and 4(*b*) is narrowed by reducing the thickness of the NiTa amorphous film and the Cr underlayer and more intense bias magnetic field is applied. It has been found that, to optimize the bias magnetic field, it is important to make the gap distance narrower between the free layer and the magnetic domain control film while keeping satisfactory the magnetic properties of the magnetic domain control film at the inclined portion of the end of the free layer.

[**0113**] Further, in the ion beam sputtering method used in the present invention, the thickness of the film formed at the inclined portion of the end of the stack of magnetoresistive layers can be changed by changing the incident angle of sputtered particles. As a result of an experiment while changing the incident angle of the sputtered particles in the ion beam sputtering method, it has been found that Vhc increases unless adopting conditions that the NiTa amorphous film and the Cr underlayer are deposited as far as around the lower portion at the top end of the CoCrPt thin film at the inclined portion of the end of the stack of magnetoresistive layers.

[**0114**] As shown above, by optimizing the conditions for forming the NiTa amorphous film and the Cr underlayer, the magnetic domain control bias magnetic field can be optimized, improving the head properties.

EMBODIMENT 4

[**0115**] Then, an experiment for optimizing the bias magnetic field was carried out by changing the thickness of the CoCrPt alloy thin film to change the residual magnetization of Brt. The saturation magnetic flux density of the CoCrPt alloy thin film is 1.35 T. As the type for the free layer **7** of the stack of magnetoresistive layers, a laminate ferri-type free layer having a structure of CoFe film/Ru film/NiFe film with a total film thickness of 4.2 nm was used. Further, a resist was selected so as to provide 100 nm Twf equivalent to that in Embodiment 2. Further, two types of heads, that is, a head of a structure according to the present invention and a head of the existent structure were prototyped and Vhc and ΔR of the transfer curve were compared with each other. **FIG. 14** shows the result thereof. The abscissa indicates the ratio between the magnetic domain control film thickness and the free layer film thickness.

[**0116**] In the case of the head of the existent structure, when the ratio between the magnetic domain control film thickness and the free layer thickness is less than 4, Vhc showing the deviation of the transfer curve increases extremely. On the contrary, in the structure according to the present invention, no large deviation is observed up to the ratio of 2 between the film thickness of the magnetic domain control film **11** and a film thickness of the free layer **7** in the structure according to the present invention. Further, as the film thickness decreases, the resistance change ΔR increases both in the cases of the present invention and the existent structure. Further, ΔR is larger in the case of the existent structure.

[**0117**] This shows that the bias magnetic field decreases as the ratio between the magnetic domain control film thickness and the free layer thickness decreases. Further, the resistance change coefficient is smaller in the present invention than in the existent structure at the same ratio between the magnetic domain control film thickness and the free layer film thickness and this shows that the effective bias magnetic field applied to the free layer **7** is more intense in the structure according to the present invention. Accordingly, it can be concluded that a bias voltage is applied more appropriately to the free layer in the structure according to the present invention compared with the existent structure.

[**0118**] Then, an experiment of changing the thickness of the magnetic domain control film was conducted while changing the CoCrPt alloy composition for the magnetic domain control film **11** and using the material composition showing the saturation magnetic flux density Bs of 1.55 T. In this case, the coercivity value was 1150 (Oe) and the squareness was 0.91. The Vhc value decreased in each of the cases where the ratios between the magnetic domain control film thickness and the free layer film thickness were 1 and 2. **FIG. 14** shows that the ratio between the magnetic domain control film thickness and the free layer thickness can be reduced to 0.75 for use at a Vhc value of 0.05 or less. Accordingly, this shows that Vhc can be decreased in a case where the saturation magnetic flux density is high and the residual magnetic flux density is high. A localized bias magnetic field can be applied to the free layer by the method in a structure in which the film thickness of the magnetic domain control film is decreased, that is, a structure shown in **FIG. 4**, that is, in **FIG. 2**

EMBODIMENT 5

[**0119**] The magnetic head can be prepared easily by combining a recording head to a reading head having the structure of the present invention. As described above for the present invention, the reading head of the present invention has a structure optimal to a head having a read track width of 200 nm or less and, particularly, about 100 nm, and a writing head corresponding to the narrow track width of the reading head is combined with the reading head to fabricate a magnetic head. This magnetic head is incorporated into a magnetic recording apparatus for high recording density and used for writing/reading signal information, and a magnetic recording apparatus is provided which has a low error reading rate for information resulting from the high signal quality.

[**0120**] **FIG. 15** shows an entire view of a magnetic head that incorporates a reading head having a magnetic domain control structure of the present invention. A stack of magnetoresistive layers **36** having a magnetoresistive effect is disposed by way of an insulative layer **35** on a lower shield **34**, and stacks of magnetic domain control layers M1 are disposed adjacent to both the inclined ends of the stack of magnetoresistive layers. An electrode **12** is disposed on the stack of magnetic domain control layers. An upper shield **38** is disposed by way of an insulative layer **37** above the electrode **12**. A lower magnetic pole **40*a*** is disposed by way of an insulative layer **39** above the upper shield **38**. A portion of the lower magnetic pole has a protruding structure **40*b***, which performs recording operation. Coils **42** and upper magnetic poles **41*a***, **41*b*** are present above the lower magnetic pole **40*a***. The top end of the upper magnetic pole **41*a*** has a structure recessed from the flying surface and retracted from the top end of the upper magnetic pole **41*b***. By dividing the upper magnetic pole into **41*a*** and **41*b*** as shown, magnetic fluxes generated in the magnetic pole by a current flowing through the coils **42** can be effectively collected to the top end portion, improving the recording characteristics. The writing head may be one for vertical recording having a main magnetic pole and an auxiliary magnetic pole.