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BULK ACOUSTIC WAVE HIGH OVERTONE RESONATOR

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Abstract - the acoustic waves propagation losses in solid solutions of Rare Earth in Ittrium Aluminium Garnets. Matrix were \( Y_{3-x}R_xAl_5O_{12} \) found few times lower than that of YAG matrix. The high overtone bulk acoustic wave resonators made of \( Y_{3-x}Lu_xAl_5O_{12} \) were studies. The \( Q \) factor \( 1.5 - 2.0 \times 10^5 \) at 3.5 - 4.0 GHz was experimentally found.

1 - INTRODUCTION

The practical interest to the investigation of the new materials with low acoustic wave losses is due to the possibility of the use of such a materials in acoustoelectron devices particularly in resonators. Few years ago it was found that the acoustic wave attenuation in YAG crystals can be drastically decreased if to substitute Yttrium atoms in a crystal line lattice by the rare earth elements. The purposes of this work were to study the possibility of the use of such a materials in high overtone bulk acoustic wave resonator and obtaining the high values of \( Q \) - factor.

2 - EXPERIMENTAL METHODS

The experimental measurements of the coefficient of lattice absorption \( L \) were made with the samples of \( Y_{3-x}R_xAl_5O_{12} \) using conventional echo pulse method [6] at microwave frequencies. The resonator structures were made of \( Y_{3-x}Lu_xAl_5O_{12} \). Thin plates (200 - 300 \( \mu \)m) with optically polished flat parallel (2") faces of this material were oriented normally to the [100] crystalline axis. To provide electrical coupling of the resonator to the external circuit the resonator at one of it surfaces thin ZnO films (transducer) supplied with ohmic contacts were deposited. The aperture diameter of the transducer was 140 \( \mu \)m. To connect the samples with the reflectometer microstrip lines of reentrant microwave cavity impedance transformer were used.

3 - RESULTS AND DISCUSSION

Typical dependence of the absorption coefficient for longitudinal acoustic waves as a function of \( x \) measured at room temperature on 2.5 GHz is shown on Fig.1a. This figure illustrates the fact that there is a minimum in losses when \( x \approx 0.65 - 0.75 \). It was experimentally found that the Gruneisen constant \( \gamma \) for longitudinal waves is dependent on the composition of the solid solution. (To derive that dependence the absorption was measured in Landau mechanism temperature range, where \( T \) - life time of phonons is not included in the acoustic wave absorption formula.) Solid line on Fig.1a represented results of the theory. It is interesting to compare the possibilities of such material with other low loss materials which can be used in acoustic resonators on the well known diagramm on Fig.1b. This diagramm shows frequency dependencies of the absorption at the same...
wavelength for various crystals and the values of the quality factor $Q$ which can be expected, if to use them in high overtone resonators. Lower curve corresponds to the material studies in this work. It is seen that the highest quality factors can be achieved in our experiments with the resonators. The reflection coefficient of the structure has been measured as a function of frequency. To measure this quantity the samples were placed in the reentrant coaxial cavity that served as an impedance transformer. Two typical dependencies of the moduls of the impedance as a function of frequency are shown on Fig. 2 and 3. The first one (Fig. 2) corresponds to the high efficiency transducer. In this case the set of resonant peaks of high overtone are seen. These peaks are wide enough - their mean quality factors are of an order $2 \cdot 10^4$. On the Figs. 3a and 3b typical dependencies for the sample with high losses transducer are shown (for poor and high frequency resolution respectively). Solid curves correspond to the numerical calculations of the equivalent curquit of the coaxial resonator loaded on the overtone-mode acoustic resonator. The shapes of the curves are strongly dependent on the equivalent parameters of the acoustic resonator. The best fit of the experimental points and the results of calculations allows to evaluate the effective inductance and the resistivity of the acoustic resonator and hence - the $Q$ - factor. For the samples with high losses transducers $Q$ - factor is appeared to be of the order of $1.5 \cdot 10^3$. Using this value of $Q$ and neglecting the energy conversion losses in transducers it is possible to evaluate the coefficient of lattice attenuation $\alpha_L = \omega / 2 \nu S Q$ ($\nu$ - frequency of BAW, $\nu_S$ - velocity of sound). This calculation gives $\alpha_L \sim 1.2$ dB/cm instead 0.9 dB/cm obtained by conventional echo-pulse method.

4 - CONCLUSION

In order to realise the good acoustic characteristics of the material used in resonator it is necessary to minimize conversion energy losses in transducers. Heavily doped YAG $Y_{3-x}La_xAl_5O_{12}$ is a material that can provide a high $Q$ - factor.
The dependence of the reflection coefficient on the frequency (transducer with high efficiency).

The dependencies of the reflection coefficient on the frequency for the sample with high losses transducer (3a - poor, 3b - high frequency resolution).

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