What is claimed is:

1. A method for forming a GCIB-treated resistive device, comprising:

forming a lower electrode;

forming an oxide material on the lower electrode;

exposing the oxide material to a gas cluster ion beam (GCIB) until a change occurs in resistance of a first portion of the oxide material relative to the resistance of a second portion of the oxide material; and

forming an upper electrode on the first portion.

2. The method of claim 1, wherein the GCIB is configured to change the concentration of an ionic species in the molecular structure of the first portion of the oxide material relative to the concentration of ionic species in the molecular structure of the second portion of the oxide material.

3. The method of claim 1, wherein the GCIB is configured to change a concentration of oxygen vacancies in a molecular structure of the first portion of the oxide material relative to the concentration of oxygen vacancies in the molecular structure of the second portion.

4. The method of claim 3, wherein the oxide material has a molecular structure with an initial homogeneous concentration of oxygen vacancies.

5. The method of claim 3, wherein exposing the oxide material to the GCIB drives some of the oxygen vacancies in the molecular structure of the oxide material from the first portion to the second portion.

6. The method of claim 3, wherein exposing the oxide material to the GCIB drives some of the oxygen vacancies in the molecular structure of the oxide material from the second portion to the first portion.

7. The method of claim 1, including maintaining a surface of the oxide material at room temperature during the exposure of the oxide material to the GCIB.

8. The method of claim 1, wherein exposing the oxide material to the GCIB changes the molecular structure of the first portion to amorphous during oxidation.

9. The method of claim 1, exposing the oxide material to the GCIB changes the molecular structure of the first portion to amorphous during reduction.

10. The method of claim 1, wherein forming the oxide material includes forming a metal oxide material.

11. The method of claim 10, wherein exposing the oxide material to the GCIB creates a gradient in a metal to oxide ratio.

12. The method of claim 11, including creating the gradient in the metal to oxide ratio within a range of 1 to 50 nm.

13. The method of claim 10, wherein forming the metal oxide material includes forming a TiO_X material.

14. The method of claim 10, wherein forming the metal oxide material includes forming a NiO_X material.

15. The method of claim 10, wherein forming the metal oxide material includes forming a CuO_X material.

16. The method of claim 10, including exposing the oxide material to the GCIB having at least one gas selected from a group that includes: oxygen, nitrous, ammonia and deuterium.

17. The method of claim 10, wherein forming the metal oxide material includes forming a transition metal oxide material.

18. The method of claim 10, including forming a feature in the metal oxide material having a depth of 20nm or less.

19. The method of claim 10, wherein the first portion of the metal oxide material is a grain insensitive material.

20. A memory cell, comprising:

a GCIB-treated resistive device formed by the method as in one of claims 1-19 and coupled to a bit line; and

an access transistor coupled to the GCIB-treated resistive device, and having a gate coupled to a word line.

21. A method of operating a GCIB-treated resistive device formed by the method as in one of claims 1-19, comprising:

applying a first voltage signal of a first polarity, magnitude, and duration sufficient to cause the GCIB-treated resistive device to adopt a first resistance state; and

applying a second voltage signal of a second polarity, magnitude, and duration sufficient to cause the GCIB-treated resistive device to adopt a second resistance state,

wherein application of the first and second voltage signals causes oxygen vacancies to move between a first region and a second region established in the GCIB-treated resistive device by gas cluster ion beam exposure.

22. A GCIB-treated resistive device produced according to the process as in one of claims 1-19.

23. A GCIB-treated resistive device, comprising:

a lower electrode;

an oxide material formed on the lower electrode, the oxide material including a first portion and a second portion each having an initial concentration of oxygen vacancies, the oxide material being exposed to a gas cluster ion beam (GCIB) to change the concentration of oxygen vacancies in the first portion of the oxide material relative to the concentration of oxygen vacancies in the second portion of the oxide material; and

an upper electrode formed on the first portion,

wherein resistance of the oxide material portions vary corresponding to the concentration of oxygen vacancies in the molecular structure of the first portion of the oxide material relative to the concentration of oxygen vacancies in the molecular structure of the second portion.

24. The GCIB-treated resistive device of claim 23, wherein the GCIB-treated resistive device is configured to be a memory element.

25. The GCIB-treated resistive device of claim 23, wherein the GCIB-treated resistive device is configured to be a switch.

26. The GCIB-treated resistive device of claim 23, wherein the GCIB-treated resistive device is configured to be a variable resistor.

27. A method for forming a GCIB-treated resistive device, comprising:

forming a lower electrode;

forming a semiconductor material on the lower electrode, the semiconductor being formed of a material including an initial concentration of an ionic species in a molecular structure of the semiconductor;

exposing the semiconductor material to a gas cluster ion beam (GCIB) until a change occurs in resistance of a first portion of the semiconductor material relative to the resistance of a second portion of the oxide material; and

forming an upper electrode on the first portion.

28. The method of claim 27, wherein the GCIB is configured to change the concentration of an ionic species in the molecular structure of the first portion of the semiconductor material relative to the concentration of ionic species in the molecular structure of the second portion of the semiconductor material.

29. The method of claim 28, wherein the semiconductor material has a molecular structure with an initial homogeneous concentration of ionic species that can be modified by GCIB exposure.

30. The method as in one of claims 27-29, wherein ionic species includes nitrogen ions.

31. The method as in one of claims 27-29, wherein forming a semiconductor material includes forming an aluminum nitride material.

32. The method of claim 31, wherein exposing the semiconductor material to the GCIB drives some of the nitrogen ions in the molecular structure of the semiconductor material from the first portion to the second portion.

33. The method of claim 31, wherein exposing the semiconductor material to the GCIB drives some of the nitrogen ions in the molecular structure of the semiconductor material from the second portion to the first portion.

34. A method for forming a GCIB-treated resistive device, comprising:

forming a lower electrode;

forming a dielectric material on the lower electrode;

forming a feature in the dielectric material having a dimension measured from the lower electrode of 20 nm or less;

growing an oxide material in the feature;

exposing the oxide material to a gas cluster ion beam (GCIB) until a change occurs in concentration of oxygen vacancies in the molecular structure of a first portion of the oxide material relative to a second portion of the oxide material; and

forming an upper electrode on the first portion,

wherein resistance of the oxide material portions vary corresponding to the concentration of oxygen vacancies in the molecular structure of the first portion of the oxide material relative to the concentration of oxygen vacancies in the molecular structure of the second portion.

35. The method of claim 34, including removing a portion of the oxide material extending outside the feature prior to exposing the oxide material to the GCIB.

36. A GCIB-treated resistive device produced according to the process as in one of claims 34-35.

37. A method for forming a GCIB-treated resistive device, comprising:

forming a lower electrode;

forming a dielectric material on the lower electrode;

forming a feature in the dielectric material having a dimension measured from the lower electrode of 20 nm or less;

growing a first oxide material in the feature;

exposing the first oxide material to a gas cluster ion beam (GCIB) until a change occurs in concentration of oxygen vacancies in the molecular structure of a first portion of the first oxide material relative to a second portion of the first oxide material; and

forming a second oxide material on the first portion; and

forming an upper electrode on the second oxide material,

wherein resistance of the first oxide material portions vary corresponding to the concentration of oxygen vacancies in the molecular structure of the first portion of the first oxide material relative to the concentration of oxygen vacancies in the molecular structure of the second portion.

38. A GCIB-treated resistive device produced according to the process of claim 37.

What is claimed is:

1. A method for forming a GCIB-treated resistive device, comprising:

forming a lower electrode;

forming an oxide material over the lower electrode;

exposing the oxide material to a gas cluster ion beam (GCIB) until a change occurs in resistance of a first portion of the oxide material relative to the resistance of a second portion of the oxide material; and

forming an upper electrode on the first portion.

2. The method of claim 1, wherein the GCIB is configured to change the concentration of an ionic species in the molecular structure of the first portion of the oxide material relative to the concentration of ionic species in the molecular structure of the second portion of the oxide material.

3. The method of claim 1, wherein the GCIB is configured to change a concentration of oxygen vacancies in a molecular structure of the first portion of the oxide material relative to the concentration of oxygen vacancies in the molecular structure of the second portion.

4. The method of claim 3, wherein the oxide material has a molecular structure with an initial homogeneous concentration of oxygen vacancies.

5. The method of claim 3, wherein exposing the oxide material to the GCIB drives some of the oxygen vacancies in the molecular structure of the oxide material from the first portion to the second portion.

6. The method of claim 3, wherein exposing the oxide material to the GCIB drives some of the oxygen vacancies in the molecular structure of the oxide material from the second portion to the first portion.

7. The method of claim 1, including maintaining a surface of the oxide material at room temperature during the exposure of the oxide material to the GCIB.

8. The method of claim 1, wherein exposing the oxide material to the GCIB changes the molecular structure of the first portion to amorphous during oxidation.

9. The method of claim 1, exposing the oxide material to the GCIB changes the molecular structure of the first portion to amorphous during reduction.

10. The method of claim 1, wherein forming the oxide material includes forming a metal oxide material.

11. The method of claim 10, wherein exposing the oxide material to the GCIB creates a gradient in a metal to oxide ratio.

12. The method of claim 11, including creating the gradient in the metal to oxide ratio within a range of 1 to 50 nm.

13. The method of claim 10, wherein forming the metal oxide material includes forming a TiO_X material.

14. The method of claim 10, wherein forming the metal oxide material includes forming a NiO_X material.

15. The method of claim 10, wherein forming the metal oxide material includes forming a CuO_X material.

16. The method of claim 10, including exposing the oxide material to the GCIB having at least one gas selected from a group that includes: oxygen, nitrous, ammonia and deuterium.

17. The method of claim 10, wherein forming the metal oxide material includes forming a transition metal oxide material.

18. The method of claim 10, including forming a feature in the metal oxide material having a depth of 20nm or less.

19. The method of claim 10, wherein the first portion of the metal oxide material is a grain insensitive material.

20. A memory cell, comprising:

a GCIB-treated resistive device formed by the method of claim 1 and coupled to a bit line; and

an access transistor coupled to the GCIB-treated resistive device, and having a gate coupled to a word line.

21. A method of operating a GCIB-treated resistive device formed by the method of claim 1, comprising:

applying a first voltage signal of a first polarity, magnitude, and duration sufficient to cause the GCIB-treated resistive device to adopt a first resistance state; and

applying a second voltage signal of a second polarity, magnitude, and duration sufficient to cause the GCIB-treated resistive device to adopt a second resistance state,

wherein application of the first and second voltage signals causes oxygen vacancies to move between a first region and a second region established in the GCIB-treated resistive device by gas cluster ion beam exposure.

22. A GCIB-treated resistive device produced according to the process of claim 1.

23. A GCIB-treated resistive device, comprising:

a lower electrode;

an oxide material formed over the lower electrode, the oxide material including a first portion and a second portion each having an initial concentration of oxygen vacancies, the oxide material being exposed to a gas cluster ion beam (GCIB) to change the concentration of oxygen vacancies in the first portion of the oxide material relative to the concentration of oxygen vacancies in the second portion of the oxide material; and

an upper electrode formed on the first portion,

wherein resistance of the oxide material portions vary corresponding to the concentration of oxygen vacancies in the molecular structure of the first portion of the oxide material relative to the concentration of oxygen vacancies in the molecular structure of the second portion.

24. The GCIB-treated resistive device of claim 23, wherein the GCIB-treated resistive device is configured to be a memory element.

25. The GCIB-treated resistive device of claim 23, wherein the GCIB-treated resistive device is configured to be a switch.

26. The GCIB-treated resistive device of claim 23, wherein the GCIB-treated resistive device is configured to be a variable resistor.

27. A method for forming a GCIB-treated resistive device,

comprising:

forming a lower electrode;

forming a semiconductor material on the lower electrode, the semiconductor being formed of a material including an initial concentration of an ionic species in a molecular structure of the semiconductor;

exposing the semiconductor material to a gas cluster ion beam (GCIB) until a change occurs in resistance of a first portion of the semiconductor material relative to the resistance of a second portion of the semiconductor material; and

forming an upper electrode on the first portion

28. The method of claim 27, wherein the GCIB is configured to change the concentration of an ionic species in the molecular structure of the first portion of the semiconductor material relative to the concentration of ionic species in the molecular structure of the second portion of the semiconductor material.

29. The method of claim 28, wherein the semiconductor material has a molecular structure with an initial homogeneous concentration of ionic species that can be modified by GCIB exposure.

30. The method of claim 28, wherein ionic species includes nitrogen ions.

31. The method of claim 27, wherein forming a semiconductor material includes forming an aluminum nitride material.

32. The method of claim 31, wherein exposing the semiconductor material to the GCIB drives some of the nitrogen ions in the molecular structure of the semiconductor material from the first portion to the second portion.

33. The method of claim 31, wherein exposing the semiconductor material to the GCIB drives some of the nitrogen ions in the molecular structure of the semiconductor material from the second portion to the first portion.

34. A method for forming a GCIB-treated resistive device, comprising:

forming a lower electrode;

forming a dielectric material on the lower electrode;

forming a feature in the dielectric material having a dimension measured from the lower electrode of 20 nm or less;

growing an oxide material in the feature;

exposing the oxide material to a gas cluster ion beam (GCIB) until a change occurs in concentration of oxygen vacancies in the molecular structure of a first portion of the oxide material relative to a second portion of the oxide material; and

forming an upper electrode on the first portion,

wherein resistance of the oxide material portions vary corresponding to the concentration of oxygen vacancies in the molecular structure of the first portion of the oxide material relative to the concentration of oxygen vacancies in the molecular structure of the second portion.

35. The method of claim 34, including removing a portion of the oxide material extending outside the feature prior to exposing the oxide material to the GCIB.

36. A GCIB-treated resistive device produced according to the process of claim 34.

37. A method for forming a GCIB-treated resistive device, comprising:

forming a lower electrode;

forming a dielectric material on the lower electrode;

forming a feature in the dielectric material having a dimension measured from the lower electrode of 20 nm or less;

growing a first oxide material in the feature;

exposing the first oxide material to a gas cluster ion beam (GCIB) until a change occurs in concentration of oxygen vacancies in the molecular structure of a first portion of the first oxide material relative to a second portion of the first oxide material; and

forming a second oxide material on the first portion; and

forming an upper electrode on the second oxide material,

wherein resistance of the first oxide material portions vary corresponding to the concentration of oxygen vacancies in the molecular structure of the first portion of the first oxide material relative to the concentration of oxygen vacancies in the molecular structure of the second portion.

38. A GCIB-treated resistive device produced according to the process of claim 37.