CLAIMS

1. An electromechanical responsive film including:

   a composition including sodium (Na), potassium (K), niobium (Nb) and oxygen (O);

   wherein the composition has a formula of $(Na_xK_y)NbO_{3-\delta}$;

   wherein $0 \leq x < 1$;

   wherein $0 \leq y < 1$;

   wherein $0 < x+y < 1$;

   wherein the composition satisfies at least one condition selected from a group consisting of a first condition of $(x+y+4)/2 \leq (3-\delta) \leq (x+y+5)/2$ and a second condition of $0 < \delta < 1$, and

   wherein the electromechanical responsive film has an effective longitudinal piezoelectric strain coefficient ($|d_{33}|$) higher than 250 pm/V at a frequency of 1 kHz or lower.

2. The electromechanical responsive film according to claim 1, wherein the electromechanical responsive film is an epitaxial film.

3. The electromechanical responsive film according to claim 1, wherein the electromechanical responsive film is a polycrystalline film.

4. The electromechanical responsive film according to any one of claims 1 to 3, wherein the electromechanical responsive film has an effective longitudinal piezoelectric strain coefficient ($|d_{33}|$) higher than 500 pm/V at a frequency of 1 kHz or lower.

5. The electromechanical responsive film according to claim 4, wherein the electromechanical responsive film has an effective longitudinal piezoelectric strain coefficient ($|d_{33}|$) higher than 800 pm/V at a frequency of 1 kHz or lower.

6. The electromechanical responsive film according to any one of claims 1 to 5, wherein x is equal to 0.

7. The electromechanical responsive film according to any one of claims 1 to 5, wherein y is equal to 0.

8. The electromechanical responsive film according to claim 7, wherein the formula is $Na_{0.86}NbO_{2.93}$.

9. The electromechanical responsive film according to any one of claims 1 to 5, wherein the formula is $(K_{0.17}Na_{0.65})NbO_{2.91}$.

10. The electromechanical responsive film according to any one of claims 1 to 9, wherein the electromechanical responsive film has a ferroelectric phase – paraelectric phase transition temperature of about 450 °C.

11. The electromechanical responsive film according to any one of claims 1 to 10, wherein the electromechanical responsive film has an orthorhombic phase - tetragonal phase transition temperature of about 210 °C.

12. The electromechanical responsive film according to any one of claims 1 to 11, wherein the electromechanical responsive film has a thickness of any value selected from 50 nm to 10 μm.

13. A stacked arrangement including:

an electromechanical responsive film including a composition including sodium (Na), potassium (K), niobium (Nb) and oxygen (O);

wherein the composition has a formula of $(Na_xK_y)NbO_{3-\delta}$;

wherein $0 \leq x < 1$;

wherein $0 \leq y < 1$;

wherein $0 < x+y < 1$;

wherein the composition satisfies at least one condition selected from a group consisting of a first condition of $(x+y+4)/2 \leq (3-\delta) \leq (x+y+5)/2$ and a second condition of $0< \delta <1$, and

wherein the electromechanical responsive film has an effective longitudinal piezoelectric strain coefficient ($|d_{33}|$) higher than 250 pm/V at a frequency of 1 kHz or lower.

14. The stacked arrangement according to claim 13, wherein the stacked arrangement includes:

a substrate;

a bottom electrode layer on the substrate; and

a top electrode layer such that the electromechanical responsive film is between the top electrode layer and the bottom electrode layer.

15. The stacked arrangement according to claim 14,

wherein the substrate is a silicon wafer including a silicon oxide layer;

wherein the bottom electrode includes platinum; and

wherein the electromechanical responsive film is a polycrystalline film of $Na_{0.86}NbO_{2.93}$.

16. The stacked arrangement according to claim 13, wherein the stacked arrangement includes:

a substrate; and

an electrode layer such that the electromechanical responsive film is between the electrode layer and the substrate.

17. The stacked arrangement according to claim 16,

wherein the substrate includes a single crystal of niobium-doped strontium titanate (Nb-doped $SrTiO_3$); and

wherein the electromechanical responsive film is an epitaxial film of $Na_{0.86}NbO_{2.93}$ or $(K_{0.17}Na_{0.65})NbO_{2.91}$.

18. A method of forming an electromechanical responsive film, the method including:

forming the electromechanical responsive film such that the electromechanical responsive film includes a composition including sodium (Na), potassium (K), niobium (Nb) and oxygen (O);

wherein the composition has a formula of $(Na_xK_y)NbO_{3-\delta}$;

wherein $0 \leq x < 1$;

wherein $0 \leq y < 1$;

wherein $0 < x+y < 1$;

wherein the composition satisfies at least one condition selected from a group consisting of a first condition of $(x+y+4)/2 \leq (3-\delta) \leq (x+y+5)/2$ and a second condition of $0 < \delta < 1$, and

wherein the electromechanical responsive film has an effective longitudinal piezoelectric strain coefficient ($|d_{33}|$) higher than 250 pm/V at a frequency of 1 kHz or lower.

19. The method according to claim 18,

wherein the electromechanical responsive film is formed over a substrate via sputtering.

20. The method according to claim 18 or claim 19, wherein the electromechanical responsive film is an epitaxial film.

21. The method according to claim 18 or claim 19, wherein the electromechanical responsive film is a polycrystalline film.

22. The method according to any one of claims 18 to 21, wherein the electromechanical responsive film has an effective longitudinal piezoelectric strain coefficient ($|d_{33}|$) higher than 500 pm/V at a frequency of 1 kHz or lower.

23. The method according to claim 22, wherein the electromechanical responsive film has an effective longitudinal piezoelectric strain coefficient ($|d_{33}|$) higher than 800 pm/V at a frequency of 1 kHz or lower.

24. The method according to any one of claims 18 to 23, wherein x is equal to 0.

25. The method according to any one of claims 18 to 23, wherein y is equal to 0.

26. The method according to claim 25, wherein the formula is $Na_{0.86}NbO_{2.93}$.

27. The method according to any one of claims 18 to 23, wherein the formula is $(K_{0.17}Na_{0.65})NbO_{2.91}$.

28. The method according to any one of claims 18 to 27, wherein the electromechanical responsive film has a ferroelectric phase – paraelectric phase transition temperature of about 450 °C.

29. The method according to any one of claims 18 to 28, wherein the electromechanical responsive film has an orthorhombic phase - tetragonal phase transition temperature of about 210 °C.

30. The method according to any one of claims 18 to 29, wherein the electromechanical responsive film has a thickness of any value selected from 50 nm to 10 μm.

31. A method of forming a stacked arrangement, the method including:

forming an electromechanical responsive film including a composition including sodium (Na), potassium (K), niobium (Nb) and oxygen (O);

wherein the composition has a formula of $(Na_xK_y)NbO_{3-\delta}$;

wherein $0 \leq x < 1$;

wherein $0 \leq y < 1$;

wherein $0 < x+y < 1$;

wherein the composition satisfies at least one condition selected from a group consisting of a first condition of $(x+y+4)/2 \leq (3-\delta) \leq (x+y+5)/2$ and a second condition of $0 < \delta < 1$, and

wherein the electromechanical responsive film has an effective longitudinal piezoelectric strain coefficient ($|d_{33}|$) higher than 250 pm/V at a frequency of 1 kHz or lower.

32. The method according to claim 31, further including:

forming a bottom electrode layer on a substrate; and

forming a top electrode layer such that the electromechanical responsive film is between the top electrode layer and the bottom electrode layer.

33. The method according to claim 32,

wherein the substrate is a silicon wafer including a silicon oxide layer;

wherein the bottom electrode includes platinum; and

wherein the electromechanical responsive film is a polycrystalline film of $Na_{0.86}NbO_{2.93}$.

34. The method according to claim 31,

wherein the electromechanical responsive film is formed on a substrate; and

wherein the method includes forming an electrode layer such that the electromechanical responsive film is between the electrode layer and the substrate.

35. The method according to claim 34,

wherein the substrate includes a single crystal of niobium-doped strontium titanate (Nb-doped $SrTiO_3$); and

wherein the electromechanical responsive film is an epitaxial film of $Na_{0.86}NbO_{2.93}$ or $(K_{0.17}Na_{0.65})NbO_{2.91}$.