MAGNETORESISTIVE SENSOR WITH OVERSIZED PINNED LAYER

CROSS-REFERENCE TO RELATED APPLICATION(S)

This application claims priority from Provisional Application No. 60/317,321, filed Sep. 5, 2001 entitled "Magnetic Field Sensor with Large Pinned Layer" by T. Pokhil, O. Heinonen, and C. Hou.

BACKGROUND OF THE INVENTION

The present invention relates generally to a magnetoresistive sensor for use in a magnetic read head. In particular, the present invention relates to a magnetoresistive read sensor having enhanced pinned layer magnetization and stability.

Magnetoresistive read sensors, such as giant magnetoresistive (GMR) read sensors, are used in magnetic data storage systems to detect magnetically-encoded information stored on a magnetic data storage medium such as a magnetic disc. A time-dependent magnetic field from a magnetic medium directly modulates the resistivity of the GMR read sensor. A change in resistance of the GMR read sensor can be detected by passing a sense current through the GMR read sensor and measuring the voltage across the GMR read sensor. The resulting signal can be used to recover the encoded information from the magnetic medium.

A typical GMR read sensor configuration is the GMR spin valve, in which the GMR read sensor is a multi-layered structure formed of a nonmagnetic spacer layer positioned between a ferromagnetic pinned layer and a ferromagnetic free layer. The magnetization of the pinned layer is fixed in a predetermined direction, typically normal to an air bearing surface of the GMR read sensor, while the magnetization of the free layer rotates freely in response to an external magnetic field. The resistance of the GMR read sensor varies as a function of an angle formed between the magnetization direction of the free layer and the magnetization direction of the pinned layer. This multi-layered spin valve configuration allows for a more pronounced magnetoresistive effect, i.e. greater sensitivity and higher total change in resistance, than is possible with anisotropic magnetoresistive (AMR) read sensors, which generally consist of a single ferromagnetic layer.

The pinned layer can be a single ferromagnetic layer or a multilayer synthetic antiferromagnet (SAF). An SAF includes a ferromagnetic reference layer and a ferromagnetic pinned layer which are magnetically coupled by a coupling layer such that the magnetization direction of the reference layer is opposite to the magnetization of the pinned layer.

A pinning layer is typically exchange coupled to the pinned layer to fix the magnetization of the pinned layer in a predetermined direction. The pinning layer is typically formed of an antiferromagnetic material. In antiferromagnetic materials, the magnetic moments of adjacent atoms point in opposite directions and, thus, there is no net magnetic moment in the material.

GMR spin valves are configured to operate in either a current-in-plane (CIP) mode or a current-perpendicular-to-plane (CPP) mode. In CIP mode, the sense current is passed through in a direction parallel to the layers of the read sensor. In CPP mode, the sense current is passed through in a direction perpendicular to the layers of the read sensor.

A tunneling magnetoresistive (TMR) read sensor is similar in structure to a GMR spin valve configured in CPP mode, but the physics of the device are different. For a TMR read sensor, rather than using a spacer layer, a barrier layer is positioned between the free layer and the pinned layer (or reference layer of the SAF). Electrons must tunnel through the barrier layer. A sense current flowing perpendicularly to the plane of the layers of the TMR read sensor experiences a resistance which is proportional to the cosine of an angle formed between the magnetization direction of the free layer and the magnetization direction of the pinned layer (or reference layer of the SAF).

One principal concern in the performance of magnetoresistive read sensors is the fluctuation of magnetization in the read sensor, which directly affects the magnetic noise of the read sensor. A key determinant of the fluctuation of magnetization in the read sensor is the lateral size of the pinned layer and the pinning layer. A large pinning layer contains a greater number of structural grains than a small pinning layer. The increased number of structural grains increases the pinning field direction dispersion in the pinning layer, which decreases fluctuations of magnetization in the pinned layer. This not only decreases the magnetic noise of the read sensor, but it also decreases the variation of pinning direction from sensor to sensor and improves the long term stability of the sensor. It is important, however, to ensure that the lateral size of the free layer is not increased. The spatial resolution of the read sensor (the areal density of magnetic data it can support) is determined by the size of the free layer, and therefore a small free layer provides a higher spatial resolution than a large free layer.

The present invention addresses these and other needs, and offers other advantages over current devices.

BRIEF SUMMARY OF THE INVENTION

The present invention is a magnetoresistive stack for use in a magnetic read head. The magnetoresistive stack has a plurality of layers including a ferromagnetic free layer, a ferromagnetic pinned layer, and an antiferromagnetic pinning layer. The pinned layer and pinning layer each have a greater number of structural grains than the free layer, which decreases a fluctuation of magnetization in the magnetoresistive stack without decreasing a spatial resolution of the magnetoresistive stack.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagram describing characteristics of a pinned layer and pinning layer of the present invention.

FIG. **2A** is a layer diagram of a sensor structure of the present invention.

FIG. **2B** is an alternative view of a sensor structure of the present invention.

FIG. **3A** is a layer diagram of a first embodiment of a magnetoresistive stack of the present invention.

FIG. **3B** is a layer diagram of a second embodiment of a magnetoresistive stack of the present invention.

FIG. **3C** is a layer diagram of a third embodiment of a magnetoresistive stack of the present invention.

FIG. **4A** is a layer diagram of a fourth embodiment of a magnetoresistive stack of the present invention.

FIG. **4B** is a layer diagram of a fifth embodiment of a magnetoresistive stack of the present invention.

DETAILED DESCRIPTION

FIG. **1** shows the effect of the number of structural grains in an antiferromagnetic pinning layer on pinning field direc-