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CAD OF MEMS. COMPUTATIONS AND SIMULATIONS FOR LGS RESONANT SENSORS

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ABSTRACT

In the past few years the langasite (LGS) crystal has been considered as an alternative to quartz for resonant sensors especially microbalances. In microbalances the LGS resonator is operated in the thickness shear mode. However other vibration modes (flexural or torsional) may be excited in cantilevers to develop new applications covering biosensors and mechanical sensors. Low cost and reduction of size are also required in the fabrication process. Fortunately LGS resonant structure can be fabricated by wet micromachining [1] a process fully compatible with MEMS technology.

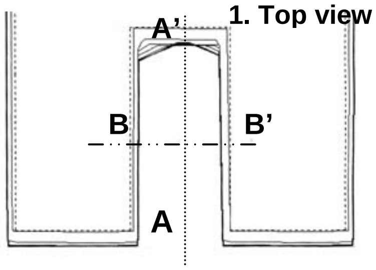
Piezoelectric excitation and wet etching are governed by the anisotropy of LGS crystal and study of new LGS sensors requires: (1) analytical modelling and computations for the piezoelectric excitation, (2) analytical analysis of anisotropic chemical etching in order to achieve numerical simulations of final cantilever shapes (3) FEM simulations of mechanical behaviour that take into account the final geometry of etched cantilevers. These three aspects are thus investigated here to conduct a CAD for LGS micro-sensors.

Metrological performances of LGS resonant cantilevers are primarily determined by orientation of LGS plates and by cantilever alignment. So LGS cuts and direction of alignment suitable to active pure flexural and pure torsional vibrations are extracted from computations that involve the constitutive equations for the piezoelectricity. Calculations and computations of resonance frequencies for the retained LGS orientations are then performed. For flexural vibrations the Bernouilli-Euler model is used to formulate the resonance frequency f_f. In the case of torsional vibrations the solution procedure for the resonance frequency f_t is based on the Saint-Venant approach [2]. Computations of resonance frequencies f_f and f_t include also the influence of cantilever dimensions, of temperature and of cantilever misalignment.

Due to the anisotropy of the micromachining process some selected cuts have to be rejected because wet etching produces undesirable shapes (asymmetric built-ins, slightly inclined shoulders). So a numerical simulation of cantilever shape is needed. A kinematic and tensorial approach has been adopted to solve this problem. Displacements of surface elements within the crystal during the dissolution are analytically formulated. Calculations of displacements involve a representative dissolution slowness surface that describes the anisotropy. Dissolution constants

introduced in the tensorial formulation of the slowness surface constitute the database of a self elaborated simulation tool. 3D shapes and 2D cross-sections (Fig. 1) are furnished by the simulator that is capable to derive shapes with double-sided masks and two steps etchings. We retain finally three orientations (Table 1) for which the dimensioning of double sided masks passes through iterative simulations.

Except the commercial X cut (Fig. 1) selected orientations lead to rather complicated shapes. Shifts in frequency or generation of spurious resonance become possible. The piezoelectric modelling predicts also a marked influence of cantilever dimensions on frequency (Fig. 2). A finite element method is thus used to derive stress mappings (Fig. 3) and to compute vibrations for cantilevers. Shapes derived by the simulator TENSOSIM are used for the meshing of the resonant structure. Falls in frequency are evaluated and deviating behaviours of structures with less favourable shapes are tested. As a result the viability of X-cut, Y-cut and Y-65 resonant sensors is confirmed.



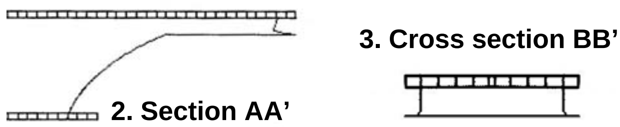


Figure 1: Simulated shapes for a cantilever micromachined on an X cut (alignment: Y axis)

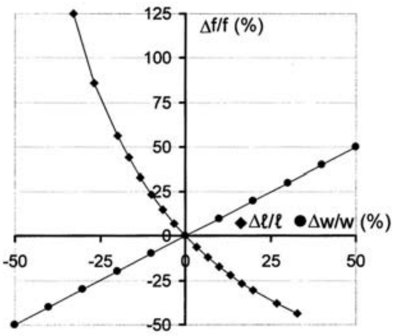


Figure 2: Influence of cantilever geometry (length ℓ and width w) on resonance frequency

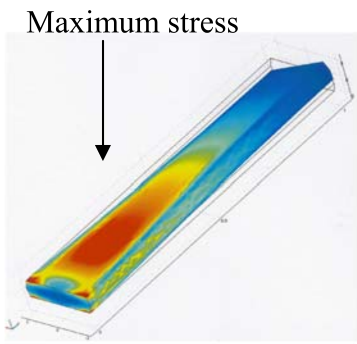


Figure 3: Stress mapping (Torsional mode)

Y−65 cut, alignment Ψ= 90° Pure flexural mode f_f = 154.5 kHz	Y cut, alignment Ψ= 225° Torsional mode f_t = 2150 kHz	X cut, alignment Y axis Pure flexural mode f_f= 385.5 kHz

Table 1: Selected cuts and expected performances. Y−65 cut is for φ = 0°, θ = −65°.

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