



\*159159\*

## A DATA STORAGE MEDIA AND A METHOD FOR FORMING THEREOF

### Field Of Invention

The present invention relates generally to a data storage media and a method for forming thereof. In particular, the invention relates to a method for forming a data storage media that utilizes different physical properties of a laser beam for providing a multi-level data storage structure capable of multi-dimensional data storage for achieving a high-density and high data transfer rate optical recording medium.

### Background

Optical data storage density is typically determined by the diameter of a light spot formed on a recording surface by irradiation of laser. The diameter  $d$  of the light spot is described as:

$$d = \frac{\lambda}{(2NA)}$$

where  $\lambda$  is the wavelength of the laser and NA is the numerical aperture. A smaller minimum spot diameter results in higher density data recording and storage. Therefore, in order to increase the recording density of an optical recording medium, shorter wavelength of laser and higher numerical aperture (NA) of objective lenses are used. However, there are disadvantages to shortening the wavelength of the laser and increasing the numerical aperture to achieve higher recording density. A coma created by a tilted optical disk increases proportionally in magnitude to the cube of the numerical aperture. Therefore, a larger numerical aperture results in a substantially smaller margin for angular tilt of the optical disk. Tilting the optical disk slightly causes the laser to create a blurred spot thereon, thereby resulting in higher recording density not being achievable.

It is known in the art that a Blu-ray disk has a recording density of not less than 23 GB and a data transfer rate as high as 36 Mbps. However, the optical system of the Blu-ray disk uses a laser wavelength of 405 nm and an objective lens with a numerical aperture of 0.85. As a result, the Blu-ray disk requires a thin light transmission layer of about 0.1 mm to achieve a sufficient tilt margin. Unfortunately,



\*G00002\*

such a thin light-transmission layer cannot be produced by conventional injection molding machines. Furthermore, its strict thickness variation within a tolerance of 0.2  $\mu\text{m}$  results in relatively higher production cost when compared with conventional optical disks. Additionally, a shorter working distance of approximately 0.3mm  
5 limited by use of the high numerical aperture objective lens leads to a higher risk of collision between the optical disk and the lens.

Use of multiple recording layers is also known in the art for achieving high recording density. For example, a dual-layer optical recording medium was proposed in order to  
10 double the recording density by recording on two recording layers from the same side of the disk. However, it is a technical challenge to achieve large transmittance for the first layer of the dual layers as a material, for example a phase change material, becomes less transparent to laser with increased thickness.

15 PCT Publication No. 02/063620 A2 (Arieli) discloses a solution for overcoming the problem that during the reading process, each layer interferes optically with the other layers. Arieli describes an optical data storage media comprising multiple recording layers and a focusing system for focusing laser onto the intended recording layer for reading therefrom. However, the need for refocusing the laser for the different  
20 recording layers in Arieli results in a slower rate of data retrieval. Furthermore, the recording density of each recording layer is dependent on the accuracy of the focusing system.

US Patent No. 5,838,653 (Fan) discloses an optical information storage system  
25 comprising multiple information storage layers. Each storage layer or portion thereof is wavelength-specific and polarization-specific. Information can only be read from a particular storage layer by a laser beam with a specific wavelength and polarization corresponding therewith. However, Fan requires a spectrum of lasers catering to the range of wavelengths and polarizations required. The use of a modulator for varying  
30 the wavelength and polarization of a single laser is complex and slows the rate of data retrieval.

Hence, this clearly affirms a need for a method for forming an improved data storage media with high recording density and high data transfer rate.

### Summary

5 A data storage media and a method for fabrication thereof is described hereinafter for overcoming the foregoing problems arising from conventional data storage media structures.

10 An object of the invention is to provide a data storage media that has a high recording density and a high rate of data recording and data reproduction. Generally, the data storage media preferably has two recording layers with the two recording layers being able to record and reproduce data and information through the utilization of at least two physical properties thereof. Each of the at least two physical properties being one of reflectance, polarization, time, frequency, wavelength and electronic spin of light  
15 being one of irradiating and reflected from the two recording layers.

The formed data storage media comprises a substrate and a recording layer having a phase change layer and a magneto-optical layer formed on the substrate. The data storage media utilizes two physical properties, namely, amplitude and polarization  
20 level of laser reflected therefrom. Laser directed at the data storage media penetrates the substrate or the cover layer to heat up said recording layer. By adjusting the laser's power, the phase change layer can be switched between a crystalline state and an amorphous state. The phase change layer in the completely amorphous state provides substantially minimal relative reflectance while the phase change layer in the  
25 completely crystalline state provides substantially maximal reflectance. Discretised variation in the laser's power provides for different possible reflectance levels. Therefore, multi-level recording can be realized in the phase-change recording layer using different levels of reflectance.

30 When the laser is directed onto said recording layer, the magneto-optical layer is heated up concurrently. When the temperature of the magneto-optical layer reaches the Curie temperature, or the Compensation temperature, thereof, a bias magnetic field is applied to vary the polarization level in the magneto-optical layer. The

polarization of the reflected or transmitted laser or light beam can be detected through magneto-optical effects. Therefore, the reflectance amplitude and the polarization level of laser reflected from the data storage media are combined to provide a medium for multi-dimensional multi-level recording and storage.

5

Therefore, in accordance with a first aspect of the invention, there is disclosed a data storage media comprising:

a substrate having a mounting face, the substrate being formed with at least one groove therein along the mounting face;

10

a first recording layer having a first face and a second face outwardly opposing the first face, the first recording layer having a first plurality of data storage locations, each of the first plurality of data storage locations having a first physical property being variable through at least two states for indicating a first data value; and

a second recording layer adjacent to the second face of the first recording layer, the first recording layer being stacked between the substrate and the second recording layer, the second recording layer having a second plurality of data storage locations, each of the second plurality of data storage locations having a second physical property being variable through at least two states for indicating a second data value, the first physical property being distinct from the second physical property,

20

wherein each of the first recording layer and the second recording layer is structurally supported by the substrate and each of the first recording layer and the second recording layer being stacked over and opposing the mounting face of the substrate, and

25

wherein a processed beam having first and second physical properties is processed from a laser beam directed towards the first and second recording layers, the laser beam being processed initially by the corresponding one of the first plurality of data storage locations with one of the at least two states thereof determining the first physical property, and subsequently by the corresponding one of the second plurality of data storage locations with one of the at least two states thereof determining the second physical property, the first and second physical properties of the processed beam being respectively indicative of the first and second data values of

30

the corresponding one of the first plurality of data storage locations and the corresponding one of the second plurality of data storage locations.

In accordance with a second aspect of the invention, there is disclosed a method for  
5 forming a data storage media comprising the steps of:

forming a substrate having a mounting face, the substrate being formed with at least one groove therein along the mounting face;

forming a first recording layer having a first face and a second face outwardly opposing the first face, the first recording layer having a first plurality of data storage  
10 locations, each of the first plurality of data storage locations having a first physical property being variable through at least two states for indicating a first data value; and

forming a second recording layer adjacent to the second face of the first recording layer, the first recording layer being stacked between the substrate and the second recording layer, the second recording layer having a second plurality of data  
15 storage locations, each of the second plurality of data storage locations having a second physical property being variable through at least two states for indicating a second data value, the first physical property being distinct from the second physical property,

wherein each of the first recording layer and the second recording layer is  
20 structurally supported by the substrate and each of the first recording layer and the second recording layer being stacked over and opposing the mounting face of the substrate, and

wherein a processed beam having first and second physical properties is processed from a laser beam directed towards the first and second recording layers,  
25 the laser beam being processed initially by the corresponding one of the first plurality of data storage locations with one of the at least two states thereof determining the first physical property, and subsequently by the corresponding one of the second plurality of data storage locations with one of the at least two states thereof determining the second physical property, the first and second physical properties of  
30 the processed beam being respectively indicative of the first and second data values of the corresponding one of the first plurality of data storage locations and the corresponding one of the second plurality of data storage locations.

**Brief Description Of The Drawings**

Embodiments of the invention are described hereinafter with reference to the following drawings, in which:

5

FIG. 1 shows a process flow diagram illustrating a method for forming a data recording device according to a first embodiment of the invention;

10 FIG. 2 shows a partial front sectional elevation of a data storage media with a first recording layer and a second recording layer formed on a substrate according to the method of FIG. 1;

FIG. 3 shows a process flow diagram illustrating a method for forming a data recording device according to a second embodiment of the invention;

15

FIG. 4 shows a partial front sectional elevation of the data storage media of FIG. 2 with a reflective layer formed on the second recording layer according to the method of FIG. 3;

20 FIG. 5 shows a process flow diagram illustrating a method for forming a data recording device according to a third embodiment of the invention;

FIG. 6 shows a partial front sectional elevation of the data storage media of FIG. 4 with a first protective layer and a second protective layer formed therein according to  
25 the method of FIG. 5;

FIG. 7 shows a process flow diagram illustrating a method for forming a data recording device according to a fourth embodiment of the invention;

30 FIG. 8 shows a partial front sectional elevation of the data storage media of FIG. 6 with an interface layer formed between the first recording layer and the second recording layer according the method of FIG. 7;

FIG. 9 shows a process flow diagram illustrating a method for forming a data recording device according to a fifth embodiment of the invention;

FIG. 10 shows a partial front sectional elevation of the data storage media of FIG. 2 with the substrate being replaced by a cover layer and the substrate being formed over the reflective layer according to the method of FIG. 9;

FIG. 11 shows a process flow diagram illustrating a method for forming a data recording device according to a sixth embodiment of the invention;

FIG. 12 shows a partial front sectional elevation of the data storage media of FIG. 6 with the substrate being replaced by a cover layer and the substrate being formed over the reflective layer according to the method of FIG. 11;

FIG. 13 shows a process flow diagram illustrating a method for forming a data recording device according to a seventh embodiment of the invention;

FIG. 14 shows a partial front sectional elevation of the data storage media of FIG. 8 with the substrate being replaced by a cover layer and the substrate being formed over the reflective layer according to the method of FIG. 13;

FIG. 15 a response plot demonstrating multi-level reflectance for said sample disk formed using the structure of FIG. 8 and the method of FIG. 7 when a laser beam at wavelengths of 780, 650 and 405 nm are applied theretothereto;

FIG. 16 shows a response plot obtained from a static tester when applied to the sample disk formed using the structure of FIG. 8 and the method of FIG. 7; and

FIG. 17 shows a response plot demonstrating that two levels of polarization are obtainable from the sample disk formed using the structure of FIG. 8 and the method of FIG. 7 with a 650 nm wavelength laser beam.

### Detailed Description

A method for forming a data storage media for addressing the foregoing problems is described hereinafter.

5

A first embodiment of the invention, a method 100 for forming a data storage media 20, is described with reference to FIG. 1. The data storage media 20 is described with reference to FIG. 2, which shows a partial front sectional elevation of the data storage media 20.

10

As shown in FIG. 2, the data storage media 20 comprises a substrate 22 which is formed in a step 110. The data storage media 20 further comprises a storage layer 24 formed and stacked adjacent to the substrate 22. The substrate 22 and the storage layer 24 are shaped and dimensioned to provide the data storage media 20 with preferably a disc shape.

15

The storage layer 24 comprises a first recording layer 26 and a second recording layer 28. The first recording layer 26 is first formed over the substrate 22 in a step 112 with the second recording layer 28 being subsequently formed thereover in a step 114. The first recording layer 26 has a first face 30a and a second face 30b outwardly opposing the first face 30a. The second recording layer 28 is stacked adjacent to the second face 30b of the first recording layer 26 with the substrate 22 opposing the first face 30a of the first recording layer 26.

20

The substrate 22 is for structurally supporting the first recording layer 26 and the second recording layer 28. The substrate 22 is preferably made from one of polycarbonate, polymethyl methacrylate (PMMA), amorphous polyolefin, ceramic, glass, metal, alloy and paper. The substrate preferably has a thickness within a range of 0.3mm to 2mm and a diameter of, for example, substantially 120mm.

25

The first recording layer 26 comprises a first plurality of data storage locations 32a and the second recording layer 28 comprises a second plurality of data storage locations 32b. The first recording layer 26 is made from a first material with each of

30

the first plurality of data storage locations 32a having a first physical property being variable through at least two states for indicating a first data value. The second recording layer 28 is made from a second material with each of the second plurality of data storage locations 32b having a second physical property and being variable  
5 through at least two states for indicating a second data value.

Each of the first physical property and the second physical property preferably corresponds with one of reflectance, polarisation, time, frequency, wavelength and electronic spin of light being one of transmitted to and reflected from the first  
10 recording layer 26 and the second recording layer 28.

The first material and the second material are preferably different with the first physical property being different and distinct from the second physical property. Alternatively, the first material and the second material are the same. At least one of  
15 the first material and the second material is process-treatable to thereby differentiate the first physical property from the second physical property. Alternatively, the fabrication process of at least one of the first recording layer 26 and the second recording layer 28 is alterable for differentiating the first physical property from the second physical property.

20 Following the step 114, a dummy layer 66 is formed over the second recording layer in a step 116. The dummy layer 66 is stacked adjacent to the second recording layer 28 with the second face 30b of the first recording layer 26 opposing the dummy layer 66 and the first recording layer 26 being stacked between the substrate 22 and the  
25 dummy layer 66. Preferably, the dummy layer 66 is made from at least one of polycarbonate, polymethyl methacrylate (PMMA), amorphous polyolefin, carbonate resin, ultraviolet light curable resin, ceramic and glass and has a thickness substantially between a range of 0.3mm and 2.0mm. Alternatively, the substrate is initially formed by one of injection molding and extrusion molding and subsequently  
30 bonded onto the storage layer 24 in the step 116.

The data storage media 20 further comprises data axes 46 formed substantially perpendicular to the second face 30b of the first recording layer 26. Each data axis 46

extends correspondingly through one of the first plurality of data storage locations 32a or one of the second plurality of data storage locations 32b. A laser beam 48 is directable towards the first recording layer 26 and the second recording layer 28 along one of the data axes 46 to obtain a processed beam 50 therefrom. The laser beam 48  
5 is directed through the substrate 20 which is preferably light transmissible. The processed beam has a first physical property and a second physical property.

The laser beam 48 coincides with each of the first recording layer 26 and the second recording layer 28 for forming a mark on each of the first recording layer 26 and the  
10 second recording layer 28, with the mark on each thereof being coincident with one of the first plurality of data storage locations 32a and one of the second plurality of data storage locations 32b respectively and being representative of data.

When the laser beam 48 is directed towards the first face 30a of the first recording  
15 layer 26 along the one of the data axes 46, the laser beam 48 is processed initially by the corresponding one of the first plurality of data storage locations 32a with one of the at least two states thereof determining the first physical property, and subsequently by the corresponding one of the second plurality of data storage locations 32b with one of the at least two states thereof determining the second  
20 physical property. The determined first physical property and second physical property of the processed beam 50 indicates the first data value and second data value of the corresponding one of the first plurality of data storage locations 32a and the corresponding one of the second plurality of data storage locations 32b respectively.

25 The first physical property is preferably reflectance and the second physical property is preferably optical polarization. One of the at least two states of each of the first plurality of data storage locations 32a corresponds with reflectance level thereof and one of the at least two states of each of the second plurality of data storage locations 32b corresponds with optical polarization level thereof.

30 However, the first physical property and the second physical property of the invention, the data storage media 20, are respectively not limited to reflectance and optical polarisation. Alternatively, at least one of the first physical property and the

second physical property of the data storage media 20 is one of reflectance, polarization, time, frequency, wavelength and electronic spin of light being transmitted to and reflected from the first recording layer 26 and the second recording layer 28.

5

The first material is preferably made from a combination of one or more elements, for example, chalcogenide elements. The one or more elements are preferably selected from Te, Ge, Sb, Ga, Bi, Pd, Po, Sn, As, Ag, In, Se, S, Si, P and organic recording materials. The first material enables the first recording layer 26 to function as a phase  
10 change material with the at least two states thereof being at least two crystallinity levels. The first physical property is variable between a substantially crystalline state and a substantially amorphous state with the at least two crystallinity levels extending and forming graduations therebetween. Therefore, varying a portion of the first recording layer 26 between the substantially crystalline state and the substantially  
15 amorphous state varies at least one of reflectance and transmittance of the portion of the first recording layer 26.

The first physical property of the first material is variable by the laser beam 48 having a magnitude which corresponds with the at least two crystallinity levels.

20

When the corresponding one of the first plurality of data storage locations 32a is in a completely amorphous state, a substantially low reflectance is achieved. Increasing the crystallinity of the corresponding one of the first plurality of data storage locations 32a results in an increase of the reflectance thereof. When the corresponding one of  
25 the first plurality of data storage locations 32a is in a completely crystalline state, a substantially high reflectance is achieved.

The second material is preferably made from a combination of one or more of Fe, Co and Ni and one or more of Tb, Cr, Gd, Dy, Sm, Nd, Mn, Pt, Pd, Al, Au, Ag, Cu, Mg.

30 The second material enables the second recording layer 28 to function as a magneto-optical material with the at least two states thereof being at least two polarization states. The second physical property of the second material is variable between two optical polarization levels with the at least two polarization states extending and

forming graduations therebetween. Therefore, varying the second physical property of a portion of the second recording layer 28 between the two optical polarization levels varies the at least two polarization states of the portion of the second recording layer 28.

5

The second recording layer 28 preferably has substantial magnetic anisotropy with the second material having high coercivity forces to enable small recording data bits to be formed, thereby increasing the quantity of the second plurality of data storage locations 32b on the second recording layer 28.

10

The second physical property of the second material is variable by heat generated by the laser beam 48 on the portion of the second material to achieve the Curie temperature, or the compensation temperature, thereof and a field direction of a magnetic field applied thereto. The magnetic field is generated by one of a permanent magnet and an electromagnet.

15

Each of the first recording layer 26 and the second recording layer 28 is formed by deposition of the corresponding one of the first material and the second material by one of vacuum deposition, electron beam vacuum deposition, ion plating, chemical vapor deposition, plasma CVD, laser deposition, spinning coating, molecular beam epitaxy and sputtering methods.

20

Preferably, the first recording layer 26 and the second recording layer 28 are being doped by further sputtering of a mixture comprising Argon and at least one of Nitrogen and Oxygen thereto.

25

Magnitude ranges and level ranges are preferably pre-defined to facilitate use of the data storage media 20. The magnitude ranges are associated with a first plurality of values comprising the first data value. The level ranges are associated with a second plurality of values comprising the second data value.

30

The first physical property and the second physical property of the processed beam 50 are respectively magnitude and optical polarization level thereof. Therefore, detection

of the magnitude and the optical polarization level of the processed beam 50 and identifying one of the magnitude ranges and one of the level ranges corresponding therewith enables the corresponding one of the plurality of first values and the corresponding one of the plurality of second values to be identified.

5

Therefore, the first data value and the second data value are stored on respectively the first recording layer 26 and the second recording layer 28 at one of the plurality of data storage locations 32a/32b of each thereof wherefrom the processed beam 50 is reflected to obtain the corresponding one of the plurality of first values and the

10

corresponding one of the plurality of second values.

The one of the first plurality of data storage locations 32a and the one of the second plurality of data storage locations 32b along each of the data axes 46 collectively store at least two numerical bits of data in combination.

15

However, it is possible to achieve four distinguishable states for the first physical property, for example four distinct levels of reflectance, and two distinct states for the second physical property, for example two polarization levels. Therefore, the one of the first plurality of data storage locations 32a and the one of the second plurality of data storage locations 32b along each of the data axes 46 can collectively achieve a combined 8 levels of recording translating to 3 binary bits of data storage thereat. The first recording layer 26 and the second recording layer 28 provide a multi-level recording structure to the data storage media 20. The variable first physical property of each of the first plurality to data storage locations 32a and the variable second physical property of each of the second plurality of data storage locations 32b cater to the multi-dimensional data recording capability of each of the first recording layer 26 and the second recording layer 28. Therefore, the storage device 20 functionally achieves a multi-dimensional multi-level optical recording medium.

20

25

30

Additionally, one of an AND operator, an OR operator, a NAND operator and a NOR operator is applicable to the obtained first data value and second data value to obtain further data therefrom.

A second embodiment of the invention, a method 120 of FIG. 3 for forming a data storage media 70 as shown in FIG. 4, comprises of four main steps: a step 110 for forming a substrate 22, a step 112 for forming a first recording layer 26, a step 114 for forming a second recording layer 28 and a step 116 for forming a dummy layer 66.

5 The descriptions in relation to the structural configurations of and positional relationships between the substrate 22, the dummy layer 66, the storage layer 24 and the first plurality of data storage locations 32a and the second plurality of data storage locations 32b corresponding with the first recording layer 26 and the second recording layer 28 with reference to the first embodiment of FIG. 2 are incorporated herein.

10

The data storage media 70 further comprises a reflective layer 72 stacked adjacent to a face of the second recording layer 28 which faces away from the first recording layer 26. The reflective layer 72 is formed in a step 122 subsequent to the step 114 of forming the second recording layer 28. Once the reflective layer 72 has been formed  
15 on the second recording layer 28, the dummy layer 66 is formed and bonded thereonto in the step 116.

The reflective layer 72 is for dissipating excessive heat accumulated during data read/write processes wherein heat is generated by the laser beam 48 upon its  
20 application to the second recording layer 28. Preferably, the reflective layer 72 is made from at least one of Au, Al, Ag, Ti, Cr, Cu, Pd, W, Pt and alloys thereof.

A third embodiment of the invention, a method 130 as shown in FIG. 5 for forming a data storage media 80 as shown in FIG. 6, comprises five main steps: a step 110 for forming a substrate 22, a step 112 for forming a first recording layer 26, a step 114 for forming a second recording layer 28, a step 116 for forming a dummy layer 66 and a  
25 step 122 for forming a reflective layer 72. The descriptions in relation to the structural configurations of and positional relationships between the substrate 22, the dummy layer 66, the storage layer 24 and the reflective layer 72 and the first plurality  
30 of data storage locations 32a and the second plurality of data storage locations 32b corresponding with the first recording layer 26 and the second recording layer 28 with reference to FIG. 4 are incorporated herein.

The data storage media 80 further comprises a first protective layer 82 and a second protective layer 84. Each of the first protective layer 82 and the second protective layer 84 preferably has a thickness that is substantially between a range of 1nm to 250 nm.

5

In a step 132, the first protective layer 82 is formed over the substrate 22 prior to the first recording layer 26 being formed thereon in the step 112. Following the second recording layer 28 being formed in the step 114, the second protective layer 84 is formed thereon in a step 134. Eventually, the structure of the data storage media formed from the method 130 is such that the first protective layer 82 is stacked adjacent to the first face 30a of the first recording layer 26 while the second protective layer 84 is stacked adjacent to the second recording layer 28 and interfacing the reflective layer 72 and the second recording layer 28. Additionally, the first recording layer 26 and second recording layer 28 are disposed between and interfacing the first protective layer 82 and the second protective layer 84. Each of the first and second protective layers 82/84 is made from at least one of an oxide, a nitride, a chalcogenide element, fluoride and carbide of a metal.

Alternatively, each of the first and second protective layers 82/84 is a dielectric layer preferably made from at least one of SiO<sub>2</sub>, SiO, Al<sub>2</sub>O<sub>3</sub>, GeO<sub>2</sub>, In<sub>2</sub>O<sub>3</sub>, TeO<sub>2</sub>, TiO<sub>2</sub>, Ta<sub>2</sub>O<sub>5</sub>, MoO<sub>3</sub>, WO<sub>3</sub>, Si<sub>3</sub>N<sub>4</sub>, AlN, BN, TiN, ZnS, CdS, CdSe, ZnTe, AgF, PdF<sub>2</sub>, SiC and mixtures thereof. The first protective layer 82 and the second protective layer 84 are to prevent the first recording layer 26 and the second recording layer 28 from corroding.

25

A fourth embodiment of the invention, a method 140 as shown in FIG. 7 for forming a data storage media 90 as shown in FIG. 8, comprises seven main steps: a step 110 for forming a substrate 22, a step 112 for forming a first recording layer 26, a step 114 for forming a second recording layer 28, a step 116 for forming a dummy layer 66, a step 122 for forming a reflective layer 72 and steps 132 and 134 for respectively forming a first protective layer 82 and a second protective layer 84. The descriptions in relation to the structural configurations of and positional relationships between the substrate 22, the dummy layer 66, the storage layer 24, the reflective layer 72, the first

30

protective layer 82 and the second protective layer 84 and the first plurality of data storage locations 32a and the second plurality of data storage locations 32b corresponding with the first recording layer 26 and the second recording layer 28 with reference to the third embodiment of FIG. 6 are incorporated herein.

5

The storage layer 24 of the data storage media 90 further comprises an interface layer 92 stacked between the first recording layer 26 and the second recording layer 28. Following the step 112 of forming the first recording layer 26, the interface layer 92 is formed on the first recording layer 26 in a step 142. Preferably, the interface layer 92 is optically transparent to the laser beam 48 directed therethrough. The interface layer 92 is preferably made from one of a dielectric material and a metallic material being one of magnetic and non-magnetic. The interface layer 92 enables improved regulation and control of the second recording layer's temperature.

15 A fifth embodiment of the invention, a method 150 for forming a data storage media 95, is shown in FIG. 9. The data storage media 94 as shown in FIG. 10, comprises two main elements: a substrate 22, and a storage layer 24 having a first recording layer 26 and a second recording layer 28. The descriptions in relation to the structural configurations of and positional relationships between the storage layer 24, and the first plurality of data storage locations 32a and the second plurality of data storage locations 32b corresponding with the first recording layer 26 and the second recording layer 28 with reference to the first embodiment of FIG. 2 are incorporated herein.

The substrate 22 of the first embodiment of the invention is replaced with a cover layer 95 stacked adjacent to the first face 30a of the first recording layer 26. The cover layer 97 preferably has an optical transmittance of at least 80% and a thickness substantially between a range of 10um to 400um. In the fifth embodiment of the invention, the substrate 22 has been spatially altered and disposed over a face of the second recording layer 28 outwardly opposing the first recording layer 26. The second recording layer 28 is therefore stacked between the first recording layer 26 and the substrate 22.

30

In the method 144, the substrate 22 is formed in a step 146. The second recording layer 28 is then formed over the substrate 22 in a step 147 followed by the first recording layer 26 being formed thereon in a step 148. Eventually in a step 149, the cover layer 95 is formed and bonded onto the first recording layer 26. Preferably, the cover layer 95 is formed by one of solvent casting, polymerization casting, spin coating, die coating and pressure-based lamination. Preferably, the cover layer 95 further undergoes a curing process once it has been formed.

The data storage media 94 in the fifth embodiment is preferably for a short wavelength laser light source, for example 405 nm violet-blue laser diode, is used for generating the laser beam 48. In the fifth embodiment, the laser beam is transmitted into data storage media 94 through the cover layer 95. The cover layer 95 is preferably made of at least one of polycarbonate, cellulose triacetate and polydicyclopentadiene, (methyl)methacrylate, and (methyl)propylacrylate and formed by one of solvent casting, polymerization-casting and die-coating methods. Additionally, the cover layer 95 is further formable by one of spin-coating followed by UV curing and lamination through application of a pressure-sensitive adhesive layer. Thickness tolerance of the cover layer 95 is preferably not more than 3  $\mu\text{m}$ .

A sixth embodiment of the invention, a method 150 for forming a data storage media 96, is shown in FIG. 11. The data storage media 96 as shown in FIG. 12, comprises five main elements: a substrate 22, a storage layer 24 having a first recording layer 26 and a second recording layer 28, a reflective layer 72, a first protective layer 82 and a second protective layer 84. The descriptions in relation to the structural configurations of and positional relationships between the storage layer 24, the reflective layer 72, the first protective layer 82 and the second protective layer 84 and the first plurality of data storage locations 32a and the second plurality of data storage locations 32b corresponding with the first recording layer 26 and the second recording layer 28 with reference to the third embodiment of FIG. 6 are incorporated herein.

The substrate 22 of the third embodiment of the invention is replaced with a cover layer 97 stacked adjacent to the first face 30a of the first recording layer 26. The

cover layer 97 preferably has an optical transmittance of at least 80% and a thickness substantially between a range of 10um to 400um. In the sixth embodiment of the invention, the substrate 22 has been spatially altered and disposed over a face of the reflective layer 72 outwardly opposing the second protective layer 84. The reflective layer 72 is therefore stacked between the second protective layer 84 and the substrate 22.

In the method 150, the substrate 22 is formed in a step 152. The reflective layer 72 is then formed over the substrate 22 in a step 154 followed by the second protective layer 84 being formed thereon in a step 156. Followingly, the second recording layer 28 and the first recording layer 26 are formed on the second protective layer 84 respectively in a step 158 and a step 160. The first protective layer 82 is then formed over the first recording layer 26 in a step 162. Eventually in a step 164, the cover layer 97 is formed and bonded onto the first protective layer 82. Preferably, the cover layer 97 is formed by one of solvent casting, polymerization casting, spin coating, die coating and pressure-based lamination. Preferably, the cover layer 97 further undergoes a curing process once it has been formed.

The data storage media 96 in the sixth embodiment is preferably for a short wavelength laser light source, for example 405 nm violet-blue laser diode, is used for generating the laser beam 48. In the sixth embodiment, the laser beam is transmitted into data storage media 96 through the cover layer 97. The cover layer 97 is preferably made of at least one of polycarbonate, cellulose triacetate and polydicyclopentadiene, (methyl)methacrylate, and (methyl)propylacrylate and formed by one of solvent casting, polymerization-casting and die-coating methods. Additionally, the cover layer 97 is further formable by one of spin-coating followed by UV curing and lamination through application of a pressure-sensitive adhesive layer. Thickness of the cover layer 97 is preferably not more than 3  $\mu\text{m}$ .

A seventh embodiment of the invention, a method 170 for forming a data storage media 98, is shown in FIG. 13. The data storage media 98 as shown in FIG. 14, comprises seven main elements: a substrate 22, a storage layer 24 having a first

recording layer 26 and a second recording layer 28, a reflective layer 72, a first protective layer 82, a second protective layer 84 and interface layer 92. The descriptions in relation to the structural configurations of and positional relationships between the storage layer 24, the reflective layer 72, the interface layer 92, the first protective layer 82 and the second protective layer 84 and the first plurality of data storage locations 32a and the second plurality of data storage locations 32b corresponding with the first recording layer 26 and the second recording layer 28 with reference to the fourth embodiment of FIG. 8 are incorporated herein.

- 10 The substrate 22 of the fourth embodiment of the invention is replaced with a cover layer 99 stacked adjacent to the first face 30a of the first recording layer 26. The cover layer 99 preferably has an optical transmittance of at least 80% and a thickness substantially between a range of 10um to 400um. In the seventh embodiment of the invention, the substrate 22 has been spatially altered and disposed over a face of the reflective layer 72 outwardly opposing the second protective layer 84. The reflective layer 72 is therefore stacked between the second protective layer 84 and the substrate 22.

- In the method 170, the substrate 22 is formed in a step 152. The reflective layer 72 and the second protective layer 84 are then formed on the substrate 22 respectively in a step 174 and a step 176. The second recording layer 28 is then formed over the second protective layer 84 in a step 178 followed by the interface layer 92 and the first recording layer 26 being formed thereover respectively in a step 180 and a step 182. Subsequently, the first protective layer 82 is then formed over the first recording layer 26 in a step 184. Eventually in a step 164, the cover layer 99 is formed and bonded onto the first protective layer 82. Preferably, the cover layer 99 is formed by one of solvent casting, polymerization casting, spin coating, die coating and pressure-based lamination. Preferably, the cover layer 99 further undergoes a curing process once it has been formed.

30

Similar to the data storage media 98 in the sixth embodiment, the data storage media 98 in the seventh embodiment is preferably also for a short wavelength laser light source, for example 405 nm violet-blue laser diode, is used as the laser beam 48. In

the seventh embodiment, the laser beam is transmitted into data storage media 98 through the cover layer 99. The cover layer 99 is preferably made of at least one of polycarbonate, cellulose triacetate and polydicyclopentadiene, (methyl)methacrylate, and (methyl)propylacrylate and formed by one of solvent casting, polymerization-casting and die-coating methods. Additionally, the cover layer 99 is further formable by one of spin-coating followed by UV curing and lamination through application of a pressure-sensitive adhesive layer. Thickness tolerance of the cover layer 99 is preferably not more than 3  $\mu\text{m}$ .

- 10 The wavelength of the laser beam 48 in each of the first to seventh embodiments is preferably within a range of 200nm to 900nm. However, for each of the fifth, sixth and seventh embodiments, the wavelength of the laser beam 48 used therein is preferably within a range of 200nm-450nm. Specifically, for each of the first, second third and fourth embodiments, the wavelength of the laser beam 48 used therein when  
15 the data storage media 20/70/80/90 is a digital versatile disc (DVD) is preferably within a range of 600nm to 660nm. Additionally, for each of the first, second third and fourth embodiments, the wavelength of the laser beam 48 used therein when the data storage media 20/70/80/90 is a compact disc (CD) is preferably within a range of 750nm to 800nm.
- 20 The following examples demonstrate certain aspects of the invention, the data storage media and the method for forming thereof, and should not be taken as limiting the scope thereof.

In an example, a sample disk was prepared in accordance to the steps of the method  
25 140 of FIG. 7 and the structural configuration of the data recording device 90 of Fig. 8.

A polycarbonate substrate 22 having a thickness of 0.6 mm and a diameter of 120 mm is first disposed on a sputtering system. The track pitch is 0.74  $\mu\text{m}$ . The first  
30 protective layer 82 was formed from a mixture of ZnS (80at%) and  $\text{SiO}_2$  (20at%) and with a thickness of 90nm, while the second protective layer 84 was formed from  $(\text{ZnS})_{80}(\text{SiO}_2)_{20}$  with a thickness of 10nm

The first recording layer 26 was formed from a  $\text{Ge}_2\text{Sb}_2\text{Te}_5$  phase change material and having a thickness of 20nm. The interface layer 92 was formed from  $(\text{ZnS})_{80}(\text{SiO}_2)_{20}$  and has a thickness of 18.5nm. The second recording layer 28 was formed from  
 5 TbFeCo magneto-optical material and has a thickness of 25nm. As aforementioned, the first recording layer 26 and the second recording layer 28 forms the storage layer 24.

In accordance with the method 140 of Fig. 7, the reflective layer 10 has a thickness of  
 10 150nm and was formed from an Al alloy on the polycarbonate substrate 22 using a sputtering method. The first protective layer 82 and the second protective layer 84 were formed by RF magnetron sputtering. The first recording layer 26, the second recording layer 28 and the reflective layer 72 were formed by DC magnetron sputtering in an argon atmosphere. The dummy layer 66 is eventually bonded over  
 15 the substrate 22 with a UV resin using a spin coating method.

The resulting sample disk was then initialized with a laser beam with varying magnitude in conjunction with an externally applied bias magnetic field. Through varying the magnitude of the laser beam for initialization of the sample disk, different  
 20 levels of reflectivity was obtained therefrom. The resulting sample disk was in the amorphous state and therefore had a low reflectance.

Fig. 15 demonstrates multi-level reflectance for said sample disk formed. By applying the laser beam at varying wavelengths of 780, 650 and 405 nm thereto, Fig.  
 25 15 demonstrates that at least four levels of reflectance and therefore data discretisation can be distinctly detected therefrom for each of the wavelengths. Although the variation in the reflectance is small for the 405 nm wavelength, it can be further improved by optimizing the physical structure of the sample disk.

30 Fig. 16 shows the results obtained from a static tester when applied to the sample disk. The parameters for application of the static tester are a wavelength of 780 nm

for the laser beam 48 and a numerical aperture of 0.5. Fig. 16 further shows that four distinct levels can be written to and erased from the sample disk.

5 Fig. 17 demonstrates that two levels of polarization are obtainable from the sample disk with a 650 nm wavelength laser beam 48. Fig. 17 further shows that a reversible change in the polarization direction of the second recording layer 28 is also achievable. The data reproduced from the second recording layer is read by detecting the reflectance and the polarization direction of the processed beam 50.

10 As demonstrated in Figs. 15, 16 and 17, the sample disk is able to store data of at least 3 bits along each data axis 46 as compared to the one bit data restriction of most conventional optical media.

15 In the foregoing manner, a data storage media and a method for the formation thereof is described according to seven embodiments of the invention for addressing the foregoing disadvantages of conventional data storage media. Although only seven embodiments of the invention are disclosed, it will be apparent to one skilled in the art in view of this disclosure that numerous changes and/or modification can be made without departing from the scope and spirit of the invention.

**Claims**

## 1. A data storage media comprising:

a substrate having a mounting face, the substrate being formed with at least one groove therein along the mounting face;

5 a first recording layer having a first face and a second face outwardly opposing the first face, the first recording layer having a first plurality of data storage locations, each of the first plurality of data storage locations having a first physical property being variable through at least two states for indicating a first data value; and

10 a second recording layer adjacent to the second face of the first recording layer, the first recording layer being stacked between the substrate and the second recording layer, the second recording layer having a second plurality of data storage locations, each of the second plurality of data storage locations having a second physical property being variable through at least two states for indicating a second data value, the first physical property being distinct from the second physical property,

15 wherein each of the first recording layer and the second recording layer is structurally supported by the substrate and each of the first recording layer and the second recording layer being stacked over and opposing the mounting face of the substrate, and

20 wherein a processed beam having first and second physical properties is processed from a laser beam directed towards the first and second recording layers, the laser beam being processed initially by the corresponding one of the first plurality of data storage locations with one of the at least two states thereof determining the first physical property, and subsequently by the corresponding one of the second plurality of data storage locations with one of the at least two states thereof determining the second physical property, the first and second physical properties of the processed beam being respectively indicative of the first and second data values of the corresponding one of the first plurality of data storage locations and the corresponding one of the second plurality of data storage locations.

## 2. The media as in claim 1, further comprising:

a plurality of data axes formed substantially perpendicular to the second face of the first recording layer, each of the plurality of data axes extending through a corresponding one of the first plurality of data storage locations and a corresponding one of the second plurality of data storage locations,

wherein the laser beam is further directed along one of the plurality of data axes.

3. The media as in any of claims 1 and 2, each of the first physical property and the second physical property corresponds with one of reflectance, polarisation, time, frequency, wavelength and electronic spin of light being one of transmitted to and reflected from the first recording layer and the second recording layer.
4. The media as in any of claims 1 and 3, the substrate being formed from one of polycarbonate, polymethyl methacrylate (PMMA), amorphous polyolefin, ceramic, glass, metal, alloy and paper.
5. The media as in any of claims 1 to 4, the substrate having a thickness substantially between a range of 0.3mm to 2mm.
6. The media as in any of claims 1 to 5, the substrate being formed by one of injection molding and extrusion molding.
7. The media as in any of claims 1 to 6, wherein the first physical property is reflectance, the second physical property is optical polarization, one of the at least two states of each of the first plurality of data storage locations corresponds with reflectance level thereof and one of the at least two states of each of the second plurality of data storage locations corresponds with optical polarization level thereof.
8. The media as in any of claims 1 to 7, the first recording layer being formed from a first material, the first material being a phase change material with the

at least two states thereof being at least two crystallinity levels, and the first physical property of the first material being variable between a substantially crystalline state and a substantially amorphous state,

5 wherein varying a portion of the first material between the substantially crystalline state and the substantially amorphous state varies at least one of reflectance and transmittance of the portion of the first material.

9. The media as in claim 8, the first material being made from at least one element selected from at least one of Te, Ge, Sb, Ga, Bi, Pd, Po, Sn, As, Ag, 10 In, Se, S, Si, P and organic recording materials.

10. The media as in any of claims 8 and 9, the first physical property of the first material being variable by a laser beam having a magnitude, the magnitude of the laser beam corresponding to the at least two crystallinity levels.

15 11. The media as in any of claims 1 to 10, the second recording layer being formed from a second material, the second material being a magneto-optical material with the at least two states thereof being at least two polarization states, and the second physical property of the second material being variable 20 between two optical polarization levels,

wherein varying the second physical property of a portion of the second material between the two optical polarization levels varies the at least two polarization states of the portion of the second material.

25 12. The media as in claim 11, the second material being made from at least one of Fe, Co and Ni and at least one of Tb, Cr, Gd, Dy, Sm, Nd, Mn, Pt, Pd, Al, Au, Ag, Cu and Mg.

30 13. The media as in any of claims 10 to 12, the second physical property of the second material being variable by heat generated by the laser beam on the portion of the second material and a field direction of a magnetic field applied thereto.

14. The media as in any of claims 10 to 13, the magnetic field being generated by one of a permanent magnet and an electromagnet.
- 15 The media as in any one of claims 10 to 14, the corresponding one of the first  
5 material and the second material is deposited by one of vacuum deposition, electron beam vacuum deposition, ion plating, chemical vapor deposition, plasma CVD, laser deposition, spin coating, molecular beam epitaxy and sputtering.
- 10 16 The media as in any one of claims 1 to 15 each of the first recording layer and the second recording layer being doped by sputtering of a mixture comprising Argon and at least one of Nitrogen and Oxygen thereto.
- 17 The media as in any of claims 1 to 6 wherein at least one of the first physical  
15 property of the first recording layer and the second physical property of the second recording layer being one of reflectance, polarization, time, frequency and wavelength and electronic spin of at least one of the laser beam and the processed beam.
- 20 18 The media as in any of claims 1 to 17 the first recording layer being formed from a first material and the second recording layer being formed from a second material,  
wherein the first material is one of different from and the same as the second material.
- 25 19 The media as in any one of claims 1 to 18 further comprising:  
a cover layer being stacked adjacent to the first recording layer with the first face thereof opposing the cover layer and the first recording layer being stacked between the cover layer and the substrate,  
30 wherein the cover layer is made from at least one of polycarbonate, cellulose triacetate, polydicyclopentadiene, (methyl)methacrylate and (methyl)propylacrylate, and the cover layer has an optical transmittance of at least 80%.

20. The media as in claim 19 the cover layer being formed by one of solvent casting, polymerization casting, spin coating, die coating and pressure-based lamination,
- 5            wherein the cover layer having a thickness substantially between a range of 10um to 400um.
21. The media as in each of claims 19 and 20, the laser beam having a wavelength substantially between a range of 200nm to 450nm.
- 10
22. The media as in any of claims 1 to 18, further comprising:
- a dummy layer being stacked adjacent to the second recording layer with the second face of the first recording layer opposing the dummy layer and the first recording layer being stacked between the substrate and the dummy layer,
- 15            wherein the dummy layer is made from at least one of polycarbonate, polymethyl methacrylate (PMMA), amorphous polyolefin, carbonate resin, ultraviolet light curable resin, ceramic and glass.
- 20    23. The media as in claim 22, the dummy layer being formed by one of injection molding and extrusion molding,
- wherein the dummy layer has a thickness substantially between a range of 0.3mm and 2.0mm.
- 25    24. The media as in any of claims 22 and 23, the laser beam having a wavelength of substantially between a range of 600nm to 800nm.
25. The media as in any one of claims 1 to 24, further comprising:
- an interface layer stacked between the first recording layer and the
- 30        second recording layer, the interface layer being optically transparent to the laser beam directed therethrough.

26. The media as in claim 25, the interface layer being formed from one of a dielectric material and a metallic material being one of magnetic and non-magnetic.
- 5 27. The media as in any one of claims 1 to 26, further comprising:  
a first protective layer stacked adjacent to the first face of the first recording layer; and  
a second protective layer stacked adjacent to the second recording layer, the first and second recording layers being disposed between and  
10 stacked between the first protective layer and the second protective layer,  
wherein each of the first and second protective layers is made from at least one of an oxide, a nitride, a chalcogenide element, fluoride, carbide of a metal.
- 15 28. The media as in any one of claims 1 to 26, further comprising:  
a first protective layer stacked adjacent to the first face of the first recording layer; and  
a second protective layer stacked adjacent to the second recording layer, the first and second recording layers being disposed between and  
20 stacked between the first protective layer and the second protective layer,  
wherein each of the first and second protective layers is made from at least one of SiO<sub>2</sub>, SiO, Al<sub>2</sub>O<sub>3</sub>, GeO<sub>2</sub>, In<sub>2</sub>O<sub>3</sub>, TeO<sub>2</sub>, TiO<sub>2</sub>, Ta<sub>2</sub>O<sub>5</sub>, MoO<sub>3</sub>, WO<sub>3</sub>, Si<sub>3</sub>N<sub>4</sub>, AlN, BN, TiN, ZnS, CdS, CdSe, ZnTe, AgF, PdF<sub>2</sub>, SiC and mixtures thereof.
- 25 29. The media as in each of claims 27 and 28, each of the corresponding one of the first protective layer and the second protective layer formed with a thickness substantially between a range of 1 nm to 250 nm.
- 30 30. The media as in any one of claims 27 to 29, further comprising:  
a reflective layer stacked adjacent to a face of the second protective layer outwardly opposing the second recording layer, the reflective layer for

dissipating excessive heat accumulation wherein heat is generated by the laser beam during application thereof to the second recording layer.

31. The media as in any one of claims 1 to 26, further comprising:
  - 5 a reflective layer stacked adjacent to a face of the second recording layer outwardly opposing the first recording layer, the reflective layer for dissipating excessive heat accumulation wherein heat is generated by the laser beam during application thereof to the second recording layer.
- 10 32. The media as in any one of claims 30 and 31, the reflective layer being formed from at least one of Au, Al, Ag, Ti, Cr, Cu, Pd, W, Pt and alloys thereof.
33. A method for forming a data storage media comprising the steps of:
  - forming a substrate having a mounting face, the substrate being formed
    - 15 with at least one groove therein along the mounting face;
    - forming a first recording layer having a first face and a second face outwardly opposing the first face, the first recording layer having a first plurality of data storage locations, each of the first plurality of data storage locations having a first physical property being variable through at least two
      - 20 states for indicating a first data value; and
      - forming a second recording layer adjacent to the second face of the first recording layer, the first recording layer being stacked between the substrate and the second recording layer, the second recording layer having a second plurality of data storage locations, each of the second plurality of data storage locations having a second physical property being variable through at
        - 25 least two states for indicating a second data value, the first physical property being distinct from the second physical property,
      - wherein each of the first recording layer and the second recording layer is structurally supported by the substrate and each of the first recording layer and the second recording layer being stacked over and opposing the mounting
        - 30 face of the substrate, and
        - wherein a processed beam having first and second physical properties is processed from a laser beam directed towards the first and second recording

layers, the laser beam being processed initially by the corresponding one of the first plurality of data storage locations with one of the at least two states thereof determining the first physical property, and subsequently by the corresponding one of the second plurality of data storage locations with one of the at least two states thereof determining the second physical property, the first and second physical properties of the processed beam being respectively indicative of the first and second data values of the corresponding one of the first plurality of data storage locations and the corresponding one of the second plurality of data storage locations.

10

34. The method as in claim 33, further comprising the step of:

providing a plurality of data axes formed substantially perpendicular to the second face of the first recording layer, each of the plurality of data axes extending through a corresponding one of the first plurality of data storage locations and a corresponding one of the second plurality of data storage locations,

15

wherein the laser beam is further directed along one of the plurality of data axes.

20

35. The method as in claims 33 and 34, wherein each of the first physical property and the second physical property corresponds with one of reflectance, polarisation, time, frequency, wavelength and electronic spin of light being one of transmitted to and reflected from the first recording layer and the second recording layer.

25

36. The method as in any of claims 33 to 35, the step of forming a substrate comprising the step of:

forming the substrate from one of polycarbonate, polymethyl methacrylate (PMMA), amorphous polyolefin, ceramic, glass, metal, alloy and paper.

30

37. The method as in any of claims 33 to 36, the step of forming a substrate further comprising the step of:

forming a substrate with a thickness substantially between a range of 0.3mm to 2mm.

38. The method as in any of claims 33 to 37, the step of forming a substrate  
5 comprising the step of:  
one of injection molding and extrusion molding.
39. The method as in any of claims 33 to 38, wherein the first physical property is  
reflectance, the second physical property is optical polarization, one of the at  
10 least two states of each of the first plurality of data storage locations  
corresponds with reflectance level thereof and one of the at least two states of  
each of the second plurality of data storage locations corresponds with optical  
polarization level thereof.
40. The method as in any of claims 33 to 39, the step of forming the first  
15 recording layer comprising the step of:  
forming the first recording layer from a first material, the first material  
being a phase change material with the at least two states thereof being at least  
two crystallinity levels, and the first physical property of the first material  
20 being variable between a substantially crystalline state and a substantially  
amorphous state,  
wherein varying a portion of the first material between the  
substantially crystalline state and the substantially amorphous state varies at  
least one of reflectance and transmittance of the portion of the first material.  
25
41. The method as in claim 40, the step of forming the first recording layer from a  
first material comprising the step of:  
forming the first recording layer from a first material being made from  
at least one element selected from at least one of Te, Ge, Sb, Ga, Bi, Pd, Po,  
30 Sn, As, Ag, In, Se, S, Si, P and organic recording materials.
42. The method as in any of claims 40 and 41, the step of forming the first  
recording layer further comprising the step of:

varying the first physical property of the first material by a laser beam having a magnitude, the magnitude of the laser beam corresponding to the at least two crystallinity levels.

- 5     43.     The method as in any of claims 33 to 42, the step of forming the second recording layer comprising the step of:

forming the second recording layer from a second material, the second material being a magneto-optical material with the at least two states thereof being at least two polarization states, and the second physical property of the  
10     second material being variable between two optical polarization levels,

wherein varying the second physical property of a portion of the second material between the two optical polarization levels varies the at least two polarization states of the portion of the second material.

- 15     44.     The method as in claim 43, the step of forming the second recording layer from a second material comprising the step of:

forming the second recording layer from a second material being made from at least one of Fe, Co and Ni and at least one of Tb, Cr, Gd, Dy, Sm, Nd, Mn, Pt, Pd, Al, Au, Ag, Cu and Mg.

20

45.     The method as in any of claims 42 to 44, the step of forming the second recording layer comprising the step of:

varying the second physical property of the second material by heat generated by the laser beam on the portion of the second material and a field  
25     direction of a magnetic field applied thereto.

46.     The method as in any of claims 42 to 45, the step of varying the second physical property of the second material comprising the steps of:

generating the magnetic field by one of a permanent magnet and an  
30     electromagnet.

47. The method as in any one of claims 42 to 46, each of the step of forming the first recording layer and the step of forming the second recording layer further comprising the step of:
- 5 deposition of the corresponding one of the first material and the second material by one of vacuum deposition, electron beam vacuum deposition, ion plating, chemical vapor deposition, plasma CVD, laser deposition, spin coating, molecular beam epitaxy and sputtering.
48. The method as in any one of claims 33 to 47, further comprising the step of:
- 10 doping each of the first recording layer and the second recording layer by sputtering of a mixture comprising Argon and at least one of Nitrogen and Oxygen thereto.
49. The method as in any of claims 33 to 38, wherein at least one of the first
- 15 physical property of the first recording layer and the second physical property of the second recording layer being one of reflectance, polarization, time, frequency and electronic spin of at least one of the laser beam and the processed beam.
- 20 50. The method as in any of claims 33 to 49, the step of forming the first recording layer comprising the step of forming the first recording layer from a first material and the step of forming the second recording layer comprising the step of forming the second recording layer from a second material,
- 25 wherein the first material is one of different from and the same as the second material.
51. The method as in any one of claims 33 to 50, further comprising the step of:
- 30 forming a cover layer being stacked adjacent to the first recording layer with the first face thereof opposing the cover layer and the first recording layer being stacked between the cover layer and the substrate,
- wherein the cover layer is made from at least one of polycarbonate, cellulose triacetate, polydicyclopentadiene, (methyl)methacrylate and

(methyl)propylacrylate, and the cover layer has an optical transmittance of at least 80%.

52. The method as in claim 51, the step of forming a cover layer comprising the  
5 step of:

forming a cover layer by one of solvent casting, polymerization casting, spin coating, die coating and pressure-based lamination,

wherein the cover layer having a thickness substantially between a range of 10um to 400um and the laser beam having a wavelength substantially  
10 between the range of 200nm to 450nm.

53. The method as in any of claims 33 to 50, further comprising the step of:

forming a dummy layer being stacked adjacent to the second recording layer with the second face of the first recording layer opposing the dummy layer and the first recording layer being stacked between the substrate and the  
15 dummy layer,

wherein the dummy layer is made from at least one of polycarbonate, polymethyl methacrylate (PMMA), amorphous polyolefin, carbonate resin, ultraviolet light curable resin, ceramic and glass.

20

54. The method as in claim 53, the step of forming a dummy layer comprising the step of:

forming a dummy layer by one of injection molding and extrusion molding,

wherein the dummy layer has a thickness substantially between a range of 0.3mm and 2.0mm and the laser beam having a wavelength substantially  
25 between the range of 600nm and 800 nm.

55. The method as in any one of claims 33 to 54, further comprising the step of:

forming an interface layer stacked between the first recording layer and the second recording layer, the interface layer being optically transparent to the laser beam directed therethrough.  
30

56. The method as in claim 55, the step of forming the interface layer comprising the step of:

forming the interface layer from one of a dielectric material and a metallic material being one of magnetic and non-magnetic.

5

57. The method as in any one of claims 33 to 56, further comprising the steps of:

forming and stacking a first protective layer adjacent to the first face of the first recording layer; and

forming and stacking a second protective layer adjacent to the second recording layer, the first and second recording layers being disposed between and stacked between the first protective layer and the second protective layer, wherein each of the first and second protective layers is made from at least one of an oxide, a nitride, a chalcogenide element, fluoride, carbide of a metal.

15

58. The method as in any one of claims 33 to 56, further comprising the steps of:

forming a first protective layer stacked adjacent to the first face of the first recording layer; and

forming a second protective layer stacked adjacent to the second recording layer, the first and second recording layers being disposed between and stacked between the first protective layer and the second protective layer,

wherein each of the first and second protective layers is made from at least one of SiO<sub>2</sub>, SiO, Al<sub>2</sub>O<sub>3</sub>, GeO<sub>2</sub>, In<sub>2</sub>O<sub>3</sub>, TeO<sub>2</sub>, TiO<sub>2</sub>, Ta<sub>2</sub>O<sub>5</sub>, MoO<sub>3</sub>, WO<sub>3</sub>, Si<sub>3</sub>N<sub>4</sub>, AlN, BN, TiN, ZnS, CdS, CdSe, ZnTe, AgF, PdF<sub>2</sub>, SiC and mixtures thereof.

25

59. The method as in each of claims 57 and 58, each of the step of forming a first protective layer and the step of forming a second protective layer comprising the step of:

forming the corresponding one of the first protective layer and the second protective layer with a thickness substantially between a range of 1 nm to 250 nm.

30

60. The method as in any one of claims 57 to 59, further comprising the step of:  
forming and stacking a reflective layer adjacent to a face of the second protective layer outwardly opposing the second recording layer, the reflective layer for dissipating excessive heat accumulation wherein heat is generated by the laser beam during application thereof to the second recording layer.
61. The method as in any one of claims 33 to 56, further comprising the step of:  
forming and stacking a reflective layer adjacent to a face of the second recording layer outwardly opposing the first recording layer, the reflective layer for dissipating excessive heat accumulation wherein heat is generated by the laser beam during application thereof to the second recording layer.
62. The method as in any one of claims 60 and 61, the step of forming and stacking a reflective layer comprising the step of:  
forming the reflective layer from at least one of Au, Al, Ag, Ti, Cr, Cu, Pd, W, Pt and alloys thereof.