Calculation of Thin Disk Non Axis Symmetric Vibration Resonant Frequencies

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Abstract - **In this paper the calculation of values of resonance frequencies of the thin disk that have being provided for the ZnO thin disk and operating in the non axis symmetric radial vibration mode. Obtained results were compared with FEA analyses and experimental one presented in [1].**

Keywords – **Non Axis Symmetric Mode, Radial Vibration, Thin Disk, Resonant Frequencies.**

I. Introduction

Piezoelectric disk resonators are widely used in the next generation wireless communication systems [2] because of their high quality factor, small size, low power consumption and possibility of their integration on one chip. Piezoelectric transduction allows the design of low impedance elements. This paper presents the method of calculation of disk resonators operating frequencies, which can be used for these devices size approximation.

II. Calculation of Resonance Frequencies of Radial Vibration for the Thin Disk Resonator

An example of disk piezoelectric resonator [1] is shown in Fig.1. It has three supporting beams and no uniform electrodes. Such geometrical structure excites the third mode non axis symmetric radial vibration in disk.

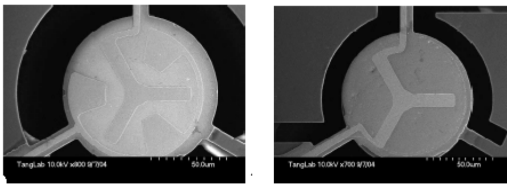

Fig.1 Example (photo) of the piezoelectric disk resonator [1].

The values of the resonance frequencies for different form of electrodes and mounting can be calculated as roots of the following equation:

$$m_{11} \cdot m_{22} - m_{12} \cdot m_{21} = 0, \qquad (1)$$

where coefficients m_{ij} are found from the disk deflected mode analyses proposed in [3], and their values are:

$$m_{11} = J_{\nu-1}(\gamma R) + (\zeta - \nu) J_{\nu}(\gamma R)/\gamma R; \quad m_{12} = -n \cdot \zeta \cdot J_{\mu}(kR)/\gamma R,$$

$$m_{21} = n \cdot J_{\nu}(\gamma R)/\gamma R; \quad m_{22} = c_{11}/c_{66}^{E}\left(J_{\mu-1}(kR) - (1+\mu)J_{\mu}(kR)/kR\right)$$

where $\nu^2 = 1 + n^2 c_{66}^E / c_{11}$, $\mu^2 = 1 + n^2 c_{11} / c_{66}^E$; $\gamma^2 = \omega^2 \rho_0 / c_{11}$ and $k^2 = \omega^2 \rho_0 / c_{66}^E$ are radial and thickness vibration frequency numbers; $c_{11} = c_{11}^E - (c_{13}^E)^2 / c_{33}^E$; $c_{12} = c_{12}^E - (c_{13}^E)^2 / c_{33}^E$ are modified elastic modules c_{ij}^E; n- number of harmonic.

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III. Simulation Results

In Table 1 is given 3 first dimensionless resonant frequencies (frequency number) of the thin piezoelectric disk calculated using Eq. (1) for different values of the parameter ***n***. Material of the disk is ZnO, its parameters are following: $c_{11}^E = c_{22}^E = 210$GPa; $c_{33}^E = 211$GPa; $c_{12}^E = c_{13}^E = 121$GPa; $c_{23}^E = 105$GPa; $\rho_0 = 5675$ kg/m^3; $e_{31} = e_{32} = -0.36$ C/m^2; $e_{33} = 1.57$ C/m^2; $\chi_3^{\varepsilon} = 1.4\chi_0$; $\chi_0 = 8{,}85 \cdot 10^{-12}$ F/m; $Q = 80$. Simulation was provided in Math Lab. For the structure shown in Fig. 1 n=3.

TABLE 1
ZnO THIN DISK RESONATOR RESONANT FREQUENCIES

gR \ n	0	1	2	3
1	2.1299	2.7395	1.6423	2.2735
2	5.4153	5.5902	5.237	6.622
3	8.5879	8.7829	9.2346	9.8144

Values of disks resonant frequency are chosen taking into account maximum of radial vibration harmonic sum value [3]. And in our case they are: 2.7395 5.4153, 8.5879. We compare values of finite-elements analyses (FEA), experimental [1] and theoretical frequency numbers for thin disk resonator presented in Fig. 1, disk diameter is 100 μm, width 0.8 μm. For the third mode frequency numbers are: FEA analysis – 7.497, experimental – 8.24075, theoretical – 8.5879. So the tolerance is 4.209%.

VI. Conclusion

The resonance frequencies of ZnO thin disk non symmetric radial vibration were calculated in this paper. The tolerance 4.209% show good agreement between theoretical and experimental results.

References

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