Finite element method simulations of MEMS bilayers

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Cantilevers are structures classically used to extract mechanical performances of thin MEMS materials. Those structures allow the determination of stress gradients along the thickness of the characterized film. This is illustrated in Figure 1.

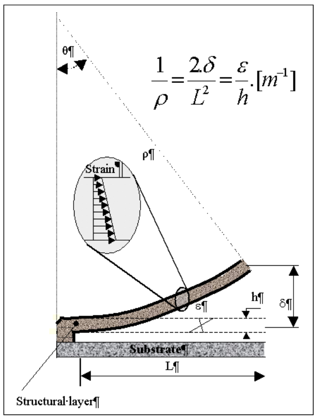

Figure 1 Stress gradient measurement from the shape of a cantilever

If a bilayer – a stack of two materials- is created, a stress gradient can appear. This is due to the mechanical properties mismatch for the two materials such as the thermal expansion coefficient.
This stress gradient will result in a circular shape of the released cantilever. This stress gradient can be due to :

- lattice misfit
- film growth effects
- thermal expansion coefficient misfits

between the two layers

The starting point of our analysis was the observation of an oxide residue below silicon cantilevers released from a SOI –Silicon On Insulator- wafer. Those patterned and released cantilevers presented a circular shape (cfr figure 2). Simulations taking into account only the thermal expansion coefficient misfit between the two materials (Si-SiO_2) reproduced nicely the mechanical phenomenon.

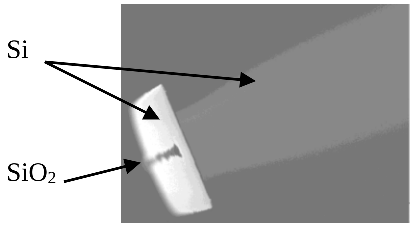

Figure 2 SEM picture of a stressed bilayer-cantilever

Values of the thermal expansion coefficient were found in the literature for Si (α_{Si}= 2.33E-6 / ° C) and SiO_2 (α_{SiO2}= 0.35E-6 / ° C). The growth temperature of the oxide was also considered. We did a simulation of a 200µm length cantilever using the ABAQUS software. The loading consisted in decreasing the temperature from the growth temperature (1050°C) to the ambient temperature (20°C). The results of this simulation are proposed in Figure 3.

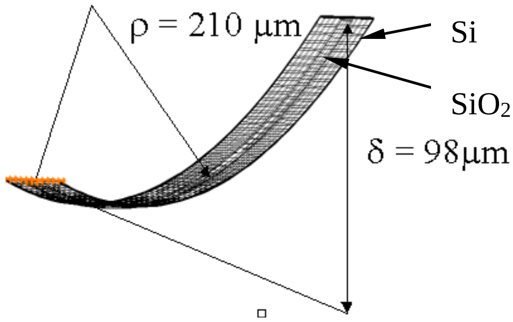

Figure 3 ABAQUS simulation of bilayer-cantilever

Those results were confirmed by an analytical model proposed by Ghering *et al* [2].
Further work consist in developing methods to measure accurately the thermal expansion coefficients of materials in order to better predict the behavior of structures realized using our own deposition recipes and methods.

[1] G.A. Gerhing et al, "**Cantilever unified theory and optimization for sensors and actuators",**
Smart Mater. Struct. 9 (2000), pp 918-931