

**Magnetic Recording Medium, Method of
Manufacturing the Same, and Magnetic Recording Apparatus**

Technical Field of the Invention

The present invention relates generally to a magnetic recording medium which is installed on various kinds of magnetic recording apparatuses such as an external storage of a computer, a method of manufacturing the magnetic recording medium, and a magnetic recording apparatus using the magnetic recording medium.

Prior Art

Magnetic recording media have been required to have a high recording density, and therefore, the surfaces of the magnetic recording media have been required to be flat to enable low-level floating of a recording head over the surface. To improve the magnetic recording media, a variety of proposals have been made with regard to the composition and structure of magnetic layers, materials for non-magnetic underlayer, materials for non-magnetic substrates, and so forth. Aluminum and glass are mainly used as material for the non-magnetic substrates, but in particular, plastic materials (high polymer resin material) have been proposed as materials for the non-magnetic substrates in terms of the characteristics thereof.

Problem to be Solved by the Invention

The magnetic recording media are required to be maintaining the long-term reliability in the severe environment in order to



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enable the low-level floating of the magnetic head that realizes a higher recording density, and to be used for digital electric home appliances that are expected to widely spread in the near future. An extremely low temperature of -40°C to a high temperature and high humidity of $80^{\circ}\text{C}/80\%\text{RH}$ are assumed as the severe conditions, and under such conditions, the future magnetic recording media are required to operate normally for five years. Further, the cost of the magnetic recording media for use the digital electric home appliances are required to be considerably lower than that of the conventional magnetic recording media. Magnetic recording media using plastic substrates have promise as magnetic recording media capable of dealing the circumstances. However, if a conventional magnetic recording medium using a plastic substrate is tested under the severe conditions, film expansion (a kind of film exfoliation) occurs.

It is therefore an object of the present invention to provide a magnetic recording medium using a plastic substrate as a non-magnetic substrate, and exhibits excellent characteristics without causing film expansion even under the severe conditions, a method of manufacturing the magnetic recording medium, and a magnetic recording apparatus using the magnetic recording medium.

Arrangement for Solving the Problems

Inventors of the present invention conducted various experiments and reviews to solve the above-mentioned problems, and found the following solution.

A large number of magnetic recording media were placed under the above-mentioned severe conditions to cause film expansion, the locations of the film expansion were observed. It was found

out that the film was expanded mainly between a plastic substrate and an underlayer formed just on the plastic substrate. It was assumed that this was because the chemical structure of the plastic substrate has a low affinity to the chemical structure of the layer formed thereon, and the distortion stress generated under the severe conditions such as the temperature and the humidity is concentrated on an interface having a low affinity. To address this problem, the inventors of the present invention formed a layer, which has a high affinity in chemical structure to a plastic substrate and to an underlayer and a magnetic layer formed on the plastic substrate, on the surface of the plastic substrate, and sequentially laminate the conventional underlayer, magnetic layer, etc. on the layer. The inventors of the present invention found out that a carbon film and more particularly a polymerized carbon film was suitably used as a material for the layer (hereinafter referred to as "adhesive layer") having a high affinity in chemical structure to both the plastic substrate and the layers laminated thereon. Polymerization causes the carbon film to have a high affinity in chemical structure to a plastic substrate. The carbon film also has a high affinity to an underlayer comprised of a TiW film and the like laminated on the carbon film. Forming the adhesive layer comprised of the carbon film improves the adhesion between the plastic substrate and the underlayer, and prevents film exfoliation even if the distortion stress is applied to the magnetic recording medium under the severe conditions.

Although the method of forming the carbon film is not particularly restricted, the carbon film is ordinarily formed by the sputtering method, disposition method, or CVD method. The carbon film can be polymerized by including therein a

predetermined amount of hydrogen atoms. The degree to which the carbon film is polymerized can easily be determined by the Raman scattering spectroscopy. This is based on the following principle and the conventional knowledge.

It is well known that an increase in the degree of polymerization of an organic film or a carbon film (an increase in polymerized components) increases the intensity of fluorescence generated in time of light incidence on the film. The degree of polymerization and the intensity of generated fluorescence are substantially proportional to each other.

On the other hand, the Raman effect in which light is scattered with a frequency differing from that of incident light is known as a phenomenon occurring when light is irradiated on a substance as is the case with the fluorescent light. A variety of Raman spectrum meters are commercially available for use in the Raman scattering spectroscopy in which the Raman spectrum is measured by utilizing the Raman effect, and the energy level of an object is identified and determined. The Raman scattering spectroscopy is widely used for identification and determination of laminating layer film to which is directed the present invention. The Raman spectrum found by the Raman scattering spectroscopy represents the intensity of Raman scattered light with respect to the Raman shift (wave number). Not only the Raman scattered light but also the fluorescent light may be emitted upon incidence of light according to irradiated substances. In this case, the emitted fluorescent light is expressed as a background level of a spectrum curve, and thus, the measured intensity of the Raman spectrum corresponds to the sum of the fluorescent light intensity and the

Raman scattered light intensity. Therefore, a value that is found by subtracting the fluorescent light intensity (a value from a base line to a background level in a Raman spectrum diagram; hereinafter referred to as "the value X") from the measured intensity (a value from the base line level to a peak point in the Raman spectrum diagram; hereinafter referred to as "the value B") ($B-X$) corresponds to a calibrated Raman scattered light intensity (hereinafter referred to as "the value A").

As a result of various experiments and reviews conducted based upon the above knowledge, the inventors of the present invention found out that the polymerization of the carbon film can be satisfactorily determined with excellent repeatability by picking up the Raman spectrum of the carbon film, reading the values B and A of the spectrum, and dividing the value B by the value A (the resulting value will be hereinafter referred to as "the value B/A "), and determining the degree of polymerization of the measured film according to the value B/A .

Namely, the carbon film forming the adhesive layer is polymerized by including therein a predetermined amount of hydrogen, and the suitable amount of hydrogen in atmospheric gas introduced in time of film formation can be found with reference to the value B/A of the Raman spectrum obtained by the Raman scattering spectroscopy of the formed carbon film. In this case, the value B/A is preferably equal to or greater than 6.

The inventors conducted experiments and reviews to find the optimum value of the film thickness of the carbon film, and reached the following conclusion. There is no necessity of

restricting the film thickness since the film thickness does not greatly affect the occurrence of film exfoliation. However, the film thickness affects the read write characteristics, the film thickness must be adjusted to lie within such a range as not to deteriorate the read write characteristics. From this standpoint, the optimum value of the film thickness varies according to materials for the magnetic layer and the target recording density, and therefore, the optimum value of the film thickness cannot be restricted to a specific value.

According to the present invention, the adhesive layer formed of the carbon film is formed on the plastic film, and the carbon film contains a large amount of hydrogen. Including a large amount of hydrogen in the carbon film polymerizes the carbon film. The polymerization causes the carbon film to have affinity in chemical structure to the plastic substrate. Therefore, the carbon film has a high adhesiveness to both the plastic substrate and the underlayer and the like laminated on the plastic substrate. This considerably reduces the occurrence of film exfoliation unlike the prior art.

Summary of the Invention

The present invention provides a magnetic recording medium which comprises at least a non-magnetic underlayer, magnetic layer, and protective layer sequentially formed over a non-magnetic substrate, the magnetic recording medium wherein the non-magnetic substrate is a plastic substrate, and an adhesive layer having a chemical affinity to the plastic substrate is formed on a surface of the plastic substrate.

The present invention also provides a method of manufacturing a magnetic recording medium which comprises at least a non-magnetic underlayer, magnetic layer, and protective layer sequentially formed over a non-magnetic substrate, the method wherein: a plastic substrate is used as the non-magnetic substrate, an adhesive layer having a chemical affinity to the plastic substrate is formed on a surface of the plastic substrate, and the underlayer and the subsequent layers are then formed over the adhesive layer.

The present invention also provides a magnetic recording apparatus in which is installed the magnetic recording medium.

It is preferred that the adhesive layer is a carbon film. It is further preferred that the carbon film contains a predetermined amount of hydrogen and has a polymer structure. It is still further preferred that a value B/A (a value that is found by dividing a measured diffusing intensity (value B) by a calibrated diffusing intensity (value A)) of a Raman spectrum acquired by the Raman scattering spectroscopy of the carbon film is equal to or greater than 6.

It is further preferred that the carbon film is formed under presence of mixed gas containing hydrogen gas or hydride gas. It is preferred that a percentage of the hydrogen gas or the hydride gas in the mixed gas is equal to or higher than 25%. It is correspond that the concentration of the hydrogen gas lies inside such a range that the value B/A is equal to or greater than 6.

Embodiments of the Invention

A dissertation will now be given of embodiments of the present invention, but it should be understood that they are only preferred examples of the present invention and there is no intention to limit the invention to them.

Embodiment 1

An adhesive layer formed of a carbon film containing hydrogen (hereinafter referred to as "CH film") was formed by a known sputtering method using a carbon target. Ar+H₂ gas was used as the atmosphere in sputtering, and various adhesive layers were formed by changing the concentration of hydrogen in the gas. Table 1 shows the results. The layers is comprised of a substrate, adhesive layer, underlayer, intermediate layer, magnetic layer, block layer, and protective layer that are composed of a plastic substrate, CH film, TiW film, Ru film, CoCrPt-SiO₂ film, Ti film, and CN film, respectively. The adhesive layer has a film thickness of 10nm. The resulting magnetic recording medium sample was left under such conditions as ordinary temperature, temperature of 80°C/80%RH (four hours), -40°C (four hours), and ordinary temperature in this cycle. Whether the film of the sample was expanded or not was determined by observing the sample with an optical microscope. A B/A value of the CH film is a value that is calculated from a Raman spectrum of the sample as stated previously.

Table 1

Concentration of hydrogen gas (%)	Raman spectrum B/A value	Result of leaving	
		Is film expanded?	Others
0	1.34	Yes	Cracked after film formation
5	1.48	Yes	Cracked after film formation
10	1.72	Yes	Cracked after film formation
15	2.04	Yes	Cracked after film formation
20	2.71	Yes	Cracked after film formation
25	6.10	No	-
30	9.07	No	-

As is clear from the Table 1, if the concentration of the hydrogen gas has reached 25%, the B/A value of the Raman spectrum rapidly increases from 3.0 or smaller to 6.1. This indicates that the carbon film is polymerized. The polymerization of the carbon film prevents the film from expanding or cracking film after the film formation. On the other hand, if the concentration of the hydrogen gas is not greater than 20%, the B/A value of the Raman spectrum is not greater than 3.0, and the formed film is a relatively hard amorphous carbon film. This amorphous carbon film is similar to diamond in structure, and is therefore called a DLD (Diamond Like Carbon) film. This film, however, is cracked after the film formation.

Embodiment 2

An adhesive layer formed of a carbon film containing hydrogen was formed by a known sputtering method using a carbon target. Ar+H₂ gas was used as the atmosphere in sputtering, and various adhesive layers were formed with the concentration of the hydrogen being fixed at 25% while changing the thickness of

carbon film. Table 2 shows the results of the film formation. The layers is comprised of a substrate, adhesive layer, underlayer, intermediate layer, magnetic layer, block layer, and protective layer that are composed of a plastic substrate, CH film, TiW film, Ru film, CoCrPt-SiO₂ film, Ti film, and CN film, respectively. The adhesive layer has a film thickness of 10nm. The resulting magnetic recording medium sample was left in a constant temperature oven under such conditions as ordinary temperature, temperature of 80°C/80%RH (four hours), -40°C (four hours), and ordinary temperature in this cycle. Whether the film of the sample was expanded or not was determined by observing the sample through an optical microscope. A B/A value of the CH film is a value that is calculated from a Raman spectrum of the sample.

Table 2

CH film thickness (nm)	Raman spectrum B/A value	Result of leaving	
		Is film expanded?	Read write characteristics
4	6.5	No	Favorable
6	6.7	No	Favorable
8	6.1	No	Favorable
10	6.1	No	Favorable
20	6.3	No	Unfavorable

With respect to the film expansion, the adhesive layer does not depend on the film thickness, and the film is never expanded insofar as the B/A value of the Raman spectrum is not smaller than 6. With respect to the film thickness of the CH film (carbon film), there is no problem insofar as the CH film is formed to have such a film thickness as to achieve the favorable read write characteristics.

Advantageous Effects of the Invention

As described above, according to the present invention, the adhesive layer formed of the carbon film is formed on the plastic substrate by forming the film having with the B/A value of the Raman spectrum being equal to or greater than 6 in atmosphere of the mixed gas containing hydrogen of not less than 25%, and this realizes the magnetic recording medium using the plastic substrate, which never causes the film expansion even under such conditions as -40°C to 80°C/80%RH.

Claims

1. A magnetic recording medium which comprises at least a non-magnetic underlayer, magnetic layer, and protective layer sequentially formed over a non-magnetic substrate, wherein:

the non-magnetic substrate is a plastic substrate, and an adhesive layer having a chemical affinity to the plastic substrate is formed on a surface of the plastic substrate.

2. A magnetic recording medium according to claim 1, wherein the adhesive layer is a carbon film.

3. A magnetic recording medium according to claim 2, wherein the carbon film contains a predetermined amount of hydrogen and has a polymer structure.

4. A magnetic recording medium according to claim 2 or claim 3, wherein a value of (measured diffusing intensity)/(calibrated diffusing intensity) in a Raman spectrum of the carbon film is equal to or greater than 6.

5. A method of manufacturing a magnetic recording medium which comprises at least a non-magnetic underlayer, magnetic layer, and protective layer sequentially formed over a non-magnetic substrate, wherein:

a plastic substrate is used as the non-magnetic substrate, an adhesive layer having a chemical affinity to the plastic substrate is formed on a surface of the plastic substrate, and the underlayer and the subsequent layers are then formed over the adhesive layer.

6. A method of manufacturing a magnetic recording medium according to claim 5, wherein the adhesive layer is formed of a carbon film.

7. A method of manufacturing a magnetic recording medium according to claim 6, wherein the carbon film is formed under presence of mixed gas containing hydrogen gas or hydride gas.

8. A method of manufacturing a magnetic recording medium according to claim 7, wherein a percentage of the hydrogen gas or the hydride gas in the mixed gas is equal to or higher than 25%.

9. A magnetic recording apparatus in which is installed a magnetic recording medium according to any one of claim 1 through claim 4.