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SURFACE ACOUSTIC WAVE RESONATOR, SURFACE ACOUSTIC WAVE FILTER, DUPLEXER AND COMMUNICATION DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a surface acoustic wave resonator, and a surface acoustic wave filter, a duplexer, and a communication device using the same, in particular, it relates to a surface acoustic wave resonator using a surface acoustic wave including an SH wave as the main component.

2. Description of the Related Art

Conventionally, surface acoustic wave resonators have been used widely in band pass filters, or the like, of mobile communication equipment. As an example of such a surface acoustic wave resonator, a surface acoustic wave resonator or a surface acoustic wave filter having a configuration wherein an interdigital transducer (hereinafter referred to as IDT) comprising a comb-shaped electrode is formed on a piezoelectric substrate is well known. Since a surface acoustic wave including an SH wave as the main component, such as a Love wave, a leaky wave, a BGS wave, or the like can utilize the edge reflection in such a surface acoustic wave resonator or surface acoustic wave filter, it is used practically in a small size resonator or surface acoustic wave filter, which does not require a reflector. Further, a piezoelectric single crystal, such as lithium niobate, lithium tantalate, or the like, is used as the material for the piezoelectric substrate of a surface acoustic wave resonator or a surface acoustic wave filter. At the time, in order to

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excite a surface acoustic wave including an SH wave as the main component, a 41° Y cut X propagation substrate or a 64° Y cut X propagation substrate needs to be selected in the case of a lithium niobate, and a 36° Y cut X propagation substrate needs to be selected in the case of a lithium tantalate. Here, the 41° Y cut X propagation corresponds with the Euler angle indication of (0°, 131°, 0°), the 64° Y cut X propagation corresponds with the Euler angle indication of (0°, 154°, 0°), and the 36° Y cut X propagation corresponds with the Euler angle indication of (0°, 126°, 0°).

However, the temperature coefficient of group delay time temperature characteristic (hereinafter referred to as TCD) of these piezoelectric single crystals is not good relatively. More specifically, the TCD of a 41° Y cut X propagation lithium niobate substrate is 80 ppm/°C, the TCD of a 64° Y cut X propagation lithium niobate substrate is 81 ppm/°C, and the TCD of a 36° Y cut X propagation lithium tantalate substrate is 32 ppm/°C.

In general, in order to obtain good characteristics in a surface acoustic wave resonator stably, a material with a good TCD is needed. That is, a material with a small frequency characteristic change by the temperature change is needed. Therefore, if a surface acoustic wave resonator for exciting a surface acoustic wave including an SH wave as the main component is provided with the lithium niobate or the lithium tantalate used as the substrate material as mentioned above, a problem arises in that the frequency characteristic shifts drastically. Moreover, even though lithium tantalate has a TCD better than that of lithium niobate, it also involves the same problem in the frequency characteristic shift.

For example, in a surface acoustic wave resonator having a 100 MHz center frequency, by a 50°C temperature change, a 400 KHz frequency characteristic shift is generated in the case of a 41° Y cut X propagation lithium niobate substrate, a 405 KHz frequency characteristic shift is generated in the case of a 64° Y cut X propagation lithium niobate substrate, and a 160 KHz frequency characteristic shift is generated in the case of a 36° Y cut X propagation lithium tantalate substrate.

In order to restrain such a frequency characteristic shift, it is considered to connect a temperature compensation circuit, or the like, with a surface acoustic wave resonator. However, a problem arises in that the device as a whole including the surface acoustic wave resonator gets bulky for the added temperature compensation circuit so that it is difficult to achieve a small size.

SUMMARY OF THE INVENTION

In view of these problems, the present invention is directed to surface acoustic wave resonator which operates using an SH wave as the main component and has an excellent TCD.

The surface acoustic wave resonator comprises a piezoelectric substance, and at least one interdigital transducer having at least one pair of comb-shaped electrodes formed so as to contact with the piezoelectric substance, using a surface acoustic wave including an SH wave as the main component, wherein a langasite single crystal is used as the piezoelectric substance.

Since the langasite single crystal is used as the piezoelectric substance and the SH wave is used as mentioned above, a surface acoustic wave resonator with a large coupling

degree can be obtained.

The langasite single crystal preferably has the Euler angle (ϕ, θ, φ) of $0° \leq \phi \leq 30°$, $0° \leq \theta \leq 25°$, and $\varphi = -1.07\phi + 90° \pm 5°$., and more preferably, has the Euler angle (ϕ, θ, φ) of $11° \leq \phi \leq 24°$, and $17° \leq \theta \leq 24°$.

Alternatively, the langasite single crystal preferably has the Euler angle (ϕ, θ, φ) of $0° \leq \phi \leq 30°$, $153° \leq \theta \leq 180°$, and $\varphi = 1.05\phi + 28° \pm 5°$, and more preferably has the Euler angle (ϕ, θ, φ) of $5° \leq \phi \leq 30°$, and $153° \leq \theta \leq 158.5°$.

According to the preferred embodiment of the present invention, a surface acoustic wave resonator has a TCD better than that having a lithium niobate substrate or a lithium tantalate substrate. It is possible to obtain TCD value of $|10|$ ppm/°C or less, and $|5|$ ppm/°C or less,

Moreover, since the sound velocity is low compared with other materials, a small size can be achieved, and since the edge reflection of an SH wave can be utilized, a reflector is not required so that a further small size can be achieved.

For the purpose of illustrating the invention, there is shown in the drawings several forms which are presently preferred, it being understood, however, that the invention is not limited to the precise arrangements and instrumentalities shown.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a surface acoustic wave resonator for explaining the first embodiment.

FIG. 2 is a perspective view of a vertically coupling type surface acoustic wave filter for explaining the second embodiment.

FIG. 3 is a perspective view of a laterally coupling type

surface acoustic wave filter for explaining the third embodiment.

FIG. 4 is a block diagram for explaining a duplexer of the fourth embodiment and a communication device of the fifth embodiment.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Hereinafter, the preferred embodiments of the present invention are explained in detail with reference to the drawings.

FIG. 1 is a perspective view of a surface acoustic wave resonator according to a first embodiment of the present invention.

As shown in FIG. 1, a surface acoustic wave resonator 1 is provided by forming an interdigital transducer 3 on a piezoelectric substrate 2 made of a langasite single crystal ($La_3Ga_5SiO_{14}$).

The interdigital transducer 3 is formed with an electrode material, such as Al, Au, or the like such that a pair of comb-shaped electrodes 3a, 3b are arranged so as to be interdigitated with each other.

Then, a second embodiment of the present invention will be explained. FIG. 2 is a perspective view of a longitudinally coupled surface acoustic wave filter according to a second embodiment of the present invention.

As shown in FIG. 2, the longitudinally coupled surface acoustic wave filter 11 is provided by forming two interdigital transducers 13 on a piezoelectric substrate 12 made of a langasite single crystal ($La_3Ga_5SiO_{14}$).

The interdigital transducers 13 are formed with an electrode material, such as Al, Au, or the like such that a

pair of comb-shaped electrodes 13a, 13b are arranged so as to be interdigitated with each other. Moreover, the interdigital transducers 13, 13 are arranged parallel in the surface acoustic wave propagation direction with a certain distance.

Furthermore, a third embodiment of the present invention will be explained. FIG. 3 is a perspective view of a laterally coupling type surface acoustic wave filter according to a third embodiment of the present invention.

As shown in FIG. 3, the transversally coupled surface acoustic wave filter 21 is provided by forming an interdigital transducer 23 on a piezoelectric substrate 22 made of a langasite single crystal ($La_3Ga_5SiO_{14}$).

The interdigital transducer 23 is formed with an electrode material, such as Al, Au, or the like such that comb-shaped electrodes 23a, 23b and 23c, 23d are arranged so as to be interdigitated with each other.

Then, fourth and fifth embodiments of the present invention will be explained. FIG. 4 is a block diagram of a duplexer according to a fourth embodiment of the present invention and a communication device according to a fifth embodiment of the present invention.

As shown in FIG. 4, the communication device 31 is provided by connecting an antenna terminal of a duplexer 34 comprising a surface acoustic wave filter 32 for a receiver and a surface acoustic wave filter for a transmitter 33 with an antenna 35, connecting an output terminal with a receiving circuit 36, and connecting an input terminal with a transmitting circuit 37. For the receiving surface acoustic wave filter 32 and the transmitting surface acoustic wave filter 33 of the duplexer 34, the surface acoustic wave filters 11, 21 according to the second and third embodiments

are used.

Characteristics derived from a cutting angle of the material used for the substrate of the surface acoustic wave resonator used for the application mentioned above are shown in Table 1. Those marked with * before the specimen number are outside the range of the present invention.

P in the displacement distribution refers to a longitudinal wave, SH a transverse wave having a displacement in the horizontal direction, that is, an SH wave, and SV a transverse wave having a displacement in the vertical direction. Further, the displacement distribution is indicated with the largest wave as 1, and the other waves in the ratio with respect to the largest wave.

[Table 1]

Specimen Number	Material	Euler angle			TCD (ppm/°C)	K(%)	Displacement distribution		
		ϕ	θ	ψ			P	SH	SV
*1	$LiNbO_3$	0.0	131.0	0.0	80.000	17.20	0.0300	1.00	0.4000
*2	$LiNbO_3$	0.0	154.0	0.0	81.000	11.30	0.1000	1.00	0.3700
*3	$LiTbO_3$	0.0	126.0	0.0	32.000	4.70	0.0300	1.00	0.1300
4	$La_3Ga_5SiO_{14}$	0.0	0.0	85.0	-16.000	2.30	0.1800	1.00	0.2800
5	$La_3Ga_5SiO_{14}$	0.0	23.5	89.5	-0.200	4.23	0.7400	0.21	0.9060
*6	$La_3Ga_5SiO_{14}$	0.0	25.0	89.5	25.345	2.15	0.8200	1.00	1.0000
7	$La_3Ga_5SiO_{14}$	5.0	22.0	84.0	5.970	3.73	0.2000	1.00	0.2400
8	$La_3Ga_5SiO_{14}$	10.0	0.0	80.0	16.700	3.01	0.0059	1.00	0.0100
9	$La_3Ga_5SiO_{14}$	10.0	10.0	79.5	5.270	3.77	0.0480	1.00	0.0699
10	$La_3Ga_5SiO_{14}$	10.0	20.0	79.0	-8.651	4.80	0.3100	1.00	0.3000
11	$La_3Ga_5SiO_{14}$	10.0	22.0	79.0	5.990	4.44	0.3700	1.00	0.4600
12	$La_3Ga_5SiO_{14}$	10.0	23.0	79.0	2.740	4.71	0.5700	1.00	0.7100
13	$La_3Ga_5SiO_{14}$	10.0	24.0	79.0	-5.490	4.69	0.7200	1.00	0.9800
*14	$La_3Ga_5SiO_{14}$	10.0	25.0	79.0	-8.360	4.66	0.8100	0.62	1.0000
15	$La_3Ga_5SiO_{14}$	11.0	17.0	78.5	0.064	4.57	0.2100	1.00	0.2800
16	$La_3Ga_5SiO_{14}$	12.0	17.0	77.5	-0.110	4.72	0.2400	1.00	0.3150
17	$La_3Ga_5SiO_{14}$	14.5	15.0	75.0	1.159	4.72	0.2100	1.00	0.2920
18	$La_3Ga_5SiO_{14}$	14.5	16.0	75.0	0.610	4.89	0.2500	1.00	0.3400
19	$La_3Ga_5SiO_{14}$	14.5	17.0	74.5	0.067	4.58	0.2100	1.00	0.2750
20	$La_3Ga_5SiO_{14}$	14.5	18.0	74.5	-0.300	4.74	0.2500	1.00	0.3320
21	$La_3Ga_5SiO_{14}$	14.5	19.0	74.5	-0.830	4.93	0.3100	1.00	0.4080
22	$La_3Ga_5SiO_{14}$	14.5	20.0	74.5	-1.520	5.14	0.4000	1.00	0.5110
23	$La_3Ga_5SiO_{14}$	14.5	23.0	74.0	-7.450	5.19	0.8000	1.00	0.9900
*24	$La_3Ga_5SiO_{14}$	14.5	25.0	73.0	-29.910	2.66	0.8100	0.23	1.0000
25	$La_3Ga_5SiO_{14}$	15.0	17.0	74.0	0.068	4.65	0.2200	1.00	0.2920
26	$La_3Ga_5SiO_{14}$	20.0	0.0	69.9	8.860	3.01	0.0059	1.00	0.0100
27	$La_3Ga_5SiO_{14}$	20.0	10.0	69.5	5.650	4.23	0.1300	1.00	0.1980
28	$La_3Ga_5SiO_{14}$	20.0	18.0	68.5	-0.290	5.07	0.3000	1.00	0.4000
29	$La_3Ga_5SiO_{14}$	20.0	20.0	68.5	-2.030	5.51	0.4600	1.00	0.5980
30	$La_3Ga_5SiO_{14}$	20.0	23.0	68.0	-8.330	5.59	0.7900	1.00	0.9900
*31	$La_3Ga_5SiO_{14}$	20.0	30.0	67.0	-23.400	2.75	0.8200	0.24	1.0000
32	$La_3Ga_5SiO_{14}$	24.0	17.0	64.5	0.260	5.12	0.2900	1.00	0.4460
33	$La_3Ga_5SiO_{14}$	24.0	24.0	63.0	1.080	5.37	0.7700	1.00	0.9620
*34	$La_3Ga_5SiO_{14}$	24.0	25.0	63.0	-6.050	5.38	0.8100	0.70	1.0000
35	$La_3Ga_5SiO_{14}$	30.0	0.0	59.0	13.240	3.91	0.6100	1.00	0.1030
36	$La_3Ga_5SiO_{14}$	30.0	10.0	59.0	-5.800	3.82	0.1600	1.00	0.2390
37	$La_3Ga_5SiO_{14}$	30.0	20.0	57.5	-1.850	5.88	0.5000	1.00	0.6540
38	$La_3Ga_5SiO_{14}$	30.0	23.0	57.0	-3.800	6.01	0.7200	1.00	0.9200
39	$La_3Ga_5SiO_{14}$	30.0	25.0	56.5	2.148	5.87	0.8000	0.81	1.0000
*40	$La_3Ga_5SiO_{14}$	31.0	0.0	5.90	14.025	4.02	1.0000	0.90	0.0930
*41	$La_3Ga_5SiO_{14}$	31.0	25.0	56.5	2.345	5.96	0.8200	0.79	1.0000

As shown in Table 1, in the case a langasite single crystal ($La_3Ga_5SiO_{14}$) is used, the TCD is improved dramatically compared with a conventional lithium niobate, and is also improved compared with a lithium tantalate.

Moreover, as seen in Table 1, in the surface acoustic wave resonators using a langasite single crystal ($La_3Ga_5SiO_{14}$), a displacement distribution SH 1 can be found, that is, the SH wave can be the largest there, and thus it is learned that the SH wave can be utilized effectively.

More specifically, from Table 1, it is learned that the displacement distribution SH can be 1 within the range wherein the Euler angle (ϕ, θ, φ) is ($0° \leq \phi \leq 30°$, $0° \leq \theta \leq 25°$, and $\varphi = -1.07\phi + 90° \pm 5°$), that is, within the range of the specimen numbers 4, 5, 7 to 13, 15 to 23, 25 to 30, 32, 33, and 35 to 39. $\varphi = -1.07\phi + 90° \pm 5°$ is the formula found out from the experiment values of the specimens shown in Table 1.

Furthermore, as shown in Table 1, it is learned that in a langasite single crystal ($La_3Ga_5SiO_{14}$), since the TCD value is $|10|$ ppm/°C or less within the range wherein the Euler angle thereof is ($11° \leq \phi \leq 24°$, and $17° \leq \theta \leq 24°$), that is, within the range of the specimen numbers 15 to 23, 25 to 30, 32 and 33, the TCD is particularly good compared with the other parts in Table 1.

Therefore, by using a langasite single crystal ($La_3Ga_5SiO_{14}$) with the Euler angle in the piezoelectric substrates 2, 12, 22 of the surface acoustic wave resonator shown in FIG. 1 and the surface acoustic wave filters shown in FIGS. 2, 3, since the TCD is $|10|$ ppm/°C or less, for example, in the case of a surface acoustic wave resonator having a 100 MHz center frequency, only about 50 KHz frequency characteristic shift is generated by a 50°C temperature change,

and thus it can sufficiently cope with the use in an environment with a large temperature change.

Then, characteristics derived from a cutting angle different from those of Table 1 of the material used for the substrate of the surface acoustic wave resonator are shown in Table 2. Those marked with * before the specimen number are outside the range of the present invention. As in Table 1, P in the displacement distribution refers to a longitudinal wave, SH a transverse wave having a displacement in the horizontal direction, that is, an SH wave, and SV a transverse wave having a displacement in the vertical direction. Further, the displacement distribution is indicated with the largest wave as 1, and the other waves in the ratio with respect to the largest wave.

[Table 2]

Specimen Number	Material	Euler angle			TCD (ppm/°C)	K(%)	Displacement distribution		
		ϕ	θ	ψ			P	SH	SV
*42	$La_3Ga_5SiO_{14}$	0.0	153.0	24.5	-11.851	6.98	0.7300	0.90	1.0000
43	$La_3Ga_5SiO_{14}$	0.0	154.0	23.0	-9.673	6.82	0.7000	1.00	0.9200
44	$La_3Ga_5SiO_{14}$	0.0	158.5	25.5	2.550	6.66	0.5900	1.00	0.8380
45	$La_3Ga_5SiO_{14}$	0.0	165.0	27.0	-22.489	5.88	0.3700	1.00	0.5580
46	$La_3Ga_5SiO_{14}$	0.0	170.0	28.5	-25.604	5.09	0.2500	1.00	0.3940
47	$La_3Ga_5SiO_{14}$	0.0	180.0	29.5	-30.532	4.89	0.4600	1.00	0.8300
*48	$La_3Ga_5SiO_{14}$	0.0	181.0	29.5	-31.210	4.77	0.6300	0.95	1.0000
49	$La_3Ga_5SiO_{14}$	5.0	158.0	30.5	0.897	6.67	0.6000	1.00	0.8400
50	$La_3Ga_5SiO_{14}$	5.0	158.5	31.0	0.900	6.69	0.6300	1.00	0.8860
*51	$La_3Ga_5SiO_{14}$	10.0	140.0	39.5	-6.250	4.68	0.8100	0.32	1.0000
*52	$La_3Ga_5SiO_{14}$	10.0	150.0	34.0	1.940	6.77	0.7800	0.72	1.0000
53	$La_3Ga_5SiO_{14}$	10.0	153.0	34.5	-1.820	6.89	0.7700	1.00	1.0000
54	$La_3Ga_5SiO_{14}$	10.0	155.0	35.0	-1.470	6.80	0.7300	1.00	0.9620
55	$La_3Ga_5SiO_{14}$	10.0	158.5	36.0	-0.210	6.61	0.6100	1.00	0.8400
56	$La_3Ga_5SiO_{14}$	10.0	160.0	36.5	14.960	6.48	0.5700	1.00	0.7940
*57	$La_3Ga_5SiO_{14}$	20.0	145.0	47.0	-12.120	4.46	0.8100	0.37	1.0000
*58	$La_3Ga_5SiO_{14}$	20.0	150.0	44.0	-6.970	6.00	0.8100	0.70	1.0000
59	$La_3Ga_5SiO_{14}$	20.0	160.0	47.0	12.190	6.28	0.5600	1.00	0.7500
*60	$La_3Ga_5SiO_{14}$	25.0	150.0	48.5	-12.070	5.43	0.8100	0.58	1.0000
61	$La_3Ga_5SiO_{14}$	25.0	153.0	50.0	1.455	5.91	0.8100	1.00	1.0000

62	$La_3Ga_5SiO_{14}$	25.0	154.0	50.5	0.091	6.04	0.8000	1.00	1.0000
63	$La_3Ga_5SiO_{14}$	25.0	155.0	51.0	1.480	6.16	0.7900	1.00	1.0000
64	$La_3Ga_5SiO_{14}$	30.0	158.5	57.5	-3.070	5.74	0.5600	1.00	0.7160
65	$La_3Ga_5SiO_{14}$	30.0	165.0	58.5	-19.524	5.39	0.3100	1.00	0.4320
66	$La_3Ga_5SiO_{14}$	30.0	170.0	59.0	-22.425	4.42	0.1600	1.00	0.2420
67	$La_3Ga_5SiO_{14}$	30.0	180.0	60.0	-36.780	3.38	0.5900	1.00	0.8500
*68	$La_3Ga_5SiO_{14}$	30.0	181.0	61.0	-39.185	3.35	0.6100	0.90	1.0000

As shown in Table 2, in the case a langasite single crystal ($La_3Ga_5SiO_{14}$) is used, the TCD is improved dramatically compared with a conventional lithium niobate, and is also improved compared with a lithium tantalate.

Moreover, as seen in Table 2, in the surface acoustic wave resonators using a langasite single crystal ($La_3Ga_5SiO_{14}$), a displacement distribution SH 1 can be found, that is, the SH wave can be the largest there, and thus it is learned that the SH wave can be utilized effectively.

Moreover, from Table 2, it is learned that the displacement distribution SH can be 1 within the range wherein the Euler angle (ϕ, θ, φ) is ($0° \leq \phi \leq 30°$, $153° \leq \theta \leq 180°$, and $\varphi = 1.05\phi + 28° \pm 5°$), that is, within the range of the specimen numbers 43 to 47, 49, 50, 53 to 56, 59, and 61 to 67. $\varphi = 1.05\phi + 28° \pm 5°$ is the formula found out from the experiment values of the specimens shown in Table 2.

Furthermore, as shown in Table 2, in a langasite single crystal ($La_3Ga_5SiO_{14}$), since the TCD value is $|5|$ ppm/°C or less within the range wherein the Euler angle thereof is ($5° \leq \phi \leq 30°$, and $153° \leq \theta \leq 158.5°$), that is, within the range of the specimen numbers 49, 50, 53 to 55, and 61 to 64, it is learned that the TCD is particularly good compared with the other parts in Tables 1 and 2.

Therefore, by using a langasite single crystal ($La_3Ga_5SiO_{14}$) with the Euler angle in the piezoelectric

substrates 2, 12, 22 of the surface acoustic wave resonator shown in FIG. 1 and the surface acoustic wave filters shown in FIGS. 2, 3, since the TCD is |5| ppm/°C or less, for example, in the case of a surface acoustic wave resonator having a 100 MHz center frequency, only about 25 KHz frequency characteristic shift is generated by a 50°C temperature change, and thus it can sufficiently cope with the use in an environment with a large temperature change.

Although examples of a surface acoustic wave resonator, a longitudinally coupled surface acoustic wave filter, and a transversally coupled surface acoustic wave filter have been explained in the first to third embodiments of the present invention, it is not limited thereto. For example, a transversal type surface acoustic wave filter having plural sets of interdigital transducers, or a surface acoustic wave resonator to be used in a ladder type filter with surface acoustic wave resonators arranged like a ladder, or the like, can be adopted, and the same effect can be obtained in a surface acoustic wave resonator with any kind of structure.

Furthermore, although surface acoustic wave resonators without a reflector have been explained in the first to third embodiments of the present invention, it is not limited thereto, but can be adopted in a surface acoustic wave resonator having a reflector.

While preferred embodiments of the invention have been disclosed, various modes of carrying out the principles disclosed herein are contemplated as being within the scope of the following claims. Therefore, it is understood that the scope of the invention is not to be limited except as otherwise set forth in the claims.

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What is claimed is:

1. A surface acoustic wave resonator comprising:

a piezoelectric substrate comprising a langasite single crystal;

at least one interdigital transducer having at least one pair of comb-shaped electrodes formed so as to be in contact with the piezoelectric substrate, wherein the surface acoustic wave resonator operates using a surface acoustic wave including an SH wave as the main component.

2. The surface acoustic wave resonator according to claim 1, wherein the langasite single crystal has the Euler angle (ϕ, θ, φ) in the range of:

$0° \leq \phi \leq 30°$,

$0° \leq \theta \leq 25°$, and

$\varphi = -1.07\phi + 90° \pm 5°$.

3. The surface acoustic wave resonator according to claim 2, wherein the langasite single crystal has the Euler angle (ϕ, θ, φ) in the range of:

$11° \leq \phi \leq 24°$, and

$17° \leq \theta \leq 24°$.

4. The surface acoustic wave resonator according to claim 1, wherein the langasite single crystal has the Euler angle (ϕ, θ, φ) in the range of:

$0° \leq \phi \leq 30°$,

$153° \leq \theta \leq 180°$, and

$\varphi = 1.05\phi + 28° \pm 5°$.

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5. The surface acoustic wave resonator according to claim 4, wherein the langasite single crystal has the Euler angle (ϕ, θ, φ) in the range of:

$5° \leq \phi \leq 30°$, and

$153° \leq \theta \leq 158.5°$.

6. A surface acoustic wave filter comprising at least on surface acoustic wave resonator defined by any one of claims 1 to 5.

7. A duplexer comprising at least on surface acoustic wave resonator defined by any one of claims 1 to 5 or the surface acoustic wave filter of claim 6.

8. A communication device comprising at least on surface acoustic wave resonator defined by any one of claims 1 to 5, the surface acoustic wave filter of claim 6, or the duplexer of claim 7.

9. A transversal type surface acoustic wave filter comprising:

a piezoelectric substrate comprising a langasite single crystal;

two interdigital transducers each having a pair of comb-shaped electrodes formed so as to be in contact with the piezoelectric substrate, wherein the transversal type surface acoustic wave filter operates using a surface acoustic wave including an SH wave as the main component.

10. The transversal type surface acoustic wave filter according to claim 9, wherein the langasite single crystal has

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the Euler angle (ϕ, θ, φ) in the range of:

$0° \leq \phi \leq 30°$,

$0° \leq \theta \leq 25°$, and

$\varphi = -1.07\phi + 90° \pm 5°$.

11. The transversal type surface acoustic wave filter according to claim 10, wherein the langasite single crystal has the Euler angle (ϕ, θ, φ) in the range of:

$11° \leq \phi \leq 24°$, and

$17° \leq \theta \leq 24°$.

12. The transversal type surface acoustic wave filter according to claim 9, wherein the langasite single crystal has the Euler angle (ϕ, θ, φ) in the range of:

$0° \leq \phi \leq 30°$,

$153° \leq \theta \leq 180°$, and

$\varphi = 1.05\phi + 28° \pm 5°$.

13. The transversal type surface acoustic wave filter according to claim 12, wherein the langasite single crystal has the Euler angle (ϕ, θ, φ) in the range of:

$5° \leq \phi \leq 30°$, and

$153° \leq \theta \leq 158.5°$.

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