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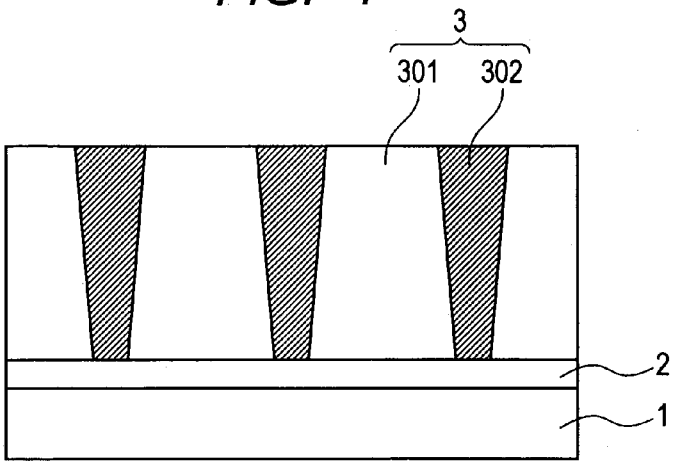
(54) Title: PIEZOELECTRIC THIN FILM, PIEZOELECTRIC ELEMENT, AND MANUFACTURING METHOD THEREOF

FIG. 4



(57) Abstract: Provided are a piezoelectric thin film having good piezoelectricity in which a rhombohedral structure and a tetragonal structure are mixed, and a piezoelectric element using the piezoelectric thin film. The piezoelectric thin film includes a perovskite type metal oxide, in which the perovskite type metal oxide is a mixed crystal system of at least a rhombohedral structure and a tetragonal structure, and a ratio between an a-axis lattice parameter and a c-axis lattice parameter of the tetragonal structure satisfies $1.15 \leq c/a \leq 1.30$. The piezoelectric element includes on a substrate: the above-mentioned piezoelectric thin film; and a pair of electrodes provided in contact with the piezoelectric thin film.

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AMENDED CLAIMS
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[1] (Amended) A piezoelectric thin film, comprising a perovskite type metal oxide,
wherein the perovskite type metal oxide has a mixed crystal system having at least a rhombohedral structure and a tetragonal structure, and
wherein a ratio between an a-axis lattice parameter and a c-axis lattice parameter of the tetragonal structure satisfies $1.15 \leq c/a \leq 1.30$.

[2] The piezoelectric thin film according to claim 1, wherein the perovskite type metal oxide contains a metal oxide represented by the following general formula (1):
$Bi_x(M_{1-y}Co_y)O_3$ General formula (1)
where M represents at least one kind of metal selected from Fe and Al, and x and y satisfy $0.95 \leq x \leq 1.25$ and $0.05 \leq y \leq 0.15$.

[3] The piezoelectric thin film according to claim 2, wherein the metal M in the general formula (1) is Fe.

[4] The piezoelectric thin film according to claim 1, wherein the tetragonal structure of the piezoelectric thin film is (001) oriented, and
wherein the rhombohedral structure of the piezoelectric thin film is (100) oriented.

[5] The piezoelectric thin film according to claim 1, wherein at least one part of the tetragonal structure and the rhombohedral structure of the piezoelectric thin film forms a columnar structure.

[6] The piezoelectric thin film according to claim 1, wherein the piezoelectric thin film has a thickness of 50 nm or more to 10 μm or less.

[7] The piezoelectric thin film according to claim 2, wherein a root mean square roughness Rq of a surface of the piezoelectric thin film and y in the general formula (1) satisfy a relationship of the following general formula (2):

$0<Rq\leq 25y+2$ General Formula (2).

[8] The piezoelectric thin film according to claim 1, wherein the piezoelectric thin film is provided on a substrate,
wherein the substrate comprises a (100) oriented single-crystal substrate, and
wherein an in-plane lattice parameter of a unit cell of the single-crystal substrate is 0.360 nm or more to 0.385 nm or less in a surface of the substrate.

[9] A piezoelectric element, comprising on a substrate:
the piezoelectric thin film according to claim 1; and
a pair of electrodes provided in contact with the piezoelectric thin film.

[10] The piezoelectric element according to claim 9, wherein the substrate comprises a (100) oriented single-crystal substrate, and
wherein an in-plane lattice parameter of a unit cell of the single-crystal substrate is 0.360 nm or more to 0.385 nm or less in a surface of the single-crystal substrate.

[11] The piezoelectric element according to claim 10, wherein the substrate comprises at least a $LaAlO_3$ single crystal.

[12] The piezoelectric element according to claim 9, wherein at least one of the pair of electrodes comprises a perovskite type metal oxide represented by one of $M1RuO_3$, where M1 represents at least one kind selected from the group consisting of Sr, Ba, and Ca, and $Sr_{(1-z)}M2_zCoO_3$, where M2 represents at least one kind selected from the group consisting of La, Pr, Sm, and Nd and z satisfies $0\leq z<1$.

[13] The piezoelectric element according to claim 12, wherein one of the pair of electrodes is provided in contact with both of the piezoelectric thin film and the substrate, and comprises a perovskite type metal oxide represented by $Sr_{(1-z)}La_zCoO_3$ where z satisfies

$0 \leq z < 1$.

[14] A manufacturing method for a piezoelectric element comprising, on a substrate, a piezoelectric thin film and a pair of electrodes provided in contact with the piezoelectric thin film,
the manufacturing method comprising:
forming a first electrode on the substrate,
the substrate comprising a single-crystal substrate selectively (100) oriented, in which an in-plane lattice parameter of a unit cell of the single-crystal substrate is 0.360 nm or more to 0.385 nm or less in a surface of the single-crystal substrate;
forming the piezoelectric thin film on the first electrode; and
forming a second electrode on the piezoelectric thin film,
wherein the forming the piezoelectric thin film includes applying a precursor solution of an organometallic compound to the single-crystal substrate, followed by drying, and heating the single-crystal substrate at 430°C or lower under an excess oxygen atmosphere, thereby obtaining a thin film formed of a crystallized metal oxide.

[15] The manufacturing method for a piezoelectric element according to claim 14, wherein the formation of the piezoelectric thin film is based on a chemical solution deposition method.

[16] The manufacturing method for a piezoelectric element according to claim 15, wherein the chemical solution deposition method is performed by multi-layer coating and a coating thickness per layer is 8 nm or more to 30 nm or less.

[17] The manufacturing method for a piezoelectric element according to claim 14, wherein the excess oxygen atmosphere contains an ozone component.

[18] The manufacturing method for a piezoelectric element

according to claim 14, wherein the first electrode comprises $Sr_{(1-z)}La_zCoO_3$ where z satisfies $0 \leq z < 1$, and is formed by a pulsed laser deposition method.

[19] A liquid discharge head, comprising the piezoelectric element according to claim 9.

[20] An ultrasonic motor, comprising the piezoelectric element according to claim 9.