Sb}_{34.2}\text{Te}_{46.6}$ . As can be seen from the figure, the material exhibited crystalline peaks, thus confirming the existence of a crystalline phase for a Fe-Ge-Sb-Te system synthesised at 300°C. An analysis of the peak position identified that the crystal structure of the synthesised  $\text{Fe}_{4.4}\text{Ge}_{14.8}\text{Sb}_{34.2}\text{Te}_{46.6}$  to be similar to the crystal structure of  $\text{Ge}_2\text{Sb}_2\text{Te}_5$ .

[064] The second sample comprised a Fe-Pt-Ge-Te system that was synthesised according to the synthesis procedure described above. XPS analysis revealed the composition of the synthesised material to be  $\text{Fe}_{4.6}\text{Pt}_{7.3}\text{Ge}_{59.5}\text{Te}_{28.6}$ . Figure 6b shows the XRD profile characterising the crystal structure of the sample. As can be seen from the XRD profile, the material exhibited crystalline peaks, thus confirming the existence of a crystalline phase for a Fe-Pt-Ge-Te system synthesised at 300°C. An analysis of the peak position identified that the crystal structure of the synthesised  $\text{Fe}_{4.6}\text{Pt}_{7.3}\text{Ge}_{59.5}\text{Te}_{28.6}$  to be similar to the crystal structure of GeTe.

[065] Based on the experimental results shown in Figures 6a to 6b, it can be concluded that phase change magnetic materials have similar crystal structures as phase change materials, or the phase change material component used to synthesise it. One possible explanation for this property is that the atoms of magnetic materials have replaced the atoms of phase change materials in the unit cell of the phase change material, without destroying/disrupting its crystal structure. Therefore, the new material exhibits not only phase change effects due to its similar crystal structure as phase change material, but also magnetic effects caused by the presence of magnetic atoms in the crystal structure.

**EXAMPLE 2: Synthesis by sputtering****Synthesis procedure**

[066] Sputtering method can be employed to synthesize the invented  
5 material. In our sputtering system supplied by Leybold Vacuum and  
schematically illustrated in figure 7(b), two DC sputtering cathodes and two RF  
sputtering cathodes are installed and four targets, 2 of which are labelled DC01  
and DC02, and the other are labelled RF02 and RF01, are physically separated  
from each other. The positions of cathodes are under the targets in figure 7(b).  
10 The rotary substrate lies on a water-cooled rotation table and the substrate  
holder as placed 50mm above the targets. A preshutter **48**, which can be  
controlled to be open or close, is between the targets and substrate holder. The  
substrate, targets and shutter are placed in a vacuum chamber. Argon gas **50** is  
introduced into the chamber at low pressure and used as the sputtering gas. A  
15 gas plasma is struck using a power source and the gas becomes ionized. The  
ions are accelerated towards and bombards the target surface, the target atoms  
are broken off from the target and deposited on the substrate surface. The thin  
film of invented material is fabricated on the substrate by pausing substrate  
under the aimed target and opening the shutter during a programmed time  
20 controlled by a computer **60**.

What is claimed is:

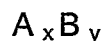
1. A phase change magnetic composite material exhibiting both magnetic effects and phase change effects, comprising:
  - 5           a phase change material component, and a ferromagnetic material component,  
              wherein  
              said phase change magnetic composite material has a crystalline phase associated therewith a first magnetic property and a first phase change property, and  
10           an amorphous phase associated therewith a second magnetic property and a second phase change property.
- 15       2. The phase change magnetic material of Claim 1, wherein said first and said second phase change property each comprises at least one property selected from electrical resistivity, thermal conductivity, light reflectivity, refractive index, absorption coefficient, dielectric constant, and thermal diffusion coefficient.
- 20       3. The phase change magnetic material of Claim 1 or 2, wherein said first and said second magnetic property each comprises at least one property selected from saturation magnetization, coercive field, anisotropy field, uniaxial anisotropy, squareness, remanence magnetization, saturation induction, Curie temperature and  
25       compensation temperature.
- 30       4. The phase change magnetic material of any one of Claims 1 to 3, wherein said material exhibits at least one physical state selected from a crystalline state, an amorphous state and a partial crystalline state.
5. The phase change magnetic material of Claim 4, wherein said material exhibits different electrical, magnetic, thermal, crystallization, and optical properties at each of said at least one physical state.

6. The phase change magnetic material of any one of Claims 1 to 5, wherein said material in the crystalline state has a coercivity of at least about 1 Oersteds.
- 5 7. The phase change magnetic material of any one of Claims 1 to 6, wherein the resistivity  $\rho$  of said material is in the range of  $1 \times 10^{-3} \Omega \text{cm} < \rho < 1 \times 10^3 \Omega \text{cm}$  at amorphous state and in the range of  $1 \times 10^{-4} \Omega \text{cm} < \rho < 1 \times 10^{-1} \Omega \text{cm}$  at crystalline state, the resistivity difference of said material  
10 between the amorphous state and the crystalline state being in the magnitude of 2 to  $10^6$ .
8. The phase change magnetic material of any one of Claims 1 to 7, wherein said phase change material component comprises at least one  
15 element selected from Group IIIB, IVB, VB or VIB of the Periodic Table.
9. The phase change magnetic material of Claim 8, wherein the phase change material component is an element selected from the group consisting of Te, S, Se, Po, P, As, Sb, Bi, Ge, Sn, Pb, Ga, In, and Ti.  
20
10. The phase change magnetic material of Claim 8 or 9, wherein the phase change component comprises a chalcogenide alloy.
11. The phase change magnetic material of Claim 10, wherein the  
25 chalcogenide alloy is selected from the group consisting of the following systems: Ge-Te, Sb-Te, Sn-Te, Sb-Se, In-Se, Ge-Sb-Te, Pt-Ge-Te, In-Sb-Te, As-Sb-Te, As-Ge-Te, Se-Sb-Te, Sn-Te-Se, Ge-Te-Sn, Sb-Se-Bi, Ga-Te-Se, In-Se-Ti, Ge-Te-Ti, Ge-Te-Sn-O, Ge-Te-Sn-Au, Ge-Te-Sn-Pd, Ge-Sb-Te-Se, Ag-In-Sb-Te and mixtures thereof.
- 30 12. The phase change magnetic material of Claim 11, wherein the chalcogenide alloy comprises a system having a formula selected from the group consisting of  $\text{Ge}_2\text{Sb}_2\text{Te}_5$ ,  $\text{GeSb}_2\text{Te}_4$ ,  $\text{GeSb}_3\text{Te}_4$ ,  $\text{GeSb}_4\text{Te}_7$ ,

$\text{In}_3\text{SbTe}_2$ ,  $\text{Ag}_5\text{In}_5\text{Sb}_{60}\text{Te}_{30}$ ,  $\text{Sb}_2\text{Se}_3$ ,  $\text{Sb}_2\text{Te}_3$ ,  $\text{Sb}_{70}\text{Te}_{30}$ ,  $\text{GeTe}$ ,  $\text{GeSb}$ , and  $\text{Sb}_2\text{Te}_3\text{-GeTe}$ .

13. The phase change magnetic material of any one of Claims 1 to 12,  
 5 wherein said ferromagnetic material component is selected from the group consisting of Fe, Co, Ni, FePt, CoPt, PdCo, TbFeCo, GdFeCo, CoCrPtB, CoCrPtTa.

14. The phase change magnetic material of any one of Claims 1 to 13,  
 10 wherein said material has a composition of formula (I):



wherein

15 A denotes the ferromagnetic material component;  
 B denotes the phase change material component;  
 x denotes the total atomic percentage of A, wherein  $1\% \leq x \leq 50\%$ , and  
 y denotes the total atomic percentage of B, wherein  $50\% \leq y \leq 99\%$ .

20 15. The phase change magnetic material of any one of Claims 1 to 13, having a composition of formula (II):



wherein

25 A denotes a ferromagnetic component;  
 B denotes the phase change component;  
 C denotes a manganese compound component;  
 x denotes the total atomic percentage of A, wherein  $1\% \leq x \leq 40\%$ ,  
 y denotes the total atomic percentage of B, wherein  $40\% \leq y \leq 98\%$ ,  
 30 and  
 z denotes the total atomic percentage of C, wherein  $1\% \leq z \leq 20\%$ .

16. The phase change magnetic material of Claim 14 or 15, wherein

A is selected from the group consisting of Co, Fe Ni and Fe-Pt,  
and

B is selected from the group consisting of Ge-Sb-Te, Ge-Te, GeSb,  
InSbTe,  $\text{Sb}_{70}\text{Te}_{30}$ ,  $\text{Sb}_2\text{Te}_3$ , Sb, Te and Ag-In-Sb-Te.

5

17. The phase change magnetic material of any one of Claims 14 to 16,  
selected from the group consisting of  $\text{Co}_{6.3}\text{Ge}_{31.1}\text{Sb}_{27.1}\text{Te}_{35.5}$ ,  $\text{Co}_{3.6}$   
 $\text{Ge}_{20.8}\text{Sb}_{30.5}\text{Te}_{44.9}$ ,  $\text{Co}_{2.8}\text{Ge}_{17.9}\text{Sb}_{31.9}\text{Te}_{47.1}$ ,  $\text{Co}_{6.1}\text{Ge}_{14.3}\text{Sb}_{33}\text{Te}_{46.5}$ ,  
 $\text{Co}_{3.0}\text{Ge}_{18.5}\text{Sb}_{30.1}\text{Te}_{48.2}$ ,  $\text{Co}_{5.0}\text{Ge}_{16.9}\text{Sb}_{31.6}\text{Te}_{46.5}$ ,  $\text{Co}_{1.5}\text{Ge}_{17.3}$   
10  $\text{Sb}_{32.9}\text{Te}_{48.3}$ ,  $\text{Co}_{5.4}\text{Ge}_{17.2}\text{Sb}_{30.5}\text{Te}_{46.9}$ ,  $\text{Co}_{2.0}\text{Ge}_{17.7}\text{Sb}_{32.5}\text{Te}_{47.8}$ ,  $\text{Co}_{5.8}$   
 $\text{Ge}_{17.1}\text{Sb}_{32.3}\text{Te}_{44.8}$ ,  $\text{Co}_{4.6}\text{Ge}_{14.9}\text{Sb}_{33.4}\text{Te}_{47.1}$ ,  $\text{Co}_{10.1}\text{Ge}_{14.4}\text{Sb}_{34.6}\text{Te}_{40.9}$ ,  
 $\text{Co}_{26.1}\text{Ge}_{17.2}\text{Sb}_{22.1}\text{Te}_{34.6}$ ,  $\text{Co}_{5.6}\text{Ge}_{15.8}\text{Sb}_{33.6}\text{Te}_{45}$ ,  $\text{Fe}_{20.2}\text{Ge}_{21.5}\text{Sb}_{16.9}$   
 $\text{Te}_{41.4}$ ,  $\text{Fe}_{9.2}\text{Ge}_{16.3}\text{Sb}_{27.4}\text{Te}_{47.2}$ ,  $\text{Fe}_{4.7}\text{Ge}_{18.5}\text{Sb}_{28.1}\text{Te}_{48.6}$ ,  $\text{Fe}_{4.4}\text{Ge}_{14.8}$   
 $\text{Sb}_{34.2}\text{Te}_{46.6}$ ,  $\text{Fe}_{11.1}\text{Ge}_{16}\text{Sb}_{25.9}\text{Te}_{47.1}$ ,  $\text{Fe}_{1.0}\text{Ge}_{15.7}\text{Sb}_{35.2}\text{Te}_{48.2}$ ,  $\text{Fe}_{7.2}$   
15  $\text{Ge}_{14.7}\text{Sb}_{32.9}\text{Te}_{45.2}$ ,  $\text{Fe}_{28.2}\text{Pt}_{32.4}\text{Ge}_{30.0}\text{Te}_{9.3}$ ,  $\text{Fe}_{4.1}\text{Pt}_{4.2}\text{Ge}_{64.5}\text{Te}_{27.1}$ ,  
 $\text{Fe}_{2.1}\text{Pt}_{5.5}\text{Ge}_{63.9}\text{Te}_{28.4}$ ,  $\text{Fe}_{1.1}\text{Pt}_{2.7}\text{Ge}_{64.3}\text{Te}_{31.9}$ ,  $\text{Fe}_{4.6}\text{Pt}_{7.3}\text{Ge}_{59.5}\text{Te}_{28.6}$ ,  
 $\text{Fe}_{5.0}\text{Pt}_{6.8}\text{Ge}_{59.6}\text{Te}_{28.6}$ ,  $\text{Fe}_{1.1}\text{Pt}_{1.1}\text{Ge}_{50.4}\text{Te}_{31.1}$ ,  $\text{Fe}_{4.8}\text{Pt}_{4.6}\text{Ge}_{58.2}\text{Te}_{32.4}$ ,  
 $\text{Fe}_{1.2}\text{Pt}_{2.5}\text{Ge}_{54.2}\text{Te}_{41.9}$ , and  $\text{Fe}_{1.0}\text{Pt}_{2.0}\text{Ge}_{62.1}\text{Te}_{34.9}$ .

20 18. The phase change magnetic material of any one of Claims 1 to 17,  
wherein the similar crystal structure of the material is at least  
substantially similar to the phase change material component.

25 19. The phase change magnetic material of any one of Claims 1 to 18,  
wherein the unit cell of the crystal structure of the material comprises at  
least one atom of the phase change material component and at least  
one atom of the magnetic material component.

30 20. The phase change magnetic material of any one of Claims 1 to 19,  
wherein said material is synthesized by a method selected from laser  
ablation, laser synthesis, sputtering, ion plating, chemical vapor  
deposition (CVD), plasma enhanced chemical vapor, metal organic  
chemical vapor deposition, spin coating, molecular beam epitaxy, top-

seeded solution growth, thermal pressing, vacuum melting, and crystal growth.

21. Use of the phase change magnetic material of any one of Claims 1 to  
5 20 in a device selected from optical media, phase change random  
access memory (PCRAM) devices, magnetic random access memory  
(MRAM) devices, solid state memory devices, sensor devices, logical  
devices, artificial neuron network, cognitive devices, three level device,  
control device, SOC device and semiconductors.

10

22. A phase change magnetic composite material for use in optical media,  
phase change random access memory (PCRAM) devices, magnetic  
random access memory (MRAM) devices, solid state memory devices,  
sensor devices, logical devices, cognitive devices, artificial neuron  
15 network, three level device, control device, SOC device, and  
semiconductors, said material, comprising:

a phase change material component, and a ferromagnetic  
material component,

wherein

20 said material exhibits both magnetic effects and phase change  
effects.

23. An optical recording medium for recording information, said medium  
comprising

25 a phase change material component, and a ferromagnetic  
material component,

wherein

said phase change magnetic composite material has

a crystalline phase associated therewith a first magnetic property  
and a first phase change property, and  
30

an amorphous phase associated therewith a second magnetic  
property and a second phase change property.