Frequency Analysis of Si-Wafers with Variable Size and Boundary Conditions

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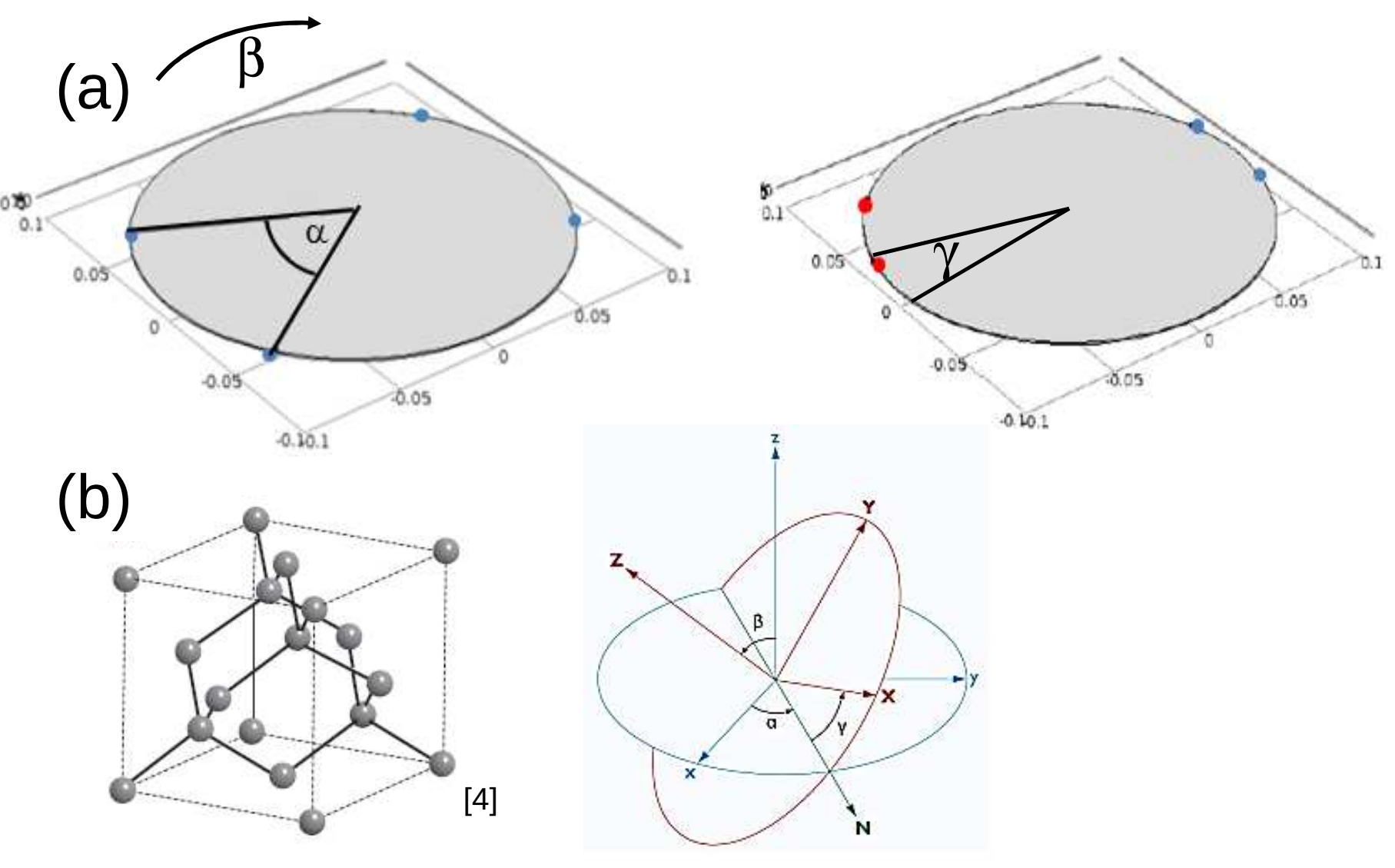
Introduction: Silicon wafers represent key elements in modern microelectronics or photovoltaics. However, this material shows a high sensitivity to vibrations that strongly depend on the realization of the wafer mounting. We performed a frequency analysis of wafers (diameters: D=150, 300 and 450 mm) in a 4-point-mounting with variable position of fixing boundary points as realized in typical experimental situations [1] and investigated the influence of material anisotropy.



(c)

$$\begin{pmatrix} C_{11} & C_{12} & C_{12} & 0 & 0 & 0 \\ C_{12} & C_{11} & C_{12} & 0 & 0 & 0 \\ C_{12} & C_{12} & C_{11} & 0 & 0 & 0 \\ 0 & 0 & 0 & C_{44} & 0 & 0 \\ 0 & 0 & 0 & 0 & C_{44} & 0 \\ 0 & 0 & 0 & 0 & 0 & C_{44} \end{pmatrix}$$

Figure 1. Wafer geometry with symmetric and asymmetric positioning of fixed boundary points (a), visualization of crystal structure and Euler coordinates (b), elasticity matrix (c)

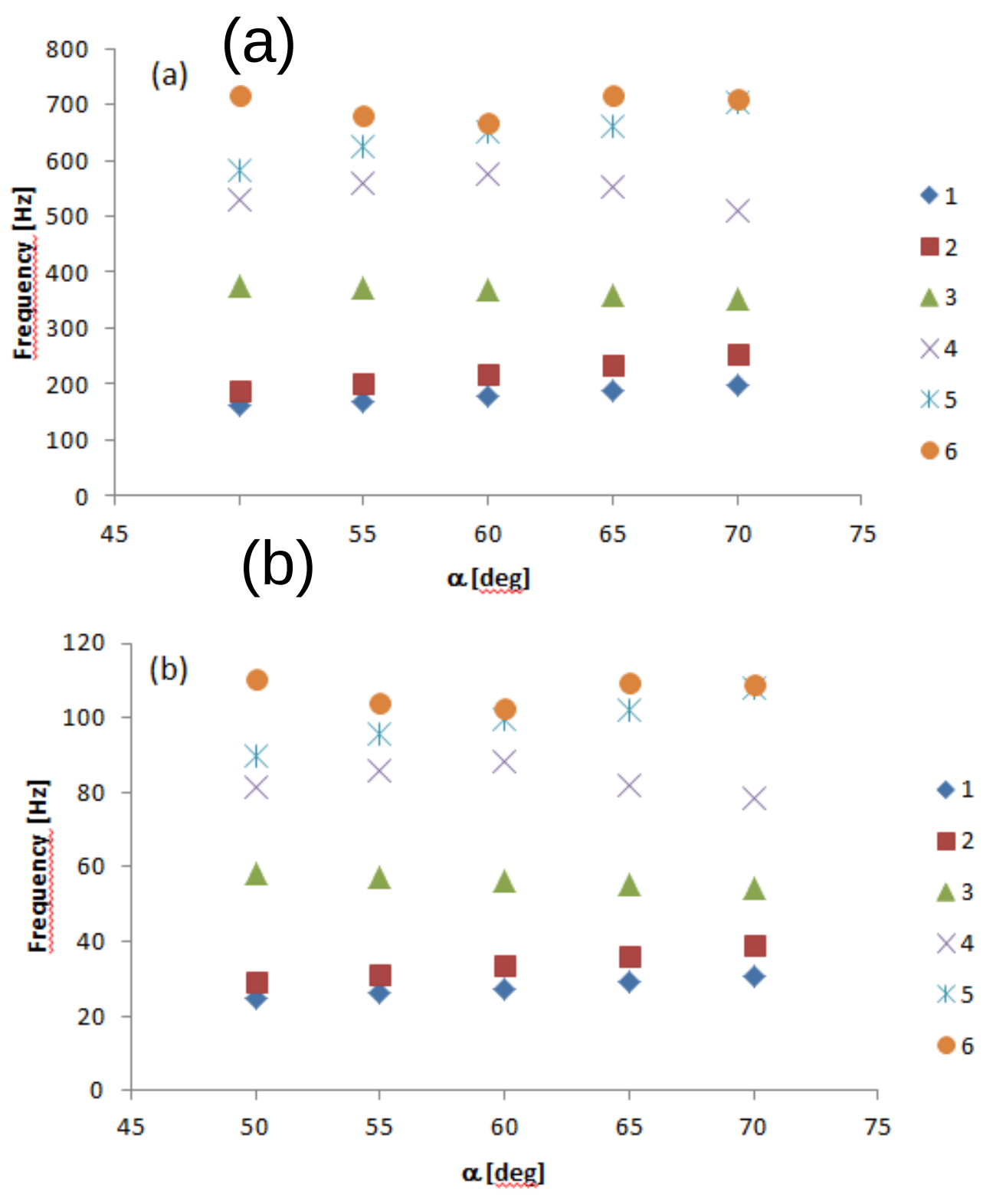
Computational Methods: We use COMSOL MULTIPHYSICS® to set up the wafer geometry and include our orthotropic material system (Fig.1). The linear relation (Hooke's law) between tension t and total strain tensor ε is $t_{ij} = C_{ijkl}\varepsilon_{kl}$. For Silicon, which is an orthotropic material, the elasticity tensor C can due to symmetry be represented by a 6x6 matrix with $C_{11} = 165,6 \cdot 10^9 Pa$, $C_{12} = 63,9 \cdot 10^9 Pa$, $C_{44} = 79,5 \cdot 10^9 Pa$. The total strain tensor can be expressed in terms of the displacement gradient as [2,3]

$$\varepsilon = \frac{1}{2}\left(\nabla\mathbf{u} + \nabla\mathbf{u}^T\right)$$

For an arbitrary cut direction (e.g. a [111] wafer) we additionally rotate the crystal axis with respect to the wafer geometry by introducing a local coordinate system.

Results:

- Dependence on angle α (see Fig. 1).



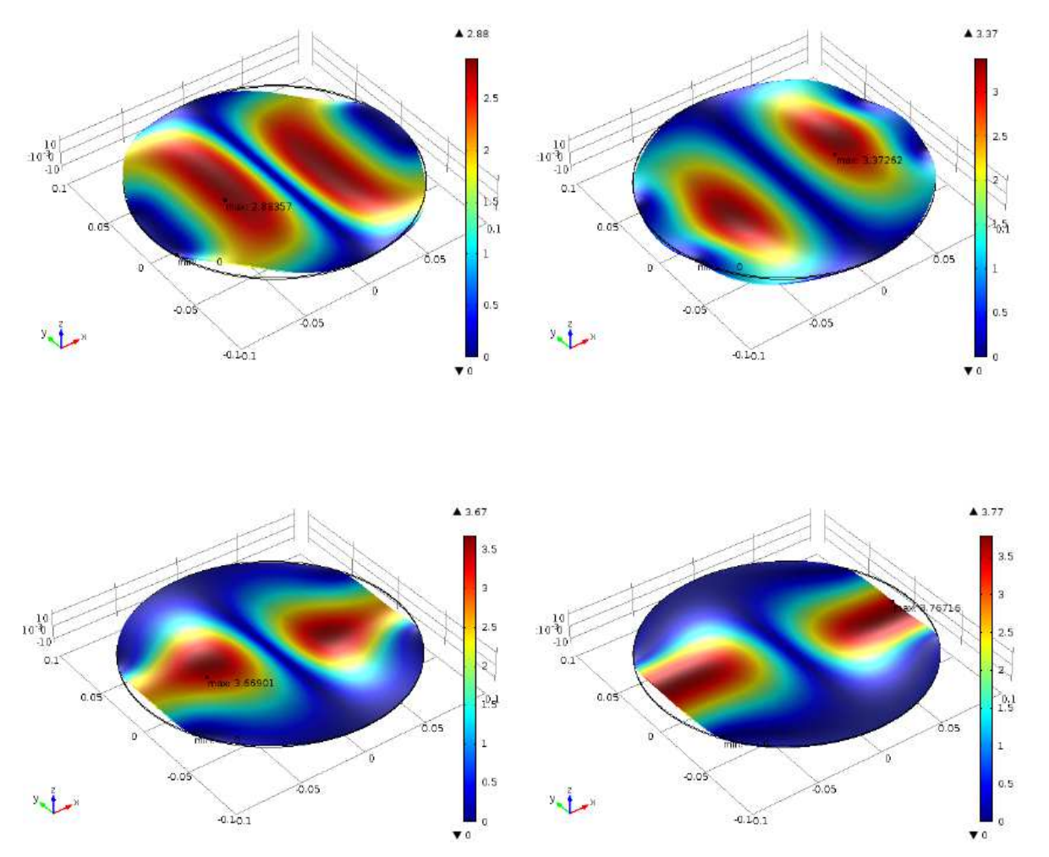


Figure 3. displacement **u**.

Figure 2. Frequencies: D=150 mm (a), D=450 mm (b)

- Variation of the orientation of a [111] wafer: influence of rotation (β)

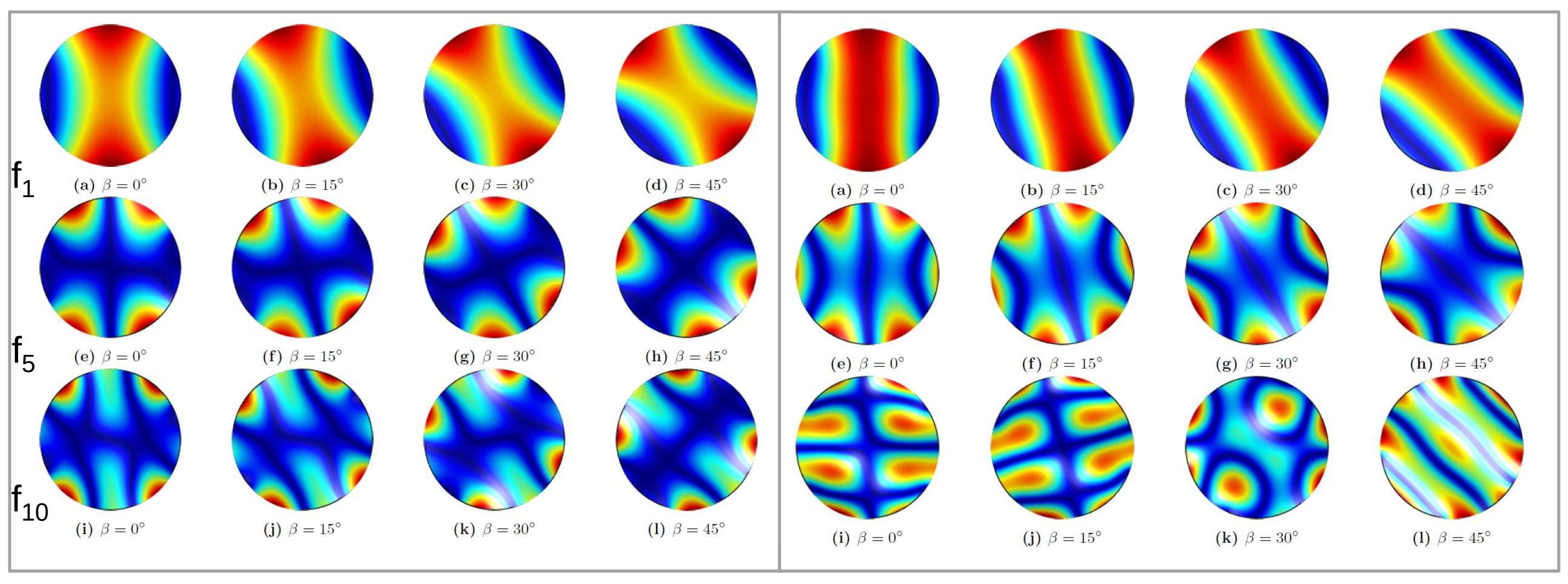


Figure 4. influence of wafer rotation (with angle β) , α=50° (left) and 70° (right).

- Influence of an asymmetric mounting

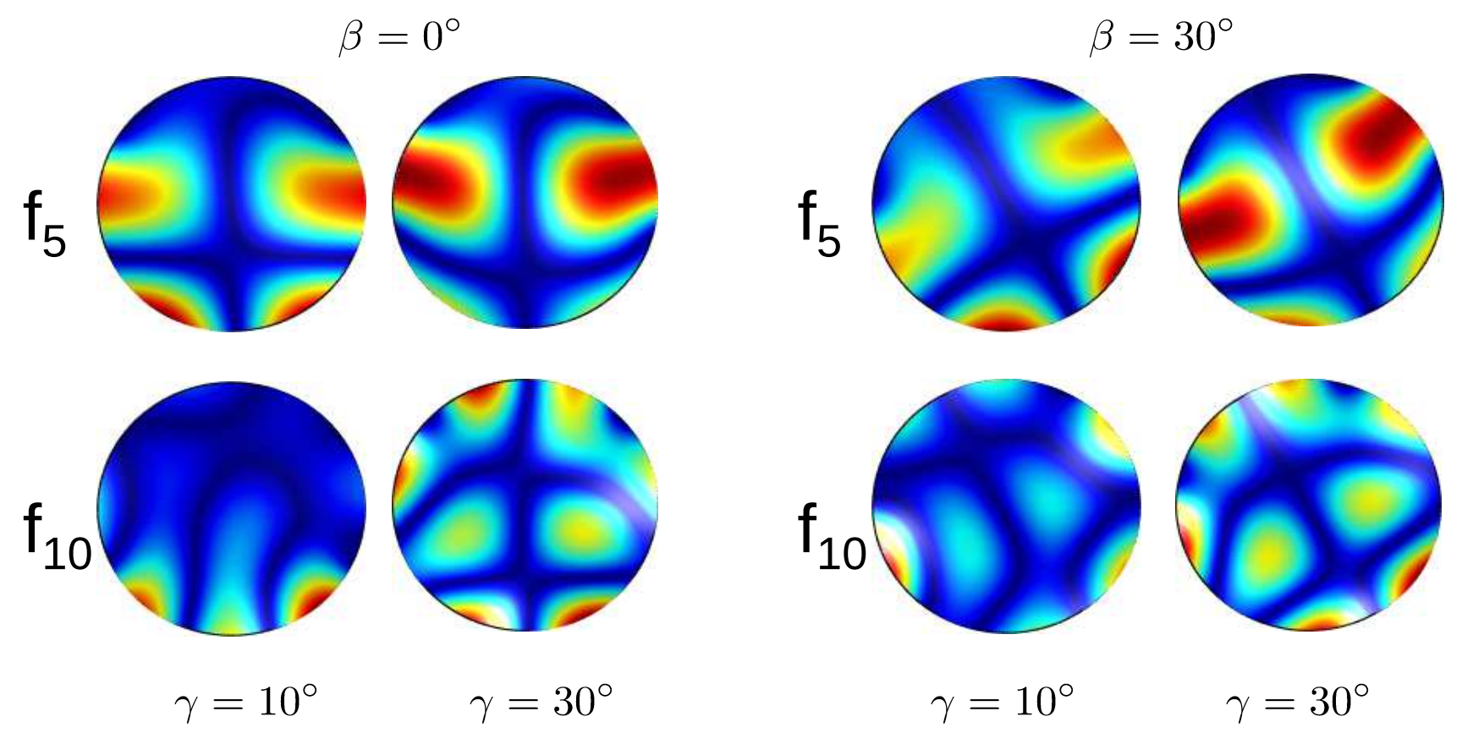
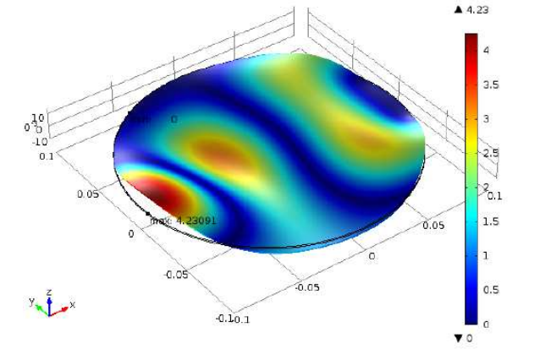


Figure 5. mode changes in dependence of β and γ



	β=0°		β=30°	
	γ=10°	γ=30°	γ=10°	γ=30°
f_5[Hz]	176,7	175,1	182,9	180,6
f_{10}[Hz]	360,7	344,3	361,0	351,8

Table 1. frequencies in dependence of β and γ

Conclusions:

- Simulations reveal a dependence of the frequencies on mounting geometry.
- The anisotropy of the material may cause a dependence on the wafer's modes on orientation within a mounting

References:

1. private communication, Rudolph Technologies Germany GmbH, Mainz
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