Claims

What is claimed is:

1. A ferroelectric device comprising:

a substrate;

a first electrode and a second electrode, wherein the first electrode is disposed on the substrate;

a thin film comprising crystalline material disposed between the first electrode and the second electrode, the crystalline material comprising hafnium oxide and zirconium oxide, wherein the crystalline material exhibits ferroelectric behavior as deposited; and

wherein the first electrode comprises tungsten, wherein greater than 50% of the total volume of the first electrode is in α phase, and the thin film having a remnant polarization of greater than about 50 $\mu C/cm^2$.

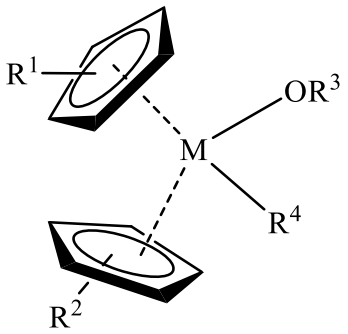
2. The ferroelectric device of claim 1, wherein the thin film is capable of exhibiting ferroelectric activity without a wakeup period.

3. The ferroelectric device of claim 1, wherein the second electrode comprises titanium nitride, tungsten, molybdenum, or combinations thereof.

4. The ferroelectric device of claim 1, wherein the first electrode has a thickness of between about 4nm and about 50 nm.

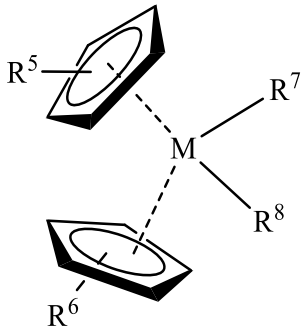
5. The ferroelectric device of claim 1, wherein the crystalline material comprises a hafnium oxide to zirconium oxide ratio of between about 1:3 and about 3:1.

6. The ferroelectric device of claim 1, wherein the crystalline material is derived from one or more metallocene precursor having Formula I:



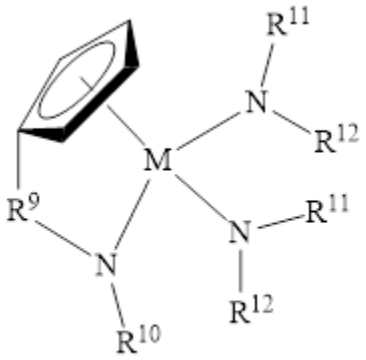
I

Formula II:



II

or Formula III:



III

wherein (i) M is selected from Zr and Hf, (ii) R^1, R^2, R^3, R^4, R^5, R^6, R^7 and R^8 are each a methyl group, (iii) R^9 is a C_1-C_4 group selected from -CH_2CH_2-, -$CH_2CH_2CH_2$-, -CH(Me)CH_2-, -CH_2CH(Me)-, -$CH_2CH_2CH_2$-, -CHMeCH_2CH_2-, and (iv) R^{10}, R^{11}, and R^{12} are each independently a C_1-C_6 linear alkyl.

7. The ferroelectric device of claim 1, wherein there is hysteresis and remanent polarization in a polarization-electric field measurement.

8. The ferroelectric device of claim 1, wherein the film has a thickness of approximately 0.2 nm to approximately 10 nm.

9. A method of creating a ferroelectric device comprising:

(i) providing a substrate;

(ii) depositing a first electrode onto the substrate, the first electrode comprising tungsten;

(iii) depositing a ferroelectric layer onto the first electrode at a deposition temperature, the ferroelectric layer comprising zirconium and hafnium;

(iv) depositing a second electrode onto the ferroelectric layer; and

(v) annealing the first electrode at a temperature of 400 degrees Celsius or less;

wherein greater than 50% of the total volume of the first electrode is in α phase.

10. The method of claim 9, wherein an annealing step is conducted at a temperature greater than about 350 degrees Celsius.

11. The method of claim 9, wherein no process steps take place at a temperature greater than about 400 degrees Celsius.

12. The method of claim 9, wherein the ferroelectric layer comprises hafnium zirconium oxide.

13. The method of claim 9, wherein the first electrode has a thickness of between about 4nm and about 50 nm.

14. A method of creating a ferroelectric device comprising:

(i) providing a substrate;

(ii) depositing a first electrode onto the substrate at a first temperature, wherein the first electrode comprises tungsten;

(iii) depositing a ferroelectric layer onto the first electrode at a second temperature; and

(iv) depositing a second electrode onto the ferroelectric layer;

(v) conducting an annealing step at a third temperature;

wherein the first temperature, the second temperature, and the third temperature are less than or equal to 400 degrees Celsius, and wherein greater than 50% of the total volume of the first electrode is in α phase.

15. The method of claim 14, wherein the first temperature is between about 15 degrees Celsius and about 400 degrees Celsius.

16. The method of claim 14, wherein a thickness of the first electrode is between about 4nm and about 50 nm.

17. The method of claim 14, wherein in the annealing step, the third temperature is greater than or equal to about 350 degrees Celsius and less than or equal to 400 degrees Celsius.

18. The method of claim 14, wherein no process steps take place at a temperature greater than about 400 degrees Celsius.

19. The method of claim 14,

wherein the second electrode comprises titanium nitride, tungsten, molybdenum, or combinations thereof.