CLAIMS

1. A non-volatile memory device, comprising:

a buffer layer of a first metal oxide; and

a primary memory layer having:

a first active layer of a second metal oxide, the first active layer being immediately adjacent and connected to the buffer layer;

a second active layer of a third metal oxide; and

a third active layer of a fourth metal oxide, the second active layer being disposed between the first active layer and the third active layer, wherein the primary memory layer is characterized by an oxygen gradient, and wherein a highest oxygen concentration is associated with the first active layer, and wherein a lowest oxygen concentration is associated with the third active layer;

wherein the third metal oxide further comprises a first dopant, the first dopant being a metal different from any metal element forming the second metal oxide;

wherein the fourth metal oxide further comprises a second dopant, the second dopant being a metal different from any metal element forming the second metal oxide; and

wherein the first dopant and the second dopant are selected such that the doped third metal oxide has a higher oxygen concentration than the doped fourth metal oxide.

2. The non-volatile memory device as set forth in claim 1, wherein each of the first active layer, the second active layer, and the third active layer is associated with a respective work function, and wherein the respective work function decreases from the first active layer to the second active layer, and wherein the respective work function decreases from the second active layer to the third active layer.

3. The non-volatile memory device as set forth in claim 1 or claim 2, wherein the first metal oxide is characterized by a stoichiometric composition; and wherein the first metal oxide comprises one of AlOx, SiOx, MgOx, CaOx, HfSiOx, or any combination thereof.

4. The non-volatile memory device as set forth in any one of claims 1 to 3, wherein the second metal oxide comprises one of Ta oxide, Hf oxide, Zr oxide, Ti oxide, La oxide, or

any combination thereof, and wherein the second metal oxide is characterized by a stoichiometric composition.

5. The non-volatile memory device as set forth in any one of claims 1 to 4, wherein the third metal oxide comprises one of Ta oxide, Hf oxide, Zr oxide, Ti oxide, La oxide, or any combination thereof.

6. The non-volatile memory device as set forth in claim 5, wherein the second metal oxide and the third metal oxide are of a same group.

7. The non-volatile memory device as set forth in any one of claims 1 to 6, wherein the fourth metal oxide comprises one of Ta oxide, Hf oxide, Zr oxide, Ti oxide, La oxide, or any combination thereof.

8. The non-volatile memory device as set forth in claim 7, wherein the third metal oxide and the fourth metal oxide are of a same group.

9. The non-volatile memory device as set forth in claim 7, wherein the second dopant is a metal that is same as the first dopant.

10. The non-volatile memory device as set forth in claim 7, wherein the second dopant is a metal that is different from the first dopant.

11. The non-volatile memory device as set forth in any one of claims 1 to 5, wherein the buffer layer comprises Al_2O_3, and wherein the first active layer comprises Ta_2O_x in which $4.5 \leqslant x \leqslant 5$.

12. The non-volatile memory device as set forth in claim 11, wherein the second active layer comprises TaO_y in which $1 \leqslant y \leqslant 2.2$, and wherein the first dopant is a metal different from any metal present in the first active layer.

13. The non-volatile memory device as set forth in claim 12, wherein the third active layer comprises TaO_z in which $0<z\leqslant 0.5$, and wherein the second dopant is a metal different from any metal present in the first active layer.

14. The non-volatile memory device as set forth in any one of claims 1 to 13, further comprises a first electrode layer and a second electrode layer, wherein the buffer layer and the primary memory layer are disposed between the first electrode layer and the second electrode layer.

15. The non-volatile memory device as set forth in any one of claims 1 to 14, wherein each of the first active layer, the second active layer, and the third active layer has a film thickness in a range from 1 nanometer to 10 nanometers.

16. The non-volatile memory device as set forth in any one of claims 1 to 15, wherein the buffer layer has a film thickness in a range from 0.5 nanometer to 5 nanometers.

17. The non-volatile memory device as set forth in claim 12, wherein the first dopant is at least one selected from the group consisting of: Al, Hf, Ti, Zr, Nb, and Ru.

18. The non-volatile memory device as set forth in claim 13, wherein the second dopant is at least one selected from the group consisting of: Al, Hf, Ti, Zr, Nb, and Ru.

19. A non-volatile memory device, comprising:

a first electrode layer;

a second electrode layer;

a buffer layer disposed between the first electrode and the second electrode, the buffer layer formed of a first metal oxide; and

a primary memory layer comprising three active layers disposed between the buffer layer and the second electrode, the first active layer is formed of a second metal oxide and physically connected to the buffer layer, the second active layer is formed of a third metal oxide, and the third active layer is formed of a fourth metal oxide and physically connected to the second electrode; wherein the first active layer having a high oxygen concentration,

the second active layer having a lower oxygen concentration than the first active layer, and the third active layer having a lower oxygen concentration than the second active layer, an oxygen concentration decreasing in stages or gradually in a direction from the first active layer to the third active layer;

wherein the third metal oxide further comprises a first dopant, the first dopant being a metal different from any metal element forming the second metal oxide;

wherein the fourth metal oxide further comprises a second dopant, the second dopant being a metal different from any metal element forming the second metal oxide; and

wherein the first dopant and the second dopant are selected such that the doped third metal oxide has a higher oxygen concentration than the doped fourth metal oxide.