

ELECTRONIC COMPONENT, METHOD FOR MAKING, AND TARGET THEREFOR

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Background of the Invention

This invention relates, in general, to electronic components, and more particularly, to dielectric materials used in the manufacture of electronic components.

10 Dielectric materials such as silicon dioxide and silicon nitride are used in a variety of applications including use as the insulating material between two conductive plates in a capacitor structure. The effective capacitance value of a given capacitor is determined in part by the dielectric constant of the dielectric material and the area of the dielectric
15 material between the two plates. In order to decrease the relative size of the capacitor and yet form a capacitor having the same capacitance value, there has to be a proportional increase in the dielectric constant of the material used in the capacitor.

Currently, conventional dielectric materials suffer from one of four
20 problems: they are incompatible with the materials used to form electronic components; they do not have a higher enough dielectric constant; they have a Curie temperature within the operational range of the electronic component; or they have high leakage current densities.

Accordingly, it would be advantageous to provide a dielectric
25 material that can be used in the manufacture of electronic components that has a higher dielectric constant value and lower leakage current densities. It would also be advantageous if the dielectric material had a Curie temperature that was below the operational temperature of electronic component so the dielectric material does not change from a
30 paraelectric state to a ferroelectric state during normal operation of the electronic component.

Brief Description of the Drawings

35 FIG. 1 illustrates enlarged cross-sectional views of electronic components formed in accordance with the present invention; and
FIG. 2 is cross-sectional view of a sputtering deposition system.

It will be appreciated that for simplicity and clarity of illustration, elements illustrated in the figures have not necessarily been drawn to scale. For example, the dimensions of some of the elements are
 5 exaggerated relative to other elements for clarity. Further, where considered appropriate, reference numerals have been repeated among the figures to indicate corresponding or analogous elements.

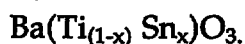
Detailed Description of the Drawings

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In general, the present invention provides a novel dielectric material that can be used in the manufacture of electronic components in a variety of applications. One skilled in the art will appreciate that the present invention can be used to manufacture integrated circuits such as
 15 microprocessors, microcontrollers, sensors, dynamic random access memories (DRAMs), embedded DRAMs, static random access memories (SRAMs), an electrically erasable and programmable read only memory (EEPROM), a flash electrically programmable read only memory (flash EPROM), or a flash electrically erasable and programmable read only
 20 memory (flash EEPROM). In addition, the dielectric material of the present invention can also be used to form discrete components such as stand-alone capacitors.

Due to the insulating properties of the dielectric material, the present invention can be used to replace conventional dielectric materials.
 25 In the examples discussed below, the dielectric material of the present invention can be used to replace silicon dioxide or silicon nitride as the insulating material in a gate structure, a capacitor structure, or a non-volatile memory device.

The dielectric material of the preferred embodiment comprises
 30 barium, titanium, tin, and an oxide. More particularly, the dielectric material can be represented by the formula:



Where X can range from a value greater than zero to about 1.

One unexpected property of the dielectric material of the present
 35 invention is that the addition of Sn to a compound provides a material that is classified as a dielectric material. This is in contrast to what might be more commonly expected; a conductive material such as is used in the

formation of interconnect structures or leadframes. Instead, the addition of tin to the compound of the present invention provides a material that has a dielectric constant greater than 1 and a resistivity greater than 1×10^5 ohm-centimeters. Historically, a dielectric constant greater than 1 has been the value used by those skilled in the art to classify a material as a dielectric material rather than a conductive or merely resistive material.

Functionally, the material of the present invention is well suited for applications where the material is used to provide electrical isolation between conductive structures, and yet, provide capacitive coupling between the conductive structures. For example, if the dielectric material is placed between two conductive regions or plates, the dielectric material will retard the flow of current between the plates and allow the conductive plates to be capacitively coupled together.

Another unexpected property of the dielectric material is that the relative value of the concentration of tin in the compound can be varied to adjust the Curie temperature of the compound. In particular, the value of X in the formula shown above can be varied to provide a compound having a different Curie temperature. The Curie temperature of a material is the temperature at which the material changes from being paraelectric to ferroelectric. A paraelectric material is said to have a single polarization value at the voltage potential applied. A ferroelectric material, however, exhibits a hysteresis in polarization which depends on the previous and present voltage potential applied to the material.

In most applications, it is desirable to form a dielectric material that remains paraelectric in nature. This allows an electronic component to be formed that has a predictable and consistent polarization. To maintain the paraelectric property of the dielectric material, the Curie temperature of the material must be below the normal operating temperatures of the electronic component so that the dielectric material does not pass through its Curie point. For example, if an electronic component is normally operated at about 0° Celsius (C) to 100°C, then ideally, the Curie temperature of the material should be -25°C or lower.

In addition to changing its electrical characteristics as described above, a dielectric material also undergoes significant physical stress as it passes through its Curie temperature. Therefore, it is desirable to form the dielectric material so that its Curie temperature is outside of its normal operating temperature range. This prevents the dielectric material, and

the electronic component containing the dielectric material, from being damaged during operation because the dielectric material does not transform from the paraelectric state to the ferroelectric state.

One skilled in the art, however, will appreciate that there are some applications where it is desirable to form an electronic component having a dielectric material that is ferroelectric in nature. For example, it may be desirable to form a non-volatile memory cell using a ferroelectric dielectric material and use the two polarization states to represent the programmed and erased states of the non-volatile memory cell.

FIG. 1 illustrates enlarged cross-sectional views of examples of applications in which the dielectric material of the present invention can be used. For example, the dielectric material can be used to form a capacitor structure as shown in electronic components 40 and 50. Electronic component 40 is a capacitor that is formed on a substrate 41. Substrate 41 is preferably a semiconductor substrate, however, other substrate materials used by those skilled in the art may also be used. Electronic component 40 has a layer of dielectric material 43, hereinafter referred to as dielectric layer 43, sandwiched between conductive plates 42 and 44.

In this embodiment, dielectric layer 43 is preferably paraelectric so that electronic component 40 has a predictable and constant polarization value. Accordingly, the relative amount of tin in the $\text{Ba}(\text{Ti}_{(1-x)}\text{Sn}_x)\text{O}_3$ compound should be adjusted so that the Curie temperature of dielectric layer 43 is less than the normal operating temperature of electronic component 40. For example, a value of x ranging from about 0.15 to 0.3 provides a dielectric material that has a Curie temperature ranging from about -25°C to -100°C . Therefore, as long as electronic component 40 remains above -25°C , dielectric layer 43 remains paraelectric. Table 1 below provides other ranges for the value of x in the compound $\text{Ba}(\text{Ti}_{(1-x)}\text{Sn}_x)\text{O}_3$ producing a dielectric material having various Curie temperatures. Table 1 also lists the property of the material at 0°C and 25°C , respectively. The value of ' >0 ' is used to indicate a concentration greater than zero and can have a value of 0.001, 0.0001, 0.00001, or less depending on the measurement capability. The value of '<1' is used to indicate a concentration less than 1 and can have a value of 0.99, 0.999, 0.9999, or greater depending on the measurement capability.

TABLE 1

	Value of X	Curie Temperature	0°C Property	-25°C Property
	>0 to 0.1	120°C to 40°C	ferroelectric	ferroelectric
5	0.1 to 0.3	40°C to -125°C	either	either
	0.15 to 0.3	0°C to -125°C	either	either
	0.01 to 0.1	119°C to 40°C	ferroelectric	ferroelectric
	0.01 to 0.3.	119°C to -125°C	either	either
	>0 to <1	less than 120°C	either	either

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As shown in the examples provided in Table 1, it is possible to form a dielectric material that is paraelectric at a temperature of about 0°C or is ferroelectric at a temperature of about 0°C. It is also possible to form a dielectric material that has a Curie temperature less than 0°C or that has a
 15 Curie temperature less than -25°C. It is also possible to form a compound where x ranges from about 0.2 to 0.4, about 0.3 to 0.5, about 0.4 to 0.6, about 0.5 to 0.7, about 0.6 to 0.8, about 0.7 to 0.9, about 0.8 to 1, and 0.9 to 1, however the range in Curie temperature is currently not fully understood.

In the preferred embodiment, dielectric material 43 comprises the
 20 compound $\text{Ba}(\text{Ti}_{(1-x)}\text{Sn}_x)\text{O}_3$, which results in a dielectric material having a bulk dielectric constant ranging from about 28,000 to 35,000. This is certainly greater than about 1 and is greater than about 10, which is larger than the constants of silicon dioxide and silicon nitride. The dielectric constant of the material of the present invention is also greater than about
 25 300, which exceeds the thin film dielectric constant of barium-strontium-titanium-oxide. This corresponds to a bulk dielectric constant for barium-strontium-titanium-oxide of about 15,000 to 20,000.

As shown in Table 1, a compound has been provided that includes tin, yet provides a dielectric material. It may also be possible to form other
 30 compounds that include tin, or tin and titanium, that also provides a material having dielectric characteristics. In addition, the compound of the preferred embodiment includes oxygen, but it should be understood that other oxides may also be used.

As shown in FIG. 1, electronic component 40 includes conductive
 35 plates 42 and 44 that are in direct contact with dielectric material 43. It should be understood that it is not necessary for dielectric material 43 to be in direct contact with conductive plates 42 and 44 as other dielectric

materials such as silicon nitride, silicon dioxide, or oxy-nitride can be formed therebetween. Additionally, the lower conductive plate of the capacitor structure can be replaced with a doped region 52 formed in substrate 41 as illustrated in electronic component 50. Therefore, the dielectric material of the present invention can be placed between two conductive regions to provide a capacitor structure.

The dielectric material of the present invention can also be used to form an electronic component 60 such as a non-volatile memory cell. For example, dielectric layers 61 and 63 comprising $\text{Ba}(\text{Ti}_{(1-x)}\text{Sn}_x)\text{O}_3$ can be used to electrically isolate a floating gate 62 from an underlying channel region 67 in substrate 41 and to electrically isolate floating gate 62 from a control gate 64. Channel region 67 refers to the portion of substrate 41 between a source region 65 and a drain region 66. It should be understood that dielectric layers 61 and 63 need not solely be formed using the dielectric material of the present invention and that it is not necessary that both layers comprise $\text{Ba}(\text{Ti}_{(1-x)}\text{Sn}_x)\text{O}_3$. It is also possible to include other dielectric materials such as silicon dioxide, silicon nitride, or the like in each of dielectric layers 61 and 63.

Also shown in FIG. 1 is an electronic component 70 that illustrates how the dielectric material of the present invention can be used as a gate dielectric material. Electronic component 70 has a layer of dielectric material 71 between a gate structure 72 and substrate 41 that is used to electrically isolate gate structure 72 from a channel region 75. In the operation of electronic component 70, a voltage potential is placed on gate structure 72 to modulate channel region 75 between a source region 73 and a drain region 74.

Methods of forming an electronic component having a dielectric material comprising tin in accordance with the present invention are now provided. One method of forming dielectric materials 43, 61, 63, or 71 is to use a metal organic decomposition process or a solution-gelation (sol-gel) process. For example, a solution is prepared containing precursors of the desired elements in the proper ratios. The solution is then dispensed or spun over the surface of a substrate to form a layer of the solution across the substrate. The solution is then heated or annealed to drive off the organic materials in the solution, thereby forming a layer of dielectric material having the desired composition.

A source of tin can be added to the solution using a precursor such as tin beta-n-butoxide, tin chloride, tin acetate, tin nitrate, tin lactate, tin ammonium acetate, tin tetra-isopropoxide, or tin isopropoxide. A source of titanium can be added to the solution using a precursor such as
5 titanium tetra-n-butoxide, titanium di-tertiary-butoxyl-tetramethyl heptanodionate, titanium tetra-tertiary butoxide, titanium ditetramethyl-heptano-dionate disopropoxide, titanium tertaethoxide, titanium lactate, titanium ammonium acetate, titanium tetra-isopropoxide, or titanium isopropoxide. A source of barium can be added to the solution using a
10 precursor such as b-diketonate complexes of barium tetramethylheptanodionate, barium hexaflouroacetylacetonate, barium(2,2,6,6-tetramethyl-3,5-heptanedione)₂, barium hexaflouroacetylacetone, or barium tetrafluoroacetylacetone.

It is also possible to form a layer of dielectric material in accordance
15 with the present invention using an ion sputtering or reactive ion sputtering (RIS) process such as is illustrated in FIG. 2. FIG. 2 illustrates a cross-sectional portion of a radio frequency (RF) sputtering system 10. It should also be understood that the present invention can also be used in a Direct Current (DC) sputtering system and one skilled in the art will
20 understand the appropriate modifications that are required. System 10 includes a sputtering chamber 11 in which the RF sputtering occurs. A sputtering target 12 is utilized as a source of material for forming a dielectric film 16 on a surface of a semiconductor substrate 13. However, other substrates can be used. Material is transferred from sputtering target
25 12 to film 16 by RF sputtering. A RF voltage source 15 is coupled to target 12 and to substrate 13 to facilitate the RF sputtering operation.

Sputtering target 12 comprises the desired amounts of barium, titanium, and tin and can be formed by mixing barium oxide, titanium oxide, and tin oxide in the correct proportions to form a ceramic sputtering
30 target. Subsequent to mixing, pressure and temperature are utilized to transform the mixture into sputtering target 12. For example, the mixture can be cold pressed at a pressure of about three hundred atmospheres (atm), and then sintered at a temperature of approximately 1200° C at atmospheric pressure. These pressures and temperatures may vary
35 depending on furnace and target sizes and also on target composition.

Thereafter, target 12 is placed in sputtering chamber 11 along with substrate 13. Target 12 and substrate 13 are connected to RF voltage source 15 in order to provide an electric field and facilitate sputtering material from target 12 onto the surface of substrate 13. Typically, voltage source 15
5 applies approximately five hundred volts to target 12 and substrate 13. A plasma is formed using an inert ambient within chamber 11 in order to complete the RF sputtering. RF sputtering operations are well known to those skilled in the art.

It is also possible to form dielectric layer 16 using a sputtering target
10 made from barium oxide, tin oxide, and titanium powder. The sputtering target and substrate 13 are placed into sputtering chamber 11, which is filled with an ambient containing oxygen. As portions of the sputtering target are transferred to substrate 13, oxygen is incorporated in the desired proportion to form a dielectric material. It is also possible to anneal or
15 heat the substrate in an oxygen-rich ambient after dielectric layer 16 is deposited instead of sputtering in an oxygen rich ambient.

It is also possible to form the dielectric material of the present invention using a metallorganic chemical vapor deposition (MOCVD) process. In such a process, some of the precursors listed earlier are
20 transported to a reaction chamber using a carrier gas in the desired proportions. The reaction conditions depend in part on the precursors selected and will be understood by those skilled in the art.

By now it should be appreciated that the present invention provides a compound that can be used to form dielectric materials in electronic
25 components. The present invention also provides for methods of forming the dielectric material, such as by forming a sputtering target, and provides applications for its use. A dielectric layer formed in accordance with the present invention has a dielectric constant that is higher than previously known dielectric materials. As a result, an electronic component can be
30 formed in less area, yet have the same capacitance value as if the electronic component had been formed using conventional materials. Therefore, the present invention allows electronic components to be formed using less surface area, and thus, at a lower manufacturing cost.

CLAIMS

1. An electronic component having a layer of dielectric material,
wherein the layer of dielectric material comprises tin.
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2. The electronic component of claim 1 wherein the layer of
dielectric material has a dielectric constant greater than about 1.
3. The electronic component of claim 1 wherein the layer of
10 dielectric material has a dielectric constant greater than about 300.
4. The electronic component of claim 1 further comprising:
a first conductive region; and
a second conductive region, wherein the layer of dielectric material
15 is between the first conductive region and the second conductive region.
5. The electronic component of claim 4 further comprising a
substrate, wherein the first conductive region is a doped region formed in
the substrate.
- 20
6. The electronic component of claim 1 wherein the layer of
dielectric material comprises titanium.
7. The electronic component of claim 6 wherein the layer of
25 dielectric material comprises an oxide.
8. The electronic component of claim 6 wherein the layer of
dielectric material comprises barium.
- 30
9. The electronic component of claim 8 wherein the layer of
dielectric material comprises an oxide.
10. The electronic component of claim 9 wherein the layer of
dielectric material has a Curie temperature of less than -25°C.
- 35
11. The electronic component of claim 1 wherein the layer of
dielectric material comprises an oxide.



12. The electronic component of claim 1 wherein the layer of dielectric material has a Curie temperature of less than 0°C.

5 13. The electronic component of claim 1 wherein the layer of dielectric material is paraelectric.

10 14. The electronic component of claim 1 wherein the layer of dielectric material is paraelectric at a temperature of about 0°C.

15 15. The electronic component of claim 1 wherein the layer of dielectric material is ferroelectric.

15 16. The electronic component of claim 1 wherein the layer of dielectric material is ferroelectric at a temperature of about 0°C.

20 17. An electronic component having a dielectric material comprising $\text{Ba}(\text{Ti}_{(1-x)}\text{Sn}_x)$, wherein x ranges from a value greater than zero to about 1.

20 18. The electronic component of claim 17 wherein x ranges from about 0.15 to 0.3.

25 19. The electronic component of claim 17 wherein x ranges from about 0.01 to 0.1.

20 20. The electronic component of claim 17 wherein x ranges from about 0.01 to a value less than 1.

30 21. The electronic component of claim 17 further comprising:
a first conductive plate; and
a second conductive plate, wherein the dielectric material is
between the first conductive plate and the second conductive plate.

35 22. The electronic component of claim 21 wherein the dielectric material is in contact with the first conductive plate and the second conductive plate.



23. The electronic component of claim 17 further comprising:
 a substrate; and
 a doped region in the substrate, wherein the dielectric material is
 5 overlying the doped region.

24. The electronic component of claim 23 further comprising a gate
 structure overlying the dielectric material.

10 25. The electronic component of claim 17 further comprising:
 a substrate; and
 a gate structure overlying the substrate, wherein the dielectric
 material is between the gate structure and the substrate.

15 26. The electronic component of claim 25 wherein the electronic
 component is a non-volatile memory cell and the gate structure is a
 floating gate in the non-volatile memory cell.

20 27. The electronic component of claim 25 wherein the electronic
 component is a non-volatile memory cell and the gate structure is a
 control gate in the non-volatile memory cell.

25 28. The electronic component of claim 17 wherein the electronic
 component is a sensor.

29. The electronic component of claim 17 wherein the dielectric
 material comprises $\text{Ba}(\text{Ti}_{(1-x)}\text{Sn}_x)\text{O}_3$, wherein x ranges from a value greater
 than zero to about 1.

30 30. An electronic component having a dielectric material
 comprising $\text{Ba}(\text{Ti}_{(1-x)}\text{Sn}_x)\text{O}_3$, wherein x ranges from about 0.01 to 0.3.

31. The electronic component of claim 30 wherein x ranges from
 about 0.15 to 0.3.

35 32. An electronic component having a dielectric material
 comprising $\text{Ti}_{(1-x)}$ and Sn_x , wherein x ranges from about 0.01 to 0.3.



33. An electronic component having a dielectric material consisting essentially of $\text{Ba}(\text{Ti}_{(1-x)}\text{Sn}_x)\text{O}_3$, wherein x ranges from a value greater than zero to a value less than about 1.

5 34. A method of forming an electronic component including the step of forming a dielectric material comprising tin.

35. The method of claim 34 wherein the step of forming the dielectric material includes forming dielectric material having a dielectric
10 constant greater than about 1.

36. The method of claim 34 wherein the step of forming the dielectric material includes forming a dielectric material having a dielectric constant greater than about 300.

15 37. The method of claim 34 wherein the step of forming the dielectric material includes forming a dielectric material comprising titanium.

20 38. The method of claim 37 wherein the step of forming the dielectric material includes forming a dielectric material comprising oxygen.

39. The method of claim 37 wherein the step of forming the dielectric material includes forming a dielectric material comprising barium.

40. The method of claim 39 wherein the step of forming the dielectric material includes forming a dielectric material comprising oxygen.

41. The method of claim 34 wherein the step of forming the dielectric material includes:
providing a precursor selected from the group consisting of tin beta-
35 n-butoxide, tin chloride, tin acetate, tin nitrate, tin lactate, tin ammonium acetate, tin tetra-isopropoxide, and tin isopropoxide; and
adding the precursor to a solution.



42. The method of claim 41 further comprising the step of adding to the solution a precursor selected from the group consisting of titanium tetra-n-butoxide, titanium di-tertiary-butoxyl-tetramethyl heptanodionate, titanium tetra-tertiary butoxide, titanium ditetramethyl-heptano-dionate disopropoxide, titanium tetraethoxide, titanium lactate, titanium ammonium acetate, titanium tetra-isopropoxide, and titanium isopropoxide.

43. The method of claim 41 further comprising the step of adding to the solution a precursor selected from the group consisting of b-diketonate complexes of barium tetramethylheptanodionate, barium hexafluoroacetylacetonate, barium(2,2,6,6-tetramethyl-3,5-heptanedione)₂, barium hexafluoroacetylacetone, and barium tetrafluoroacetylacetone.

44. The method of claim 41 comprising the step of spinning the solution onto a substrate in a metal organic decomposition process.

45. The method of claim 34 wherein the step of forming the dielectric material includes providing a sputtering target comprising barium oxide and tin oxide.

46. The method of claim 45 wherein the step of providing the sputtering target includes providing a sputtering target comprising titanium oxide.

47. The method of claim 46 further comprising the steps of:
providing a sputtering system having a sputtering chamber;
providing a substrate;
placing the sputtering target and the substrate in the sputtering chamber;
forming an inert ambient in the sputtering chamber; and
sputtering a portion of the sputtering target onto the substrate.

48. The method of claim 45 wherein the step of providing the sputtering target includes providing a sputtering target comprising titanium.



49. The method of claim 48 further comprising the steps of:
providing a sputtering system having a sputtering chamber;
providing a substrate;
5 placing the sputtering target and the substrate in the sputtering
chamber;
forming an ambient in the sputtering chamber comprising oxygen;
and
10 sputtering a portion of the sputtering target onto the substrate.

50. The method of claim 48 further comprising the steps of:
providing a substrate;
sputtering a portion of the sputtering target onto the substrate; and
heating the substrate in an ambient comprising oxygen.

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51. A sputtering target comprising barium, titanium, and tin.

52. The sputtering target of claim 51 wherein the sputtering target
comprises barium oxide and tin oxide.

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53. The sputtering target of claim 52 wherein the sputtering target
consists essentially of barium oxide, titanium oxide, and tin oxide.

