SPIN VALVE FILMS WITH IMPROVED CAP LAYERS

FIELD OF THE INVENTION

[0001] This invention relates generally to magnetic transducers for reading information from a magnetic medium and, in particular, to a spin valve magnetoresistive read sensor having a cap layer of specific composition, the spin valve having enhanced device properties and function.

BACKGROUND OF THE INVENTION

[0002] Computers often include auxiliary memory storage devices having media on which data can be written and from which data can be read for later use. A direct access storage device (disk drive) incorporating rotating magnetic disks is commonly used for storing data in magnetic form on the disk surfaces. Data is recorded on concentric, radially spaced tracks on the disk surfaces. Magnetic heads including read sensors are then used to read data from the tracks on the disk surfaces.

[0003] In high capacity disk drives, magnetoresistive read sensors, commonly referred to as MR heads, are the prevailing read sensors because of their capability to read data from a surface of a disk at greater linear densities than thin film inductive heads. An MR sensor detects a magnetic field through the change in the resistance of its MR sensing layer (also referred to as an "MR element") as a function of the strength and direction of the magnetic flux being sensed by the MR layer.

[0004] One type of MR sensor currently under development is the giant magnetoresistive (GMR) sensor manifesting the GMR effect. In the GMR sensors, the resistance of the MR sensing layer varies as a function of the spin-dependent transmission of the conduction electrons between the magnetic layers separated by a non-magnetic layer (spacer) and the accompanying spin-dependent scattering, which takes place at the interface of the magnetic and non-magnetic layers and within the magnetic layers.

[0005] GMR sensors using only two layers of ferromagnetic material (e.g., Ni—Fe or Co or Ni—Fe/Co) separated by a layer of non-magnetic metallic material (e.g., copper) are generally referred to as spin valve (SV) sensors manifesting the SV effect. In an SV sensor, one of the ferromagnetic layers, referred to as the pinned layer, typically has its magnetization pinned by exchange coupling with an antiferromagnetic (e.g., Fe—Mn or NiO) layer. The pinning field generated by the antiferromagnetic layer should be greater than demagnetizing fields to ensure that the magnetization direction of the pinned layer remains fixed during application of external fields (e.g., fields from bits recorded on the disk). The magnetization of the other ferromagnetic layer, referred to as the free layer, however, is not fixed and is free to rotate in response to the field from the disk.

[0006] Two important considerations in the development of spin valves are protection of the structure of the valve during and after production and increasing the GMR of the valve. The cap or capping layer may have a large impact on both of these functions. One example of a spin valve is taught by Lee et al., U.S. Pat. No. 6,141,191, which discloses a spin valve having a protective cap comprised of a material such as tantalum, nickel, iron, chromium or alumina. Similarly, Lin, U.S. Pat. No. 6,033,491 discloses a cap layer composed of tantalum that is sputter deposited on the stack and then later removed.

[0007] Even with the structures disclosed in these recent publications, there still exists a need for improved processes and structures that offer structural protection of the spin valve and provide enhanced GMR.

SUMMARY OF THE INVENTION

[0008] The invention relates to a spin valve type magnetoresistive sensor having electrical resistance that changes with the magnetization direction of a pinned magnetic layer and the magnetization direction of a free magnetic layer affected by an external magnetic field. More particularly, the invention provides a spin valve sensor containing tantalum nitride or copper/tantalum nitride as the cap layer, which has a higher sensitivity of detection, sufficient pinning strength, good soft magnetic properties in the free layer, as well as good protective properties against oxidation and corrosion during wafer processing.

[0009] The cap layer used in spin valve sensors not only functions as protection against oxidation and corrosion during wafer processing, but also functions as the electron scattering layer. Commonly used materials for the cap layer include tantalum (Ta) or nickel—iron—chrome (NiFeCr) for example. These cap layers have little resistance to corrosion and/or oxidation. These materials also do not function well as an electron scattering layer in a bottom pinned spin valve (BSV) sensor.

[0010] By using tantalum nitride (TaN), or a bilayer of copper/tantalum nitride (Cu/TaN) as the cap layer, the spin valves of the invention possess high sensitivity and good soft magnetic properties. Compared to spin valves with a tantalum cap layer, the DR/R of spin valves in accordance with the invention is increased by more than 15%. Compared to spin valves with a NiFeCr cap layer, the DR/R of spin valves of the invention is increased by more than 40%. Tantalum nitride, or copper/tantalum nitride can be used in the cap layer in conjunction with different antiferromagnetic (AFM) materials like PtMn, NiMn, IrMn, PdPtMn, CrMnPt, CrMnCu, CrMnPd, PtRuMn to increase the sensitivity of the spin valve. The invention is applicable to top, dual, and bottom spin valve sensors.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] **FIG. 1** depicts a dual spin valve (DSV) in accordance with one aspect of the invention.

[0012] **FIG. 2** depicts a bottom pinned spin valve (BSV) in accordance with one aspect of the invention.

[0013] **FIG. 3** depicts a top pinned spin valve (TSV) in accordance with one aspect of the invention.

[0014] **FIG. 4** illustrates DR and DR/R for bottom spin valves (BSVs) with different cap layers.

[0015] **FIG. 5** illustrates interlayer coupling fields for bottom spin valves (BSVs) with different cap layers.

[0016] **FIG. 6** illustrates DR/R of a bottom pinned spin valve (BSV) with copper/tantalum nitride as the cap layer as the applied field (oriented parallel to the pinning field direction) is varied.