Mechanical Field: Chemical Surface Acoustic Wave (SAW) Sensor

Show First Results: January 13rd, 2015,
Presentation of Results: January 27th, 2015.

Problem Description

This chemical sensor makes use of the propagation characteristics of surface acoustic waves (SAWs), which vary with different surface mass loading. The SAW is launched from the four excitation fingers by applying forces normal to the surface with varying sign on neighboring fingers. The SAW travels on the surface to the receiver fingers and are detected there (see Fig. 1). Depending on the amount of molecules of the substance to be examined, the mass of the sensitive coating varies which influences the SAW velocity.

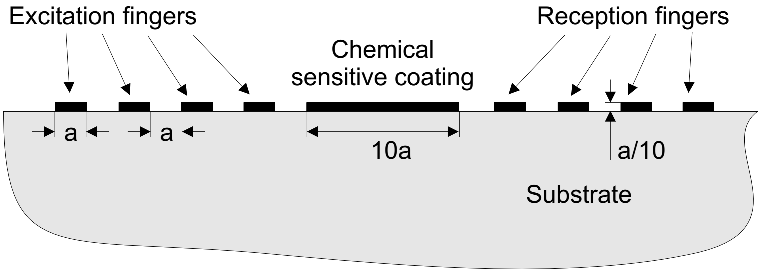

Figure 1: Chemical sensor

Modeling

- In this sensor, mechanical waves are generated. Therefore, **mechanic** has to be chosen as PDE type.
- The width a of a finger, which is equal to the spacing between fingers, is equal to $1\mu m$.
- The material of the fingers has to be chosen as copper and the sensitive coating as **steel**. The substrate consists of silicon Si.
- The shear wave velocity in the solid body can be calculated as $c_{\mathrm{S}} = \sqrt{(c_{44}/\rho)}$ with c_{44} the (4,4)-entry of the tensor of elasticity moduli and ρ the density. Take care of the mesh-size ($h < \lambda_{\mathrm{S}}/12$ with $\lambda_{\mathrm{S}} = c_{\mathrm{S}}/f$ as the shear wave length).
- The boundaries of this assembly have to be positioned at a distance, where no disturbing reflection can be detected during the interesting time interval. At the bottom, there may be set Dirichlet boundary conditions (on all DOFs) to hold the overall assembly.
- The surrounding air may be neglected.

Analysis

- Simulate a sine-excitation of five wavelengths, where $\lambda_{\mathrm{SAW}} = 4a$ at a frequency $f = c_{\mathrm{SAW}}/\lambda_{\mathrm{SAW}}$ (c_{SAW} can be calculated approximately by $c_{\mathrm{SAW}} = 0.94c_{\mathrm{S}}$) with a force of 1 kN per finger and take a look at the displacement of the midpoint of the first receiver finger on the interface between finger and substrate. For a better understanding, take screenshots at varying time steps (or even make movies) of the wave propagation process.

- Vary the mass of the sensitive coating in the material-editor in the range of ±30% and take a look at the time signal of the displacement at the first receiver finger. Should the amplitude, the phase shift, or the frequency be used to detect the mass of the coating?

For the following tasks switch to the frequency domain (i.e. perform harmonic simulations). If not said otherwise perform these simulations only for one frequency (f_{SAW}).

- Vary the mass of the coating in the range ±30% and calculate the sensitivity of the sensor with respect to the change of mass. For your calculations consider only the sensor parameter (amplitude, phase or frequency) which you have chosen in the previous task.

- Now keep the mass of the coating fix at its initial value and vary the mass of the substrate in the range ±5%. What can you observe? How cross-sensitive is the sensor with respect to the mass change of the substrate?

- Finally, conduct harmonic simulations with excitation frequencies of $f_{\mathrm{SAW}}/2$ and $2f_{\mathrm{SAW}}$. Take a look at the maximum displacements at the receiver fingers and in the silicon substrate. If there are any differences, how can they be explained? At which frequency should the sensor be operated?

Presentation

- Prepare for a 6 minute presentation (format: PDF (preferred) or MS PowerPoint) and for a 4 minute question session.