CLAIMS

1. A magnetic tunnel junction device, comprising:

a cylindrically-shaped pillar structure;

a first ferromagnetic layer disposed on a surface of at least a portion of the pillar structure, the first ferromagnetic layer having a magnetization that is changeable in the presence of at least one of an applied bias and heat;

a dielectric barrier disposed on a surface of at least a portion of the first ferromagnetic layer; and

a second ferromagnetic layer disposed on a surface of at least a portion of the dielectric barrier, the second ferromagnetic layer having a magnetization that is fixed;

wherein the first and second ferromagnetic layers and the dielectric barrier have an all-around structure such that the first and second ferromagnetic layers and the dielectric barrier layer concentrically surround each other and concentrically surround the pillar structure, wherein the pillar structure comprises:

a central insulator core having a major axis that is substantially vertical; and

a conductive shell disposed over at least a portion of the central insulator core along the major axis; and

wherein the first ferromagnetic layer is in electric contact with the conductive shell, and the first and second ferromagnetic layers and the dielectric barrier concentrically surround the conductive shell in a direction that is perpendicular to the major axis.

2. The magnetic tunnel junction device of claim 1, wherein the conductive shell comprises a spin orbit torque (SOT) metal.

3. The magnetic tunnel junction device of claim 2, wherein the SOT metal comprises at least one of tungsten, platinum and tantalum, and wherein a thickness of the SOT metal is about 2 - 20 nanometers.

4. The magnetic tunnel junction device of claim 1, wherein the central insulator core comprises at least one of silicon dioxide (SiO_2), silicon nitride (SiN) and silicon oxynitrate (SiO_xN_y).

5. The magnetic tunnel junction device of claim 1, wherein the central insulator core is about 20-100 nanometers in diameter and about 50 - 200 nanometers in height.

6. The magnetic tunnel junction device of claim 1, wherein the first ferromagnetic layer is toroidal in shape and comprises at least one of cobalt, iron and boron, the conductive shell passing through a center of the first ferromagnetic layer.

7. The magnetic tunnel junction device of claim 1, wherein the dielectric barrier is toroidal in shape and comprises at least one of magnesium oxide (MgO), aluminum oxide (AlO_x), and magnesium aluminate ($MgAlO_x$).

8. The magnetic tunnel junction device of claim 1, wherein the device is configured such that the magnetization of the first ferromagnetic layer switches as a function of a bias current flowing through the pillar structure.

9. The magnetic tunnel junction device of claim 1, wherein the pillar structure comprises a central nanowire insulator surrounded by a conductive shell, the nanowire insulator being oriented along a major axis of the pillar structure.

10. The magnetic tunnel junction device of claim 1, wherein an interface area of the magnetic tunnel junction device is determined as $2\pi rh$, where r is a radius of the pillar structure and h is a height of the first ferromagnetic layer, a switching efficiency of the magnetic tunnel junction device being controlled as a function of the interface area.

11. A method of forming a magnetic tunnel junction device having an all-around structure comprises:

forming a cylindrically-shaped pillar structure;

forming a first ferromagnetic layer on a surface of at least a portion of the pillar structure, the first ferromagnetic layer having a magnetization that is changeable in the presence of at least one of an applied bias and heat;

forming a tunneling barrier on a surface of at least a portion of the first ferromagnetic layer; and

forming a second ferromagnetic layer on a surface of at least a portion of the tunneling barrier, the second ferromagnetic layer having a magnetization that is fixed;

wherein the first and second ferromagnetic layers and the tunneling barrier concentrically surround each other and concentrically surround the pillar structure, and wherein forming the pillar structure comprises:

depositing an amorphous silicon layer on an upper surface of at least a portion of a metal connection formed in a dielectric material layer;

depositing a hard mask layer on a portion of an upper surface of the amorphous silicon layer, the hard mask layer and the amorphous silicon layer forming a dummy core;

etching the dummy core to form the pillar structure which is cylindrical in shape; and

depositing a layer of spin orbit torque (SOT) metal on at least a portion of an upper surface of the dielectric material layer and sidewalls and an upper surface of the dummy core.

12. The method of claim 11, wherein forming the first ferromagnetic layer comprises depositing a layer of at least one of cobalt, iron and boron on at least a portion of an upper surface of the SOT metal.

13. The method of claim 12, wherein forming the tunneling barrier comprises depositing at least one of a layer of magnesium oxide (MgO), aluminum oxide (AlO_x), and magnesium aluminate ($MgAlO_x$) on at least a portion of an upper surface of the first ferromagnetic layer.

14. The method of claim 13, wherein forming the second ferromagnetic layer comprises depositing at least one of a layer of cobalt, iron, boron, platinum, nickel, tungsten and iridium.

15. The method of claim 11, further comprising forming a metallic hard mask layer on at least a portion of an upper surface of the second ferromagnetic layer.

16. The method of claim 15, further comprising:

removing portions of the metallic hard mask layer formed on horizontal surfaces of the second ferromagnetic layer;

forming a dummy dielectric layer on horizontal surfaces of the magnetic tunnel junction device; and

forming a conformal dielectric layer over an upper surface of the magnetic tunnel junction device.

17. The method of claim 16, further comprising:

performing reactive ion etching to remove portions of the conformal dielectric layer formed on horizontal surfaces of the magnetic tunnel junction device;

recessing the conformal dielectric layer remaining on sidewalls of the pillar structure thereby exposing a portion of the dummy dielectric layer formed on an upper surface of the pillar structure and exposing a top portion of the metallic hard mask layer disposed on sidewalls of the pillar structure;

removing portions of the dummy dielectric layer formed on the upper surface of the pillar structure and not covered by the conformal dielectric layer; and

performing selective etching to remove remaining portions of the dummy dielectric layer disposed under the conformal dielectric layer.

18. The method of claim 17, further comprising:

removing portions of the metallic hard mask layer not protected by the conformal dielectric layer;

removing portions of the first and second ferromagnetic layers and tunneling barrier not protected by remaining portions of the metallic hard mask layer;

forming an encapsulation layer surrounding the magnetic tunnel junction device; and

forming electrical contacts with the second ferromagnetic layer and the pillar structure.