COMSOL Multiphysics for MEMS Applications

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Outline

• Multiphysics Approach
• MEMS Product Overview
• Examples in wide ranging applications
  – Actuators, Sensors & Resonators
  – Microfluidics
  – Coupled Physics and more
• COMSOL based MEMS Simulations – User Stories
• Questions and Answers
The Multiphysics Approach

Common in MEMS & Microfluidics
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MEMS – Inherently Multiphysics

- Electro-mechanical
- Electro-thermal
- Thermo-mechanical
- Fluid-structure

- Fluid-thermal
- Electrokinetics
- Electro-thermo-mechanical
- And many more couplings
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Thin Film Resonator

- Study the effect of thermal stress on resonant frequency
- Eigen Frequency Analysis with & without thermal stresses
- Change design to minimize the effect of thermal stresses

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<tr>
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<th>STRAIGHT CANTILEVERS</th>
<th>FOLDED CANTILEVERS</th>
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<tbody>
<tr>
<td></td>
<td>ANALYTICAL</td>
<td>2D MODEL</td>
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<tr>
<td>Without stress</td>
<td>15.0 kHz</td>
<td>14.8 kHz</td>
</tr>
<tr>
<td>With residual stress</td>
<td>33.1 kHz</td>
<td>31.9 kHz</td>
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MEMS – Linkage of Electrical & Structural

- Motion Affects Electric Field – Moving Meshes or Iterative Remesh
- Lumped Parameter Extraction easy (L, R, C, etc.)
- Model Courtesy of Prof. I Harouche, Univ. of Manitoba
MEMS – Electrostatic Actuation

- Shows bending of cantilever beam due to electrostatic forces
- 2 way coupling between deformations and electric field
- Calculate Capacitance and Impedence
MEMS Gyroscope

- Estimate the Q factor of a simple 2-DOF MEMS Gyroscope
- Study the effect of Slide Film Damping
Piezoelectric Modeling

- Sensors
- Actuators
- Resonators/Filters
- Transformers
- Transducers
- Fluid Structure Interactions

Radially polarized Piezo Device
Quartz Crystal Monitor
Microgripper
Actuator
Piezoelectric Modeling

- Different Material Orientations
- Stress-Charge or Strain-Charge
- Analysis
  - Eigenfrequency
  - Frequency response
  - Static
  - Transient
External Circuit Connections
Microfluidics

- Application modes for laminar flow
  - Navier-Stokes and Stokes equations
  - Incompressible and weakly compressible formulations
- Microscale effects
  - Electroosmotic flow, viscous slip, thermal creep, laminar inflow/outflow
- Two phase flow
  - Capillary flow, bubbles, inkjets
- Transport modeling
  - Electrokinetic flow
  - Convection and diffusion
- Connection to Reaction Engineering Module
Electrokinetics & Electroosmosis

- AC electrokinetic forces influence rate of transport of analyte to reaction surface
- Electroosmosis involves coupling fluid flow, mass transport and electromagnetics

Courtesy: Gaurav Soni, Marin Sigurdson, and Carl Meinhart, UC, Santa Barbara.
COMSOL - Flexible Multiphysics Environment

• Simply add them from a list – Same Interface
• Couple any of them with any of the others
COMSOL Multiphysics

- True Multiphysics – Everything can link to everything
- Flexible – You can model just about anything.
- Usable – You can keep your sanity doing it.
- Extensible – If it’s not specifically there…add it!
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MEMS Biosensor Brings about Disposable DNA Detectors

- Dielectrophoresis
- Electrothermal force
- Electroosmosis

Model Courtesy: Dr. Carl Meinhardt, UC Santa Barbara
Model Available in the MEMS Model Library
Reduced Stresses Inside Semiconductor Chips Lead to Higher Reliability

- New geometry for the probe based on simulations
- Equivalent electrical performance with 30% less force

Courtesy:
Luca Cecchetto
Lucia Zullino
Lorenzo Cerati
STMicroelectronics, Milan, Italy
Join the Leaders in Multiphysics Simulation at the COMSOL Conference 2010

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www.comsol.com/conference2010
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Questions & Answers …

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