CLAIMS

1. 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.

2. The method of claim 1, 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.

3. The method of claim 2, 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.

4. The method of claim 3, wherein forming the second ferromagnetic layer comprises depositing at least one of a layer of cobalt, iron, boron, platinum, nickel, tungsten and iridium.

5. The method of claim 1, further comprising forming a metallic hard mask layer on at least a portion of an upper surface of the second ferromagnetic layer.

6. The method of claim 5, 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.

7. The method of claim 6, 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.

8. The method of claim 7, 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.