lating layer is insufficient so as to shunt the sensing current flowing to the magnetoresistive sensor layer to the magnetic domain control layer, resulting in reduction of output, (2) the thick lower insulating layer is adhered so as to increase the gap between the magnetoresistive sensor layer and the magnetic domain control layer, thereby making the magnetic domain control different from the design, and (3) in consideration of the thickness maintaining the pressure resistance of the insulating layer, the magnetic layer thickness of the magnetic domain control layer is reduced relatively, so as not to ensure a predetermined susceptibility, thereby making it difficult to design the magnetic domain control. Further, when employing the yoke structure or the flux guide structure of the TMR element, these must be magnetic domain controlled. Simply, there is employed means for laminating a plurality of the above-mentioned magnetic domain control layer. This will involve a very difficult problem in process.

SUMMARY OF THE INVENTION

[0012] An object of the present invention is to provide a magnetoresistive sensor having, in particular, excellent reproducing resolution, in magnetic read and write, a magnetic head using the same, and a magnetic disk apparatus, and, for that, to provide magnetic domain control layers having high electric-resistivity suitable for improving the reproducing resolution of the magnetoresistive sensor.

[0013] In order to achieve the foregoing objects, the present invention solves the above-mentioned problems with respect to the magnetic domain control layer by the following means, and provides a magnetoresistive sensor having excellent reproducing resolution, a magnetic head using the same, and a magnetic disk apparatus.

[0014] Conventionally, the magnetic domain control layer is arranged on the lower magnetic shield by employing a multi-layered structure of insulating layer/(metal underlayer)/hard magnetic metal material layer/insulating layer. In the present invention, there is used means wherein the magnetic domain control layer comprises a single layer made of a hard magnetic material having high electric resistivity, thereby directly performing magnetic domain control. According to this method, the insulating layers arranged at the upper and lower sides of the magnetic layer can be omitted. Thus, when the magnetoresistive sensor layer is made thinner, a loss of the susceptibility due to the thickness of the insulating layer can be reduced, so as to lower the shunting loss of an electric current. In addition, since the magnetic domain control layer is in direct contact with the magnetoresistive sensor layer, the loss of the magnetic field of the magnetic domain control can be minimized.

[0015] As a hard magnetic material having high electric resistivity with such characteristics, there are (1) a magnetic oxide having a spinel lattice, and (2) a granular magnetic material made of a hard magnetic metal material and a non-magnetic insulating material. With respect to (1), there is γ-Fe2O3 or the like. When a γ-Fe2O3 (004) layer grows, the residual magnetization is relatively large, the coercivity is high, and the specific resistance is high and 10^5 to $10^6 \Omega$cm. Thus, this is adaptable to the above-mentioned single magnetic domain control layer. As for such a system, there is also γ-(FeCo)2O4.

[0016] However, in order to exhibit the magnetic characteristic by making the spinel lattice thinner, it is generally necessary to manufacture the layer at a very high substrate temperature (above 500° C). When the layer is manufactured in a practical temperature range below 300° C. using a sputtering method, it tends to be an amorphous layer. As means of solving this, there is envisaged a method of inserting one high orientation thin oxide film or one single crystal thin film, with an NaCl structure, under the spinel lattice magnetic layer, so as to form thereon the above-mentioned magnetic domain control layer having high electric resistivity, and this is used as means.

[0017] Examples of the underlayer material for use in this method include CoO (200), MgO (200), NiO (200), EuO (200), FeO (200) and ZnO (001). These materials can be relatively easily grown at room temperature by means of the sputtering method. When a spinel type compound γ-Fe2O3 is grown on this plane, it is found that the γ-Fe2O3 (400) plane can be manufactured on these oxides in a relatively low temperature range below 300° C. These thin oxide films can exhibit a function as the underlayer even in the thickness range of 1 nm to 5 nm. These underlayers are electrically an insulator to insulating semiconductor. Basically, they can eliminate shunting from the magnetoresistive sensor layer to the magnetic domain control layer.

[0018] In the granular magnetic material made of a hard magnetic metal material and a non-magnetic insulating material, the multi-layer laminated is formed using the mixed sputtering method or the sputtering method, so that a hard magnetic material in granular form is formed in the non-magnetic insulating material. At this time, when the granular volume is smaller than the critical volume (granular volume V in which thermal energy kT is larger than magnetic energy MV+KV), the material becomes magnetically paramagnetic, or weak soft magnetic. However, when the granular particle is larger than the critical volume and the granular shape is changed anisotropically for pinning by the insulator, it can become magnetically hard. The granular magnetic material of the present invention is a material in which the hard magnetic metal material is enclosed by the non-magnetic insulating material, and the granular volume is larger than the critical volume. When the above-mentioned conditions are met, the granular shape is optional.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] **FIG. 1** is a diagram showing the sectional structure of the media-opposed surface side of the magnetoresistive sensor of Example 1 of the present invention and the position of a magnetic domain control layer;

[0020] **FIG. 2** is a cross-sectional view of the depth direction of the magnetoresistive sensor of Example 1 of the present invention;

[0021] **FIG. 3** is a cross-sectional view of the media-opposed surface side of Example 1 (3) of the present invention showing the position relation between the magnetic domain control layer having high electric resistivity and the magnetoresistive sensor layer;

[0022] **FIG. 4** is a cross-sectional view of the media-opposed surface side of Example 1 (2) of the present invention showing the position relation between the magnetic domain control layer having high electric resistivity and the magnetoresistive sensor layer;

[0023] **FIG. 5** is a cross-sectional view of the media-opposed surface side of Example 1 (1) of the present