

Syllabus on Microsystems design

Abstract

The course will give principles of static and dynamic behaviour of microsystem structures as beams and plates in different configurations in terms of boundary conditions and loading. Basic acoustic elements will be described and their effect on microstructures damping will be shown. Approaches to reduced-order modelling of complex microstructures will be explained and the electromechanical and electroacoustic analogies will be studied in detail. Basic electromechanical transduction mechanisms will be described; their analogy models will be developed and applied to examples of real microsystems. Among the transduction mechanisms will be both reciprocal principles as electrostatic, piezoelectric, electromagnetic and electrodynamic, and non-reciprocal principles as piezoresistive and thermomechanical.

Content

1. Introduction
MEMS definition, advantages, principal features, overview of typical structures, overview of typical materials used in MEMS, overview of typical technologies used for MEMS fabrication, main applications.
2. Continuous mechanical systems – static behavior
Mechanics of deformable bodies, stiffness tensor, elastic constants, deformation mechanical structures: axially loaded beam, transversally loaded beam, engineer's beam theory.
3. Continuous mechanical systems – dynamic behavior
Overview of elastic waves in solids, free longitudinal vibrations of a bar, transverse vibrations of a bar, transverse vibrations of a plate.
4. Acoustic elements - air damping
Typical situations of the air damping in narrow gaps, radiative acoustic damping, acoustic loads on vibrating piston, effects of viscous flow, squeeze-film air damping,
5. Discrete systems: electro-mechanical & electro-acoustic analogies
Lumped electrical, mechanical & acoustic systems, electro-mechanical & electro-acoustic analogies,
6. Electrostatic transduction
Theory of electrostatic transducers, models of electrostatic transducers with transverse and lateral arrangements, comb arrangement of electrostatic transducer, examples of main applications of electrostatic transducers.
7. Piezoelectric transduction
Piezoelectric effect, piezoelectric materials, piezoelectric relations, piezoelectric constants, piezoelectric coupling coefficient, elastic waves in piezoelectric material, modeling of piezoelectric transducers with plane wave, Mason's model, acoustic wave devices.
8. Electromechanical transduction with magnetic field
Theory of electromagnetic transducers, linear model of an electromagnetic transducer, electrodynamic transducer and its linear model, examples of main applications of transducers with magnetic field.
9. Non-reciprocal transducers
Piezoresistive sensing, piezoresistive gauge factor, resistivity tensor, piezoresistive coefficient of silicon, piezoresistive sensing elements, Wheatstone bridge arrangement of sensing elements, capacitance-based sensors.