CLAIMS

1. A non-volatile memory device, comprising:

a first electrode;

a second electrode formed of a second electrode material;

a buffer region, the buffer region being disposed in direct contact with the first electrode; and

a principal memory region, the principal memory region being disposed between the second electrode and the buffer region, the principal memory region including:

a first active region, the first active region being disposed in direct contact with the buffer region, the first active region being formed with a first oxygen concentration;

a second active region, the second active region being formed with a second oxygen concentration that is lower than the first oxygen concentration;

a first scavenger region, the first scavenger region being formed with a third oxygen concentration that is lower than the second oxygen concentration; and

a second scavenger region, the second scavenger region being disposed in direct contact with the second electrode, the second scavenger region being formed with a fourth oxygen concentration,

wherein each of the second active region and the second scavenger region is disposed in direct contact with the first scavenger region, the second active region and the second scavenger region being formed physically spaced apart from one another.

2. The non-volatile memory device according to claim 1,

wherein a first interface between the first active region and the second active region is characterized by a first oxygen gradient, the first oxygen gradient corresponding to a difference between the first oxygen concentration and the second oxygen concentration, and wherein a second interface between the second active region and the first scavenger region is characterized by a second oxygen gradient, the second oxygen gradient corresponding to a difference between the second oxygen concentration and the third oxygen concentration, and wherein a third interface between the first scavenger region and the second scavenger region is characterized by a third oxygen gradient, the third oxygen gradient corresponding to a difference between the third oxygen concentration and the fourth oxygen concentration, and

wherein the second oxygen gradient is configured to be steeper than at least one of the first oxygen gradient and the third oxygen gradient.

3. The non-volatile memory device according to claim 2,
wherein the second oxygen gradient is configured to be steeper than each of the first oxygen gradient and the third oxygen gradient.

4. The non-volatile memory device according to any one of claims 1 to 3,
wherein the first oxygen concentration and the second oxygen concentration define a first range of oxygen concentrations, and wherein the third oxygen concentration and the fourth oxygen concentration define a second range of oxygen concentrations, and wherein the second range of oxygen concentrations is lower than the first range of oxygen concentrations, and wherein the first range of oxygen concentrations and the second range of oxygen concentrations are non-overlapping and distinct from one another.

5. The non-volatile memory device according to any one of claims 1 to 3,
wherein the principal memory region is characterized by a monotonic oxygen profile having at least a first range of oxygen concentrations and a second range of oxygen concentrations, and
wherein the monotonic oxygen profile is characterized by a step decrease in oxygen concentration from the first range of oxygen concentrations to the second range of oxygen concentrations.

6. The non-volatile memory device as set forth in any one of claims 1 to 5, wherein the buffer region is formed of a first metal oxide; and wherein the first metal oxide comprises at least one of MgO, AlO_{x1}, SiO_{x1}, CaO, $LaAlO_3$, $HfSiO_{x1}$, or any combination thereof.

7. The non-volatile memory device according to any one of claims 1 to 6, wherein the first active region comprises a second metal oxide formed with a stoichiometric material composition or a near-stoichiometric material composition.

8. The non-volatile memory device according to any one of claims 1 to 7, wherein the first active region comprises one of a *Ta* oxide, a *Ti* oxide, a *Hf* oxide, a *Zr* oxide, a *Sr* oxide, a *La* oxide, a *W* oxide, a *V* oxide, or any combination thereof.

9. The non-volatile memory device according to claims 1 to 7, wherein the first active region comprises Ta_2O_x in which $4 < x < 5$.

10. The non-volatile memory device according to any one of the claims 1 to 9, wherein the second active region comprises a third metal oxide.

11. The non-volatile memory device according to any one of claims 1 to 10, wherein the second active region comprises TaO_y in which $1.5 < y < x/2$.

12. The non-volatile memory device according to any one of claims 1 to 11, wherein the first scavenger region comprises a fourth metal oxide.

13. The non-volatile memory device according to any one of claims 1 to 12, wherein the first scavenger region comprises TaO_z in which $0 < z < 0.5$.

14. The non-volatile memory device according to any one of claims 1 to 13, wherein the second scavenger region comprises at least one of *Ta*, *Ti*, *Hf*, *Zr*, *Co*, *Ni*, *Fe*, or any alloy thereof.

15. The non-volatile memory device according to any one of claims 1 to 8, wherein the first electrode comprises *W*, the buffer region comprises Al_2O_3, the first active region comprises Ta_2O_5, the second active region comprises TaO_2, the second scavenger region comprises *Ta*, and the second electrode comprises *Pt*, and wherein the first scavenger region comprises TaO_z in which $0 < z \leq 0.3$.

16. The non-volatile memory device according to any one of claims 1 to 8, wherein the buffer region comprises Al_2O_3, and wherein the first active region comprises Ta_2O_x in which $4.5 \leq x \leq 5$.

17. The non-volatile memory device according to claim 16, wherein the second active region comprises TaO_y in which $1.5 \leq y \leq 2.2$, and which the second active region is doped with a first dopant, the first dopant being a metal different from any metal present in the first active region.

18. The non-volatile memory device according to claim 17, wherein the first scavenger region region comprises TaO_z in which $0 < z \leq 0.3$, and wherein the first scavenger region is doped with a second dopant, the second dopant being a metal different from any metal present in the first active region.

19. A method of making the non-volatile memory of any one of claims 1 to 18, the method comprising:

disposing the first scavenger region on the second scavenger region before disposing the second active region on the first scavenger region; and

disposing the first active region on the second active region such that the principal memory region is formed with four distinct regions of different oxygen concentrations.

20. A method of making the non-volatile memory of any one of claims 1 to 18, the method comprising:

disposing the second active region on the first active region; and

disposing the first scavenger region on the second active region before disposing the second scavenger region on the first scavenger region such that the principal memory region is formed with four distinct regions of different oxygen concentrations.