MAGNETORESISTIVE SENSOR INCLUDING MAGNETIC DOMAIN CONTROL LAYERS HAVING HIGH ELECTRIC RESISTIVITY, MAGNETIC HEAD AND MAGNETIC DISK APPARATUS

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to a magnetoresistive sensor including magnetic domain control layers for the magnetoresistive sensor for reading back magnetically recorded information, a magnetic head, and a magnetic disk apparatus. More specifically, it relates to a magnetoresistive sensor having excellent reproducing resolution, a magnetic head using the same, and a magnetic disk apparatus.

[0003] 2. Description of the Related Art

[0004] The recording density in a magnetic disk apparatus has been improved significantly, and the demand that the performance of the magnetic read/write heads thereof be enhanced is increased in regard to both characteristics of read and write.

[0005] Regarding the read head sensor, it is necessary to improve the techniques concerning three points: (1) improvement of a technique for making the efficiency higher, (2) improvement of a technique for making the track width smaller, and (3) a technique for making the gap between the write magnetic shields smaller.

[0006] With respect to (1), making the efficiency higher has been advanced by developing an MR head utilizing a magnetoresistive effect. At a low recording density of several giga bits per square inch (Gb/in2), anisotropic magnetoresistive effect (AMR) is used to convert the magnetic signal on recording media to an electric signal. At a high recording density exceeding this, a higher efficient giant magnetoresistive effect (GMR) is used to respond to this high recording density. However, when making the efficiency much higher is advanced, the structure must be changed to the perpendicular magnetic recording structure in relation to the read element, which makes the most of GMR (CPP-GMR) or a tunnel magnetoresistive effect (TMR) of a system for flowing a sensing current perpendicular to the plane.

[0007] As a known example of a magnetic head employing GMR, Japanese Patent Publication No. Hei 8(96)-21166 (Japanese Un-examined Patent Publication No. Hei 4(92)-358310) describes the structure called a spin valve. This comprises a pinned layer consisting of a magnetic material in which a anti-ferromagnetic layer pins magnetization in the specific direction, and a free layer consisting of a non-magnetic thin film laminated on the pinned layer and a magnetic layer laminated through the non-magnetic thin film, so as to change electric resistance at a relative angle of magnetization of the pinned layer and the free layer.

[0008] With respect to (2), the track width is made smaller to improve the track density. It is generally thought that the read track width is determined by the distance between electrodes flowing a sensing current for sensing changed resistance. The read sensor has a high loss of S/N when Barkhausen noise is caused, and it is necessary to control this. The Barkhausen noise is caused together with microscopic domain wall movement, and there must be arranged magnetic domain control layers so as to provide the read sensor singly in the form of a magnetic domain. The magnetic domain control layers are often arranged on opposite sides of the sensor layer portion of the read sensor, viewed from the media-opposed surface side. The magnetic domain control layer is generally a hard magnetic metal material layer formed on a suitable metal underlayer, and an insulating oxide layer is required for the contact surface of the same with the magnetoresistive sensor layer, the top surface of the lower shield, and the contact surface of the same with the upper shield. The magnetic domain control layer provides a magnetic field for the magnetoresistive sensor layer, so that the anisotropic magnetic field is increased effectively and the exterior magnetic efficiency is reduced greatly. For this reason, Japanese Un-examined Patent Publication No. Hei 9(97)-282618 describes the structure in which the gap between the electrodes is smaller, than that between the magnetic domain control layers, and a sensor region having an efficiency effective for the exterior magnetic field is used for sensing a signal.

[0009] With respect to (3) the technique for making the read gap smaller, that is, for making the gap between the read magnetic shields smaller, there has been studied improvement of linear recording density by modifying resolution. Generally, the shield layers are arranged at the upper and lower sides so as to interpose the magnetoresistive sensor layer, and a gap layer made of an insulating material is disposed between the shield layer and the magnetoresistive sensor layer so as to prevent a sensing current from being leaked to the shield. When the gap between the read magnetic shields is smaller, the thickness of the gap layer is reduced. Thus, the thickness dependence as the characteristic of the insulating layer or the presence of pinhole cannot maintain the insulating properties, so that an electric current for sensing a signal (sensing current) is leaked to the magnetic shield to reduce read output. This loss is called a shunting loss.

[0010] As a method of solving this, Japanese Un-examined Patent Publication No. Hei 5(93)-266437 describes the structure in which an insulating magnetic layer is arranged on the surface of the magnetoresistive sensor layer side of at least one of the magnetic shields.

[0011] The read element is difficult to provide a sufficient recording magnetic field in a conventional in-plane magnetic recording system. Further, CPP (Current Perpendicular to the Plane)-GMR or TMR as a high efficient magnetoresistive sensor is a magnetoresistive sensor utilizing a structure flowing a sensing current perpendicular to the plane. Thus, a future structure of the read element is thought to be of the CPP system employing a sensing current. However, employing such a structure, when the area of the magnetoresistive sensor layer is reduced, there arises a new problem that the conventional magnetic domain control layer is difficult to ensure the insulating properties of the magnetic domain control layer. In other words, the conventional magnetic domain control layer is arranged on the lower magnetic shield by employing a laminating structure of insulating layer/(metal underlayer)/hard magnetic metal material layer/insulating layer, and then is in contact with opposite ends of the magnetoresistive sensor layer. The magnetoresistive sensor layer is made thinner and finer; there are imposed three problems: (1) the throwing power of the lower insu-