MICROMINIATURE REZONATORS BASED ON LGS ($La_3Ga_5SiO_{14}$) SINGLE CRYSTAL

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ABSTRACT

The experimental results of designing microminiature resonators operating at frequencies 10 – 14 MHz with crystal elements fabricated of langasite single crystals are presented in this paper. The volume of there resonators is within 0,075 – 0,2 cm^3. The values of the motional resistance R_1, of the quality factor Q, of the temperature stability, of the long-term frequency stability and of the capacitance ration are given.

Langasite, resonator, microminiaturization.

1. INTRODUCTION

Investigation and developments carried out in Russia (Joint –stock Company "Fomos-materials") enable to create langasite crystal growth technology and methods of their quality control, which ensure cost lowering, increase of production volumes (yield) and quality (homologeneity) elevation. Various piezoelectric devices fabricated with the use of these single crystals, allowed us to determine langasite over quartz advantages at the design and manufacture stage of different piezoelectric engineering productions (resonators, oscillators, filters, temperature sensors, SAW devices etc.). The main advantages of langasite products over the quartz ones are the possibility to realize a number of parameters which are not attainable when using quartz: miniature design, lower value of motional resistance, 3-5 times lower capacitance ratio C_0/C_1 value and that the motional inductance L_1. They can operate at higher temperatures, have lower ageing value at elevated temperatures, high identity of frequency-temperature characteristics, easier technological implementation, etc. Refs 1-4The wide use of langasite is, however, limited by its high price (cost) compared to quartz. Langasite is 10-15 times more expensive than quartz. The must effective direction towards cost lowering of piezoelectric devices using langasite is the miniaturization of crystal elements. The works being made by the group of entrerprises "Piezo" made it possible to fabricate microminiature langasite resonator samples, the price of which is comparable with the price of quartz crystal units, but the parameters of samples obtained are considerably better. This paper describes several investigation results of microminiature resonators with piezoelectric elements made of langasite.

2. EXPERIMENTAL RESULTS

Scientific research people from the group of enterprises "Piezo" made the work dealing with the design and manufacturing technology of resonators with miniature piezoelectric elements fabricated of langasite single crystals. The resonators were manufactured in standard IEC enclosures of DW and CU 05 types.

LGS resonators with round piezoelectric elements

The diameter of fabricated crystal elements for microminiature resonators in CU 05 enclosures was 5,4 mm and 5 mm. Cutting sections into plates was effected by wire cutters with subsequent lapping by micropowders F800 (European Standard FEPA-42D 1984 R 1993). Electrode diameter was 2.6 mm for plates with the diameter of 5.5 mm and 1.25 mm for plates with the diameter of 5 mm. The electrode thickness was up to 0.2 µm. Piezoelectric element mounting was made with the use of argentum containing cement. Hermetical sealing was effected by means of resistance welding in an inert gas atmosphere. The extremum of frequency versus temperature dependence of these langasite resonators manufactured was at (25±3) ^oC (with the crystal element orientation accuracy of 5' from the nominal angle of cut). The average values of resonator motional resistance R_1 are 3-4 less by langasite resonators than by quartz crystal units and their capacitance ratio is 4-5 times less. 5-6 times lower motional inductance L_1 values can be obtained when using langasite resonators instead of quartz crystal units.

Table 1 lists parameters of various resonator lots.

No	Quan. pcs	F_1 kHz	R_1 ,Ohm		Q, k		L_1 ,mH	C_0 ,pF	C_0/C_1	D_e mm
			min	max	min	max				
1	20	10880	4,9	12,7	14	25	1,7	7,6	60±5	2,6
2	10	10651	12	18,4	16	30	4,5	3,4	69±3	1,2
3	10	10714	12	17,5	19	33	4,7	3,2	67±3	1,2
4	10	10707	10,5	20	15	27	4,6	3,2	67±3	1,2
5	10	10671	12	26	18	27	4,6	3,3	67±3	1,2
6	10	10657	9	17	20	35	4,7	3,3	68±3	1,2
7	10	10693	11	15	20	28	4,7	3,3	69±3	1,2

Evacuated LGS resonators in cylindrical 2x6 mm enclosures

Crystal elements for microminiature resonators in DW-type enclosures were fabricated as a rectangular plate with the size of 4.49 mm x 1.02 mm. Section sawing into group plates and group plates treatment were effected in accordance with the process analogous to the described above (applicable to round crystal elements). Plates sawing into crystal elements was made by means of wire cutters (cutting machines) with the use of micropower F1200 (grain size of 3.5 µm). No additional contour treatment was made. The electrode thickness was 0.2 µm (0.015 µm Cr + 0.185 µm Ag). For piezoelectric element mounting into the holder a special soldering paste was used. Hermetical sealing was made in vacuum. Two types of cut angles were used for crystal element fabrication: yzb/α^o and yxl/ α^o . The main parameters of resonators manufactured are given in table 2. Type 1 resonators (f_0=11800 kHz) were manufactured with crystal elements of yzb/α^o -cut and resonators of type 2 (f_0=13100 kHz) with crystal elements of yxl/α^o -cut. Frequency versus temperature of both resonator types (fig. 1) had the view of quadric parabola with the steepness coefficient k=6.2x10^{-8} 1/(^{o}C)^2.

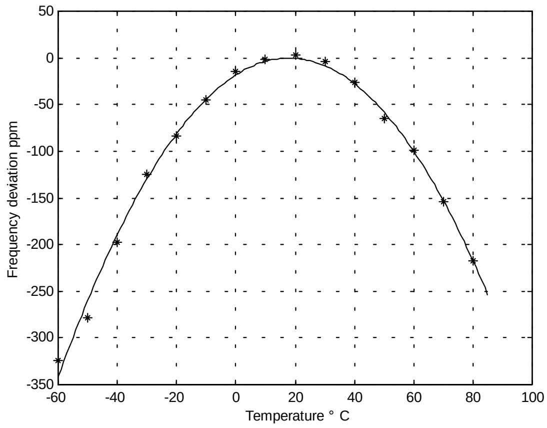


Fig.1 Frequency versus temperature of both resonator types.

Any temperature of extremum (fig. 2) can be obtained within the range 0 ^oC to +60 ^oC.

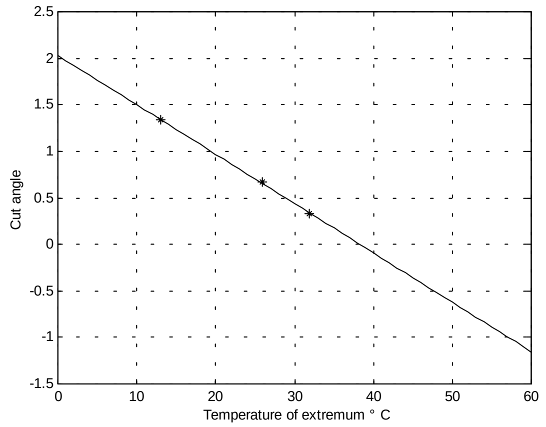


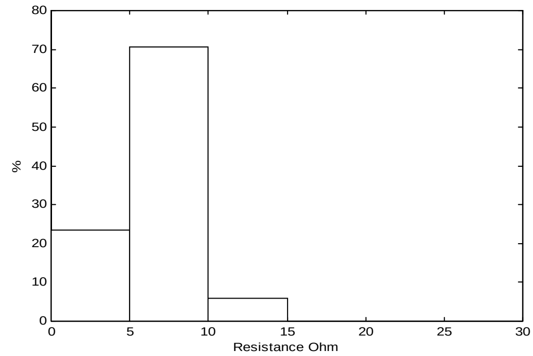
Fig.2 Extremum temperature versus cut angle

The average value of motional resistance R_1 of type 2 resonators is 1.5 times less compared with the motional resistance of type 1 resonators.

Table 2

No	Quan pcs	F_1 MHz	R_1 Ohm		Q k		L_1 mH	C_0 pF	C_0/C_1	Plate size,mm	
			min	max	min	max				X	Y
1	43	11.8	10	30	20	40	5.5	3.7	110	1.0	4.5
2	18	13.1	5	20	11	37	3.1	4.5	90	4.5	1.0

Figure 3 shows the distribution of manufactured resonators depending on their motional resistance value. Over 90% of resonators in UM-5 enclosures with round crystal elements (electrode diameter is 2 mm) have R_1< 10 Ohm and 90% of resonators with crystal elements with the electrode diameter equal to 1.2 mm have R_1 up to 20 Ohm. Resonators in microminiature enclosures of DW type with crystal elements of yzb/α^o - cut have resistance less than 20 Ohm (80%) and those with crystal elements of yxl/α^o -cut about 100%. The motional inductance of type 2 resonators is nearly two times less than the motional inductance of type 1 resonators. It should be specially noted that resonators in microminiature DW packages have higher quality factor Q compared with resonators in large-size UM-5 packages.



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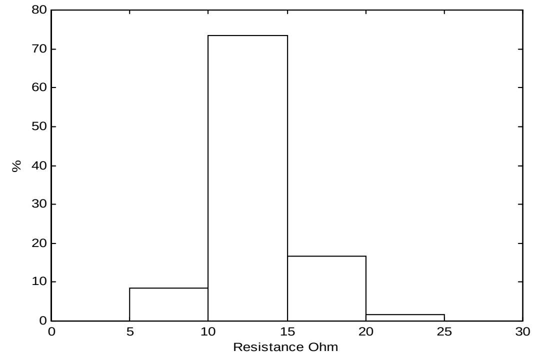

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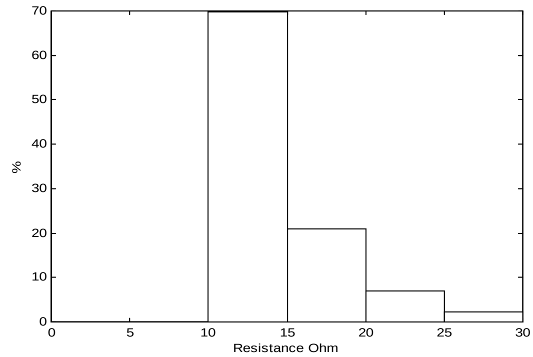

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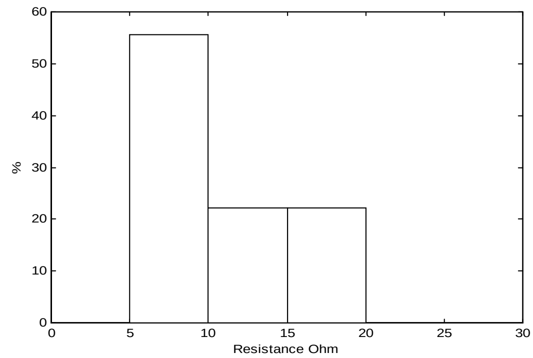
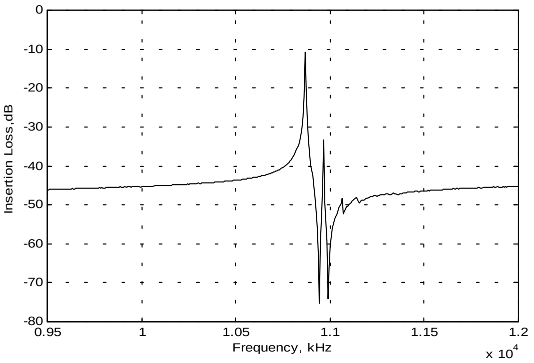


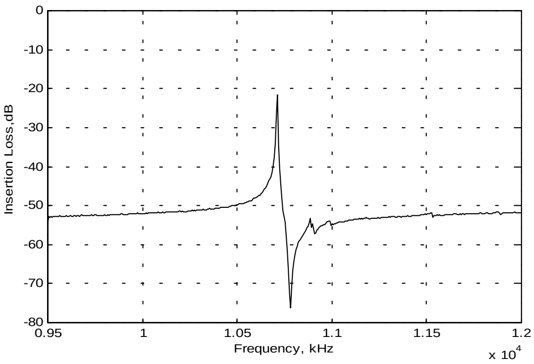
d)

Fig.3 Distribution of resonators depending on their motional resistance value R
a) disk electrode 2.6 mm
b)) disk electrode 1.2 mm
c) restangular plate, yxl/α^o-cut
d) restangular plate, yzb/α^o-cut.

In figure 4 the spectral characteristics of resonators in enclosures UM-5 and DW are presented.



a)



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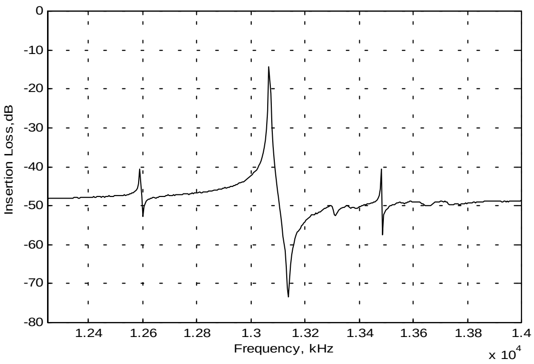

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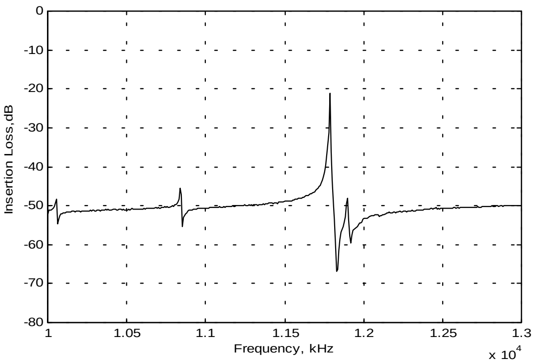

d)

Fig.4 Spectral characteristics of LGS resonators
a) disk electrode 2.6 mm
b)) disk electrode 1.2 mm
c) restangular plate, yxl/α^{o}-cut
d) restangular plate, yzb/α^{o}-cut.

3. CONCLUSION

It is possible to make the conclusion that microminiature resonators with langasite crystal elements have advantages over the analogous quartz crystal units as far as their motional resistance value R_1, motional inductance L_1 and capacitance ratio C_0/C_1 are concerned. They can be also used for designing new models of miniature piezoelectric filters and microoscillators. The cost of these resonators can be close to the cost of analogous quartz crystal units.

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