MAGNETORESISTIVE SENSOR AND MAGNETIC STORAGE APPARATUS

BACKGROUND OF THE INVENTION

The present invention relates to a magnetoresistive sensor to reproduce magnetically recorded information and also to a magnetic storage apparatus equipped therewith. More particularly, the present invention relates to a magnetoresistive sensor which has a superior reproducing resolution and to a magnetic storage apparatus using that sensor.

Magnetic storage apparatus, particularly magnetic disk apparatus, have been developed which have a remarkably improved recording density. This requires higher performance than before from the storage head, which is a key device of the magnetic disk apparatus, as well as from recording elements and reproducing elements.

The object of increasing the recording density for reproducing elements can be achieved using the following three technologies.

First, the technology of increasing sensitivity, which recently employs an MR head utilizing the magnetoresistive effect. For recording densities lower than a, few Gb/in^2, the conversion of magnetic signals on a magnetic disk into electrical signals has been accomplished by means of an anisotropic magnetoresistive effect (AMR effect). The AMR effect, however, does not provide sufficient sensitivity for higher recording densities. In the case of a magnetic disk apparatus designed for high recording density, this difficulty has been overcome by employing an MR head which makes use of the giant magnetoresistive effect (GMR effect) for higher sensitivity.

One example of heads utilizing the GMR effect is disclosed in Japanese Patent Laid-open No. 3S8310/1992. This head has a so-called spin-valve structure, which is composed of a pinned layer and a free layer, the former being magnetized in a specific fixed direction by exchange coupling between it and an antiferromagnetic layer and the latter being laminated onto the pinned layer with a thin non-magnetic conductive layer interposed between them. The electric resistance of a GMR film will vary according to the relative angle between the magnetization direction of the free layer and that of the pinned layer.

The second technology aims at reducing the reproducing track width, based on the idea that the reduced track width increases the track density. The width of the reproducing track is basically determined by the distance between the electrodes to supply the magnetoresistive film with the sense current to detect the change in resistance. Incidentally, the reproducing element needs longitudinal bias layers arranged at both sides, of the magnetoresistive film so as to suppress Barkhausen noise. The disadvantage of this provision is that the anisotropy field in portions near the longitudinal bias layer in the magnetoresistive film substantially increases due to the strong magnetic field from the longitudinal bias layer. The result is an extremely deteriorated sensitivity to the external magnetic field. This phenomenon becomes significant as the reproducing track width is reduced. A countermeasure disclosed in Japanese Patent Laid-open No. 282618/1997 consists of making the electrode distance smaller than the distance between the longitudinal bias layers so that the device does not detect signals with low sensitivity to the external magnetic field.

The third technology is concerned with the reduction of the distance between shield layers (shield gap) in the reproducing head. With a narrow shield gap, it is possible to achieve high-resolution reproduction even in the case of high linear recording density, which leads to an increase in the linear recording density. The currently available magnetic head has a shield gap of about 100 nm. Usually, the shield layers are arranged over and under the magnetoresistive film. Between the shield layer and the magnetoresistive film, a gap layer of insulating material is placed so that the sense current does not flow into the shield layer when the sense current is applied to the magnetoresistive film. As the distance between the reproducing shield layers decreases, the thickness of the gap layer also decreases, with the result that the gap layer becomes incapable of effective insulation because of its dependence on the film thickness for its characteristics and because of pinholes present therein. The consequence is that the sense current penetrates through the gap layer and leaks to the shield layer, causing the magnetic head to have a reduced reproducing output.

One way for solution to this problem is by arrangement of an insulating magnetic layer (specifically a NiZn ferrite layer) on the surface of one of the shield layers adjacent to the magnetoresistive film, as disclosed in Japanese Patent Laid-open No. 266437/1993.

An example of the insulating magnetic layer is shown in the synopsis of the lecture at the 18th conference (1994) of the Magnetics Society of Japan (p. 311). It is a thin film of Co—Al—O or Fe—Si—O which possesses higher resistivity (10^2–10^7 $\mu\Omega$.cm) than ordinary metal thin film (although this resistivity is lower than that of the above-mentioned NiZn ferrite) as well as good soft magnetic properties.

SUMMARY OF THE INVENTION

Three technologies have been introduced which were developed to cope with the need for increasing the recording density of a recording element. Although the first two are feasible with currently available means, the last one to reduce the reproducing shield gap has a problem that remains unsolved.

The idea (proposed in Japanese Patent Laid-open No. 266437/1993 mentioned above) of providing an insulating magnetic layer of NiZn ferrite on the surface of at least one of the shield layers adjacent to the magnetoresistive film poses a problem as follows. NiZn ferrite in its bulk form is of spinel structure and has a high permeability and a high resistivity (about 10^5–10^6 $\mu\Omega$.cm). However, in its thin film form prepared by sputtering at a temperature lower than about 300° C. (which is ordinarily employed for production of thin-film magnetic heads), it is amorphous rather than crystalline (spinel). Therefore, the thin film of NiZn ferrite used as the shield layer for the magnetic head has to be formed by heating the substrate above 500° C. or has to be annealed at 500–800° C. after film forming so that the resulting thin film has a spinel structure.

Unfortunately, the magnetoresistive film to produce the GMR effect is a laminate composed of thin layers (tens of A thick each) and hence it merely withstands heat up to about 300° C. Therefore, it becomes poor in magnetoresistive characteristics when NiZn ferrite requiring a high processing temperature is used as the shield layer, particularly as the upper shield layer.

On the other hand, the metal-oxide composite thin film described in the synopsis of the lecture at the 18th conference (1994) of the Magnetics Society of Japan (p. 311) offers the advantage of being prepared at a temperature lower than that which the magnetoresistive film (for GMR effect) withstands. However, it still has a disadvantage of lacking satisfactory insulation in an instance where the shield film is