

FIG. 1

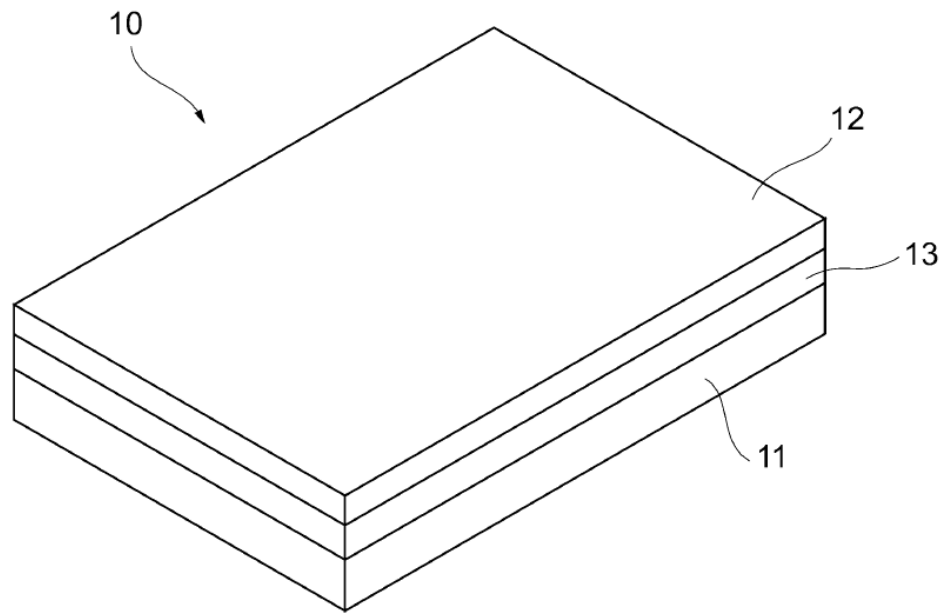


FIG. 2

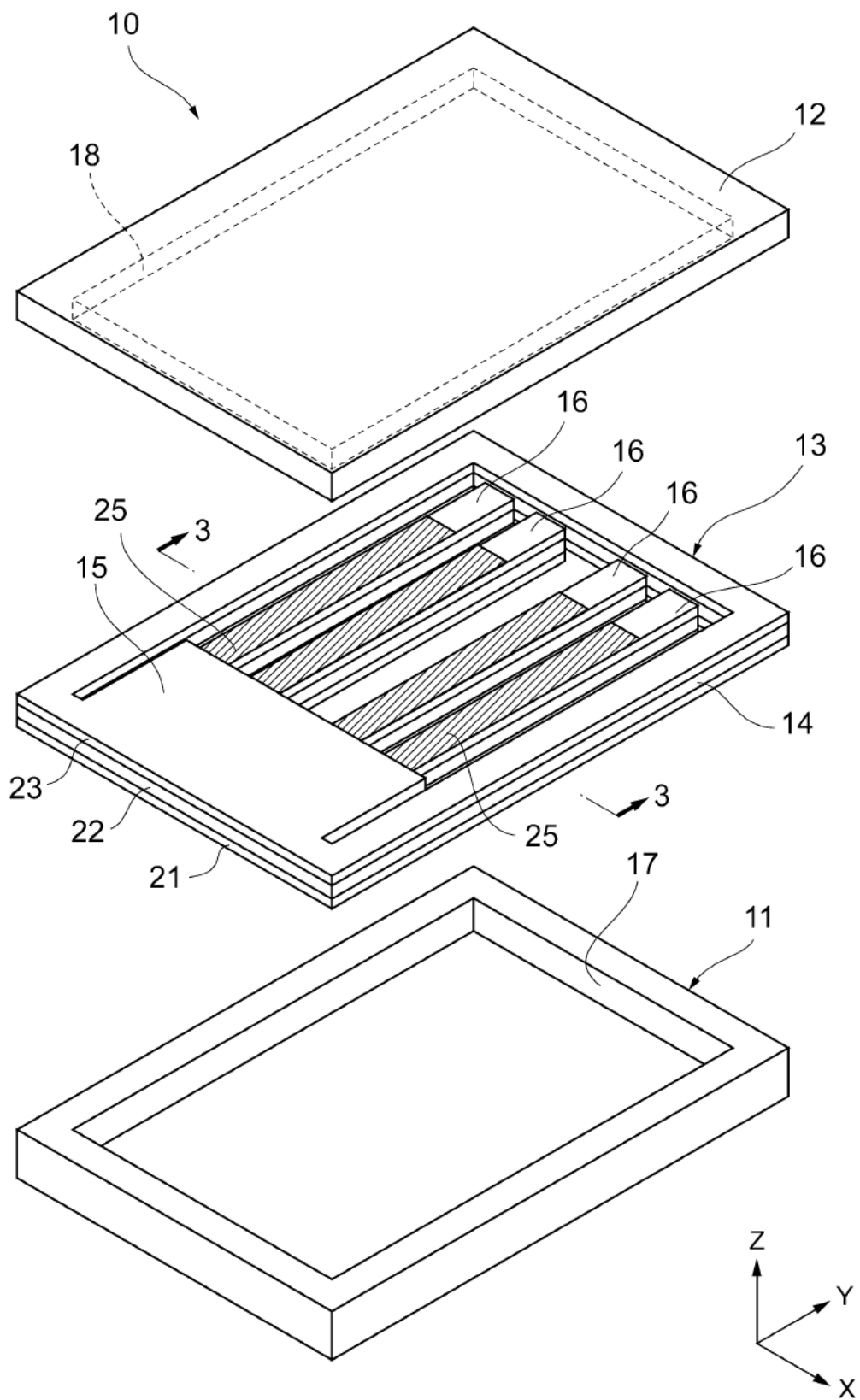


FIG. 4

Ion	Valence	Coordination number	Ionic radius
Al	3	IV	0.39
		V	0.48
		VI	0.535
N	-3	IV	1.46
	3	VI	0.16
	5	III	-0.104
		VI	0.13

Ion	Valence	Coordination number	Ionic radius
Ca	2	VI	1
		VII	1.06
		VIII	1.12
		IX	1.18
		X	1.23
		XII	1.34
Hf	4	IV	0.58
		VI	0.71
		VII	0.76
		VIII	0.83
Mg	2	IV	0.57
		V	0.66
		VI	0.72
		VIII	0.89
Nb	3	VI	0.72
	4	VI	0.68
		VIII	0.79
	5	IV	0.48
		VI	0.64
		VII	0.69
		VIII	0.74
		VI	0.745
Sc	3	VIII	0.87
		VI	1.18
Sr	2	VII	1.21
		VIII	1.26
		IX	1.31
		X	1.36
		XII	1.44
		VI	0.79
V	2	VI	0.64
	3	V	0.53
	4	VI	0.58
		VIII	0.72
		IV	0.355
	5	V	0.46
		VI	0.54
		VI	0.9
Y	3	VII	0.96
		VIII	1.019
		IX	1.075
		IV	0.6
Zn	2	V	0.68
		VI	0.74
		VIII	0.9
		IV	0.59
Zr	4	V	0.66
		VI	0.72
		VII	0.78
		VIII	0.84
		IX	0.89
		IV	0.59

FIG. 5

<u>Ion</u>	<u>Valence</u>	<u>Coordination number</u>	<u>Ionic radius</u>
Cr	2	VI	0.8
			0.73
	3	VI	0.615
	4	IV	0.41
		VI	0.55
	5	IV	0.345
		VI	0.49
		VIII	0.57
	6	IV	0.26
		VI	0.44
Fe	2	IV	0.63
		IVSQ	0.64
		VI	0.61
			0.78
		VIII	0.92
	3	IV	0.49
		V	0.58
		VI	0.55
			0.645
		VIII	0.78
	4	VI	0.585
	6	IV	0.25
Ni	2	IV	0.55
		IVSQ	0.49
		V	0.63
		VI	0.69
	3	VI	0.6
			0.56
	4	VI	0.48
Ta	3	VI	0.72
	4	VI	0.68
	5	VI	0.64
		VII	0.69
		VIII	0.74
Ti	2	VI	0.86
	3	VI	0.67
	4	IV	0.42
		V	0.51
		VI	0.605
		VIII	0.74
W	4	VI	0.66
	5	VI	0.62
	6	IV	0.42
		V	0.51
		VI	0.6

FIG. 6

	Sc composition ratio	Second element	Second element content (at%)	Valence of second element	Coordination number of second element	Stress (MPa)	Piezoelectric constant d_{33} (pC/N)
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Comparative Example 1	0.03	-	-	-	-	-200	9.0
Comparative Example 2	0.05	-	-	-	-	-225	11.0
Comparative Example 3	0.10	-	-	-	-	-403	12.0
Comparative Example 4	0.20	-	-	-	-	-560	13.0
Comparative Example 5	0.30	-	-	-	-	-802	15.0
Comparative Example 6	0.40	-	-	-	-	-1111	22.0
Comparative Example 7	0.50	-	-	-	-	-1248	18.0
Comparative Example 8	0.55	-	-	-	-	-1505	0.0

Example 1	0.03	W	0.50	4+	6	-155	9.2
Example 2	0.05	W	0.50	4+	6	-176	11.3
Example 3	0.10	W	0.50	4+	6	-342	12.2
Example 4	0.20	W	0.50	4+	6	-520	13.5
Example 5	0.30	W	0.50	4+	6	-765	15.4
Example 6	0.40	W	0.50	4+	6	-999	22.2
Example 7	0.50	W	0.50	4+	6	-1108	18.1
Comparative Example 9	0.55	W	0.50	4+	6	-1342	0.0

Example 8	0.40	Zr	0.50	4+	6	-985	22.2
Example 9	0.40	Ta	0.50	3+	6	-950	23.0
Example 10	0.40	Ti	0.50	3+	6	-947	23.1
Example 11	0.40	Cr	0.50	3+	6	-960	22.4
Example 12	0.40	Ni	0.50	3+	6	-951	23.4
Example 13	0.40	Fe	0.50	3+	6	-942	23.6

Example 14	0.40	Fe	0.005	3+	4	-1090	24.0
Example 15	0.40	Fe	0.01	3+	4	-1074	24.2
Example 16	0.40	Fe	0.10	3+	4	-1001	24.3
Example 17	0.40	Fe	0.20	3+	4	-980	24.5
Example 18	0.40	Fe	0.50	3+	4	-900	24.5
Example 19	0.40	Fe	0.70	3+	4	-754	24.2
Example 20	0.40	Fe	1.00	3+	4	-642	24.1
Example 21	0.40	Fe	1.10	3+	4	-601	16.2

FIG. 7

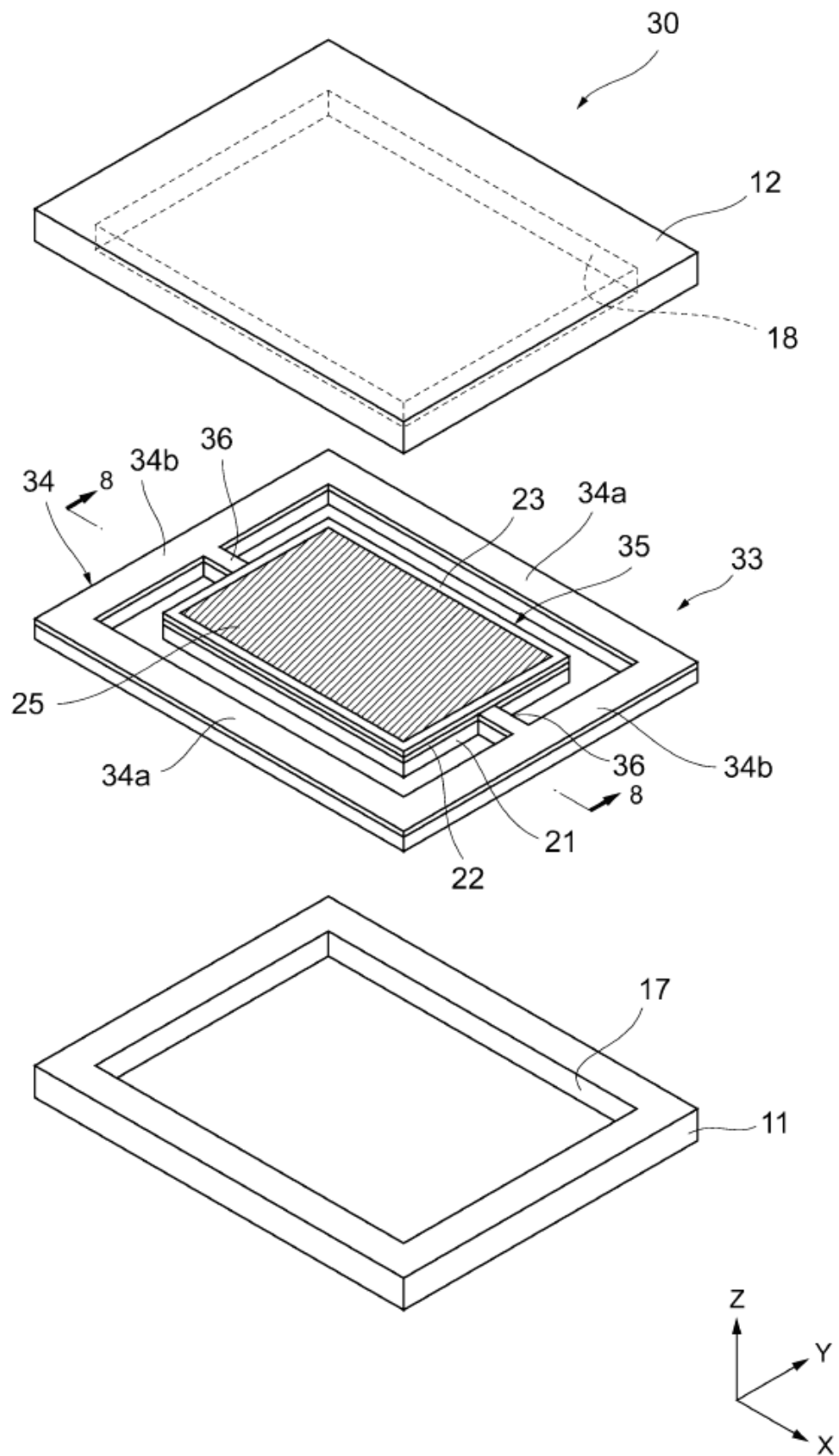


FIG. 8

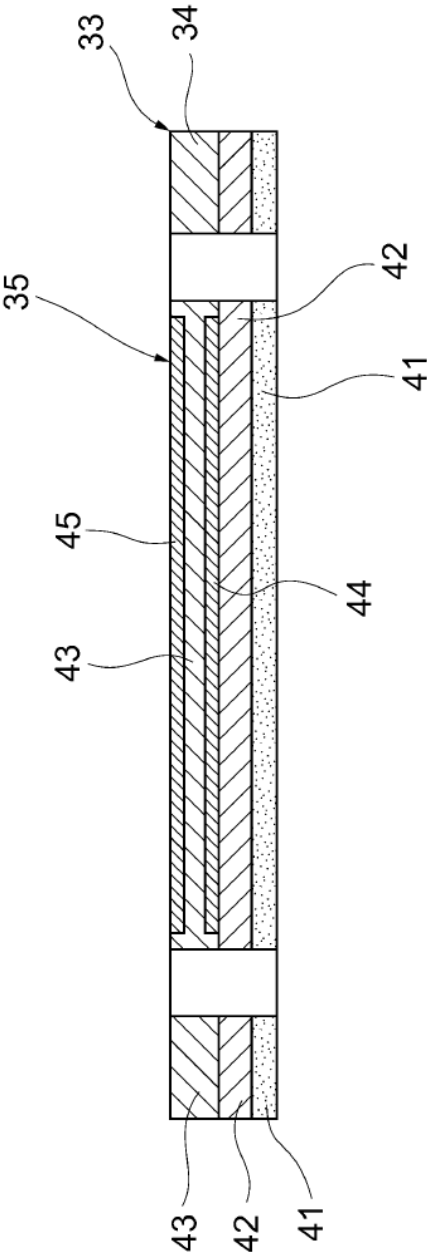


FIG. 9

	First element		Second element	Second element content (at%)	Valence of second element	Coordination number of second element	Stress (MPa)	Piezoelectric constant d_{33} (pC/N)
	Mg composition ratio	Nb composition ratio						
Comparative Example 2-1	0.2	0.2	Absent	0	-	-	-750.6	18.2
Experimental Example 2-1	0.2	0.2	Fe	0.005	3+	4	-719.4	18.0
Experimental Example 2-2	0.2	0.2	Fe	0.01	3+	4	-708.8	18.1
Experimental Example 2-3	0.2	0.2	Fe	0.10	3+	4	-660.7	18.0
Experimental Example 2-4	0.2	0.2	Fe	0.20	3+	4	-646.8	17.9
Experimental Example 2-5	0.2	0.2	Fe	0.50	3+	4	-605.0	17.9
Experimental Example 2-6	0.2	0.2	Fe	0.70	3+	4	-506.0	18.1
Experimental Example 2-7	0.2	0.2	Fe	1.00	3+	4	-423.7	17.6
Experimental Example 2-8	0.2	0.2	Fe	1.10	3+	4	-396.7	10.5

FIG.10

	First element		Second element	Second element content (at%)	Valence of second element	Coordination number of second element	Stress (MPa)	Piezoelectric constant d_{33} (pC/N)
	Mg composition ratio	Hf composition ratio						
Comparative Example 3-1	0.25	0.25	Absent	0	-	-	-1206.6	19.0
Experimental Example 3-1	0.25	0.25	Fe	0.005	3+	4	-1144.5	19.2
Experimental Example 3-2	0.25	0.25	Fe	0.01	3+	4	-1117.0	19.1
Experimental Example 3-3	0.25	0.25	Fe	0.10	3+	4	-1081.1	18.9
Experimental Example 3-4	0.25	0.25	Fe	0.20	3+	4	-960.4	19.0
Experimental Example 3-5	0.25	0.25	Fe	0.50	3+	4	-891.0	18.6
Experimental Example 3-6	0.25	0.25	Fe	0.70	3+	4	-754.0	18.8
Experimental Example 3-7	0.25	0.25	Fe	1.00	3+	4	-706.2	19.0
Experimental Example 3-8	0.25	0.25	Fe	1.10	3+	4	-589.0	13.2