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piezoelectric materials and devices

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Langasite $La_3Ga_5SiO_{14}$

First lanthanum gallium silicate (langasite — LGS) crystals were grown in Russia in the early 1980s. They resulted from a joint development of the Moscow State University (MSU) and the Institute of Crystallography of the Russian Academy of Sciences. Initially the material was supposed to be used in laser engineering, but for a number of reasons it did not find a suitable application in this field. Physical properties of the crystal have been investigated in the Institute of Crystallography. This investigation has shown that langasite is a piezoelectric crystal with characteristics making possible its application in piezoelectric engineering.

The most widely spread products of piezoelectric engineering are radio frequency (RF) control elements (resonators) and selection (filters). The main material used in piezoelectric engineering is quartz having highly stable frequency-temperature characteristics, which is the cause of its application for resonator production. Quartz is also used for filter manufacture, but its fields of application for filters are limited due to low value of electromechanically complying coefficient K^2_{emc} of quartz, which is approximately 7%. This limitation allows to manufacture narrow band filters only with the relative value of the pass band to the centre frequency of a filter up to 0.3%.

At present, digital methods of signal treatment are widely used in transmitting-receiving equipment, which imposes requirements to broaden the pass band of a useful signal in intermediate frequency (IF) amplifiers. For wide band filter manufacture it is necessary either to apply additional elements (added inductance coils) when using quartz, which leads to considerable increase of size and weight data of the product or to use a piezoelectric material with higher K^2_{emc} value.

One of these piezoelectric materials is lithium tantalate, enabling to design wide band filters. However, due to the low frequency-temperature stability and the low quality factor (Q) of resonators made of this material the application of these filters is limited. The ulative pass band value for these filters is within the limits from 0.6 to 4.0%. For filter realization with the relative pass bands from 0.3 to

0.8% a piezoelectric material is necessary possessing properties which are intermediate between those of quartz and lithium tantalate. Langasite crystal application enables to realize filters with relative pass bands from 0.3 to 0.85% and also to design resonators with the resonance spacing of 0.8% for the new types of frequency controlled oscillators.

Langasite crystals belong to piezoelecrictric materials with the value of electromechanical coupling coefficient, which is, intermediate between this coefficient of a quartz crystal and that of lithium tantalate. The main comparative characteristics of these crystals are given in table 1.

The most promising langasite crystal application is their use as piezoelectric substrates for filters operating both at bulk waves (BAW) and surface waves (SAW).

The basic piezoelectric properties of different crystals for operation at bulk waves are represented and compared in table 1. From the table it follows that as far as electromechanical coupling coefficient value of langasite crystals is concerned, it takes an intermediate position between the value for quartz crystals and that for strong piezoelectrics of lithium tantalate type; its frequency vs. temperature coefficient has also an intermediate value.

Table 1. Comparative characteristics of piezoelectric crystals.

Characteristics\Crystals	Quartz, SiO_2	Langasite, $La_3Ga_5SiO_{14}$	Lithium tetraborate, $Li_2B_2O_3$	Lithium tantalate, $LiTaO_3$
Electromechanical Coupling Factor K^2_{emc}, % (BAW)	7.0	15.8	24.0	47.0
Frequency Spacing Δf, %	0.25	0.90	4.00	7.00
Q-factor Q, $\times 10^3$	100	50	10	2
Temperature Frequency Coefficient TFC, $\times 10^{-6}$/°C	0.5	1.6	6.0	4.0

Langasite BAW filters possess have high competitivety compared with analogous quartz crystal filters. The design of this filter type is patented.

The use of langasite crystals for surface acoustic wave (SAW) filter design is very perspective in connection with the rapid growth of mobile telephony development. The telephones of new standards (WCDMA) being developed enable not only to talk, but also to transmit image, which open new possibilities for informations transmission of this type. The basic characteristics of langasite crystals for surface acoustic waves are represented in table 2.

Table 2. Comparative characteristics of surface waves in quartz and langasite crystals.

Characteristics\Crystals	Quartz, SiO_2	Langasite, $La_3Ga_5SiO_{14}$	
V_{ef} , m/s (SAW Velocity)	(0°, 132.75°, 0°) 3157	(0°, 140°, 22.5°) 2742	(0°, 140°, 25°) 2736
K^2_{emc} , % (SAW)	0.14	0.32	0.38
α_2, $\times 10^{-8}$/°C^2	-3.2	-7.8	-6.8
T_{T0} ,°C (Temp. Coeff.)	25	25	23
E (Dielectric Constant)	4.92	-	27
M, degr. (Power Flow Angle)	0	52	51

From the table represented it follows, that langasite crystals have K^2_{emc} value twice superior to that of a quartz crystal, and their temperature coefficients are equal. This enables to manufacture wide band filters with high temperature stability. It is necessary to note also that the value of propagation velocity of a surface acoustic wave in langasite crystal is considerably lower, this value determines the filter size. When manufacturing quartz and langasite filters operating at the same centre frequency, the geometrical dimensions of langasite filters will be smaller, which meets the requirements of the modern electronics and spares the material.