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MODELLING AND CHARACTERIZATION OF PIEZOELECTRIC STRUCTURES: FROM BULK MATERIAL TO THIN FILM

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OUTLINE

- **Application**: integrated structures based on piezoelectric thin films such as MEMS and NEMS.
- **Aim**: to get a predictive model for the design of an efficient device.
- **Means**: modelling by Finite Element Method and characterization by laser interferometry to assess of the mechanical response in quasistatic regime.

THEORETICAL APPROACH

⇨ The equations of piezoeletricity relate the mechanical strain and electrical displacement ($\boldsymbol{S}$, $\boldsymbol{D}$) to the stress and electrical field ($\boldsymbol{T}$, $\boldsymbol{E}$)

$$\boldsymbol{S_\alpha = s^E_{\alpha\beta} T_\beta + d_{i\alpha} E_i}$$

$$\boldsymbol{D_i = d_{i\alpha} T_\alpha + \varepsilon^T_{ij} E_j}$$

$$\alpha, \beta = 1, \cdots, 6 \qquad i, j = 1,2,3$$

where $\boldsymbol{s}$ is the compliance tensor at constant electric field, $\boldsymbol{d}$ is the piezoelectric tensor and $\boldsymbol{\varepsilon}$ the permittivity tensor at constant stress.

⇨ Assuming that $\boldsymbol{S_1 = S_2 = 0}$

$$\boldsymbol{d^{eff}_{33} = d_{33} - 2d_{31} \frac{s^E_{13}}{\left(s^E_{11} + s^E_{12}\right)}}$$

⇨ Investigated samples (Figure 1)

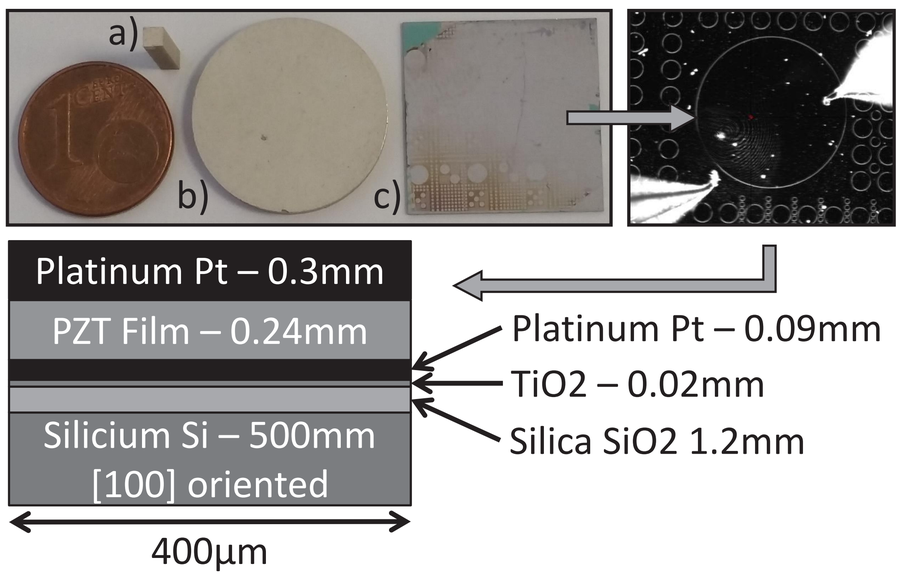

Figure 1. Samples: a) rod b) cylinder c) thin film

⇨ With COMSOL Multiphysics® FEA software

- 3D geometry modelling
- Excitation by a sinusoïdal voltage source
- Time dependant analysis performed
- Theoretical determination of the normal displacement on the top surface

✓ We obtain information on the simulated $\boldsymbol{d^{eff}_{33}}$ of the piezoelectric material in picometers per volt.

EXPERIMENTAL APPROACH

⇨ The laser set-up (Figure 2) allows displacement measurements of few picometers.

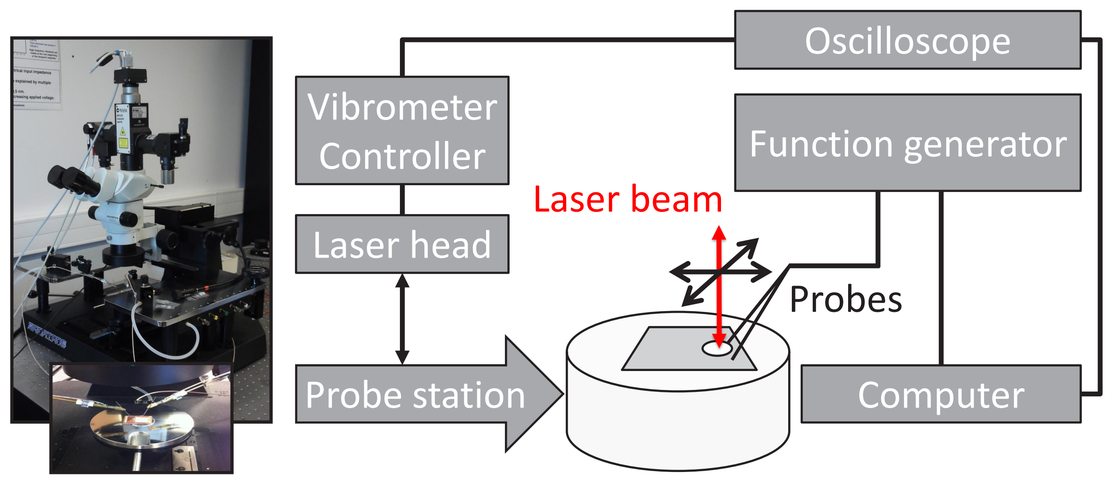

Figure 2. Experimental set-up

✓ We obtain information on the experimental $\boldsymbol{d^{eff}_{33}}$ of the piezoelectric material.

RESULT AND DISCUSSION

⇨ Values of the experimental $\boldsymbol{d^{eff}_{33}}$ are compared to the simulated ones in Table 1.

SAMPLE	EXPERIMENT (pm/V)	MODELLING (pm/V)	Δ (%)
Rod	402.07	423	4.9
Cylinder	6.92	7.36	5.9
Thin film	99.1	116	14.5

Table 1. Experiment vs.modelling

✓ Discrepancy less than 15% between modelling and experiment.

CONCLUSION

☑ Successful comparison of the modelling and the experiment for predicting the mechanical response of piezoelectric samples.

☑ Influence of the thickness on material properties.

FUTURE WORK

➲ Study of the clamping effect and the influence of each layer of the thin film.

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