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# Numerical analysis of MEMS and micro-fluidics in CFD-ACE+

## ( CFD-ACE+에서의 MEMS 및 microfluidics 수치해석)

Younsuk Choi, KwangWon Suh

Kyung Won Tech.
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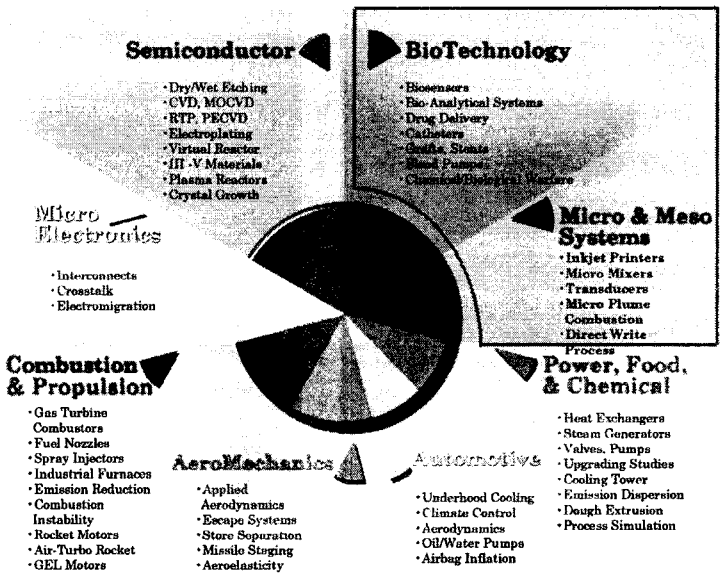
## Introduction




EMERGING MICRO WORLD >

## Introduction

### Multi-Physics Simulations

- Interacting Physico-Chemical phenomena
  - Fluid Flow, Heat, and Mass Transfer
  - Conjugate Heat Transfer and Radiation
  - Free Surface Dynamics and Multi-Phase Flows
  - Fluid-Structure Interaction
  - Electrochemistry, Ionization
  - Biochemistry, DNA and Protein Chemistry
  - Surface (Molecular) Chemistry
- Smaller sizes → Stronger Interactions between various Processes and Geometry

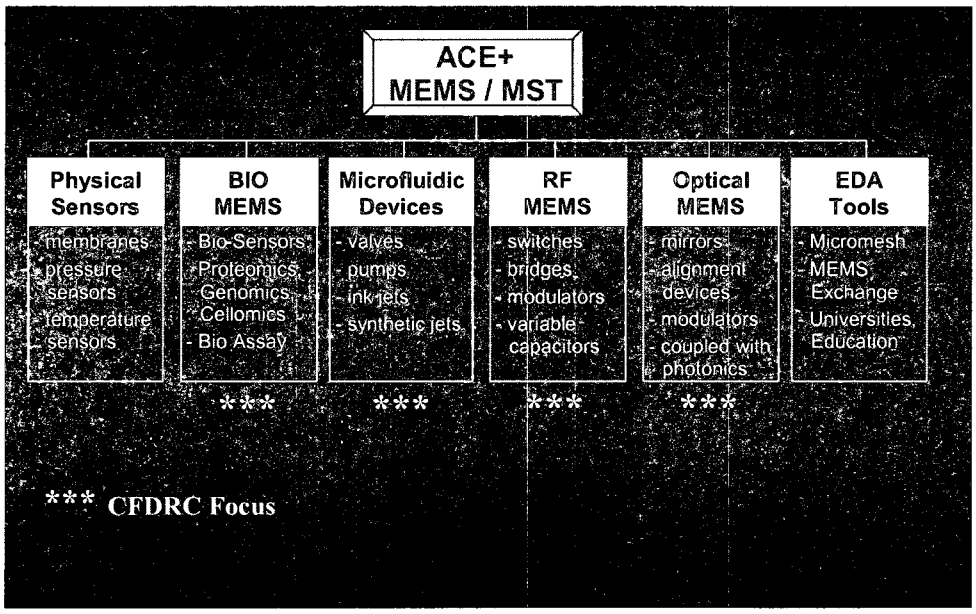
**Adequate couplings are critical**

## Introduction

<*CFD-ACE+ Capability*>

- Flow, Turbulence, Heat Transfer, Radiation(STS, DOM, MC)
- Chemistry
  (mixing, homogeneous/inhomogeneous rxn, electrochemical, bio rxn)
- Spray (particle trajectory, DEP, binding on μ-bead)
- VOF, Cavitation, User-scalar, Two-fluid
- Stress, Grid Deformation
- Electric, Magnetic, Plasma
- Kinetic(Fokker-Planck equation)
- Semi-device
- Multi-Physics (Multi-Scale, Multi-Disciplinary)

## MEMS and μ-Fluidics applications in CFD-ACE+



## MEMS and μ-Fluidics applications in CFD-ACE+

KW

### Mixing devices

- Quick Mixing Between Sample and Reagent is Critical
- Mixing Dominated by Molecular Diffusion

**Mixing Techniques**

- Lamination
- Array of Microjets
- Chaotic Advection
- Stirring with Magnetic Beads

**Devices Modeled**

- Static Laminating Micromixer
- Microplume Mixer
- Bubble Pump Driven Micromixer

## MEMS and μ-Fluidics applications in CFD-ACE+

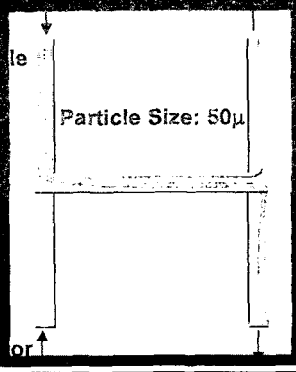
KW

### Particle transport

filter and separator

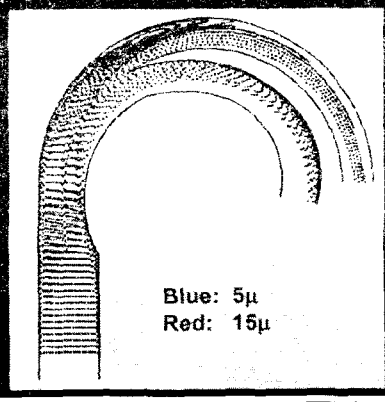
**H-Filter**
(Washington State University)

- Separation of Particles or Cells in Biological Fluids
- Separation Based on Diffusivity or Centrifugal Force




**Aerosol Separator**
(Mesoscale Systems Tech.)

- Separation of Pathogens in Air
- Analyzed Performance at Different Flow Rates



## MEMS and μ-Fluidics applications in CFD-ACE+

### Electrokinetic phenomenon

**Electrophoresis**

- Migration of Charged Species under the Influence of Electric Field
- Electrophoretic Mobility Function of Size, Charge and Shape
- Electrophoretic Separation Due to Differing Mobilities of Species
- Separation of Amino Acids, Proteins and DNA
- Capillary Electrophoresis Realized in Microchips

**Electroosmosis**

- Charge in Double Layer Near Wall Pulls the Fluid
- Electroosmotic Mobility Function of Surface Charge and Viscosity

**Electrokinetic Model**

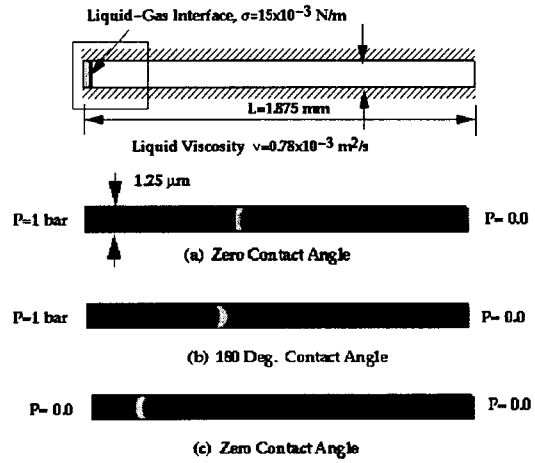
- Electroosmotic Force in Momentum Equations
- Electrostatic Equation
- Electromigration Term in Species Conservation Equation
- Ionization Equilibria

## MEMS and μ-Fluidics applications in CFD-ACE+

### Liquid handling

μ–channel liquid transport

- **Liquid transport in a microchannel under surface tension**
- **Schematic and flow conditions**
- **Interface position and shape at different contact angles and different pressure gradients**



## MEMS and μ-Fluidics applications in CFD-ACE+

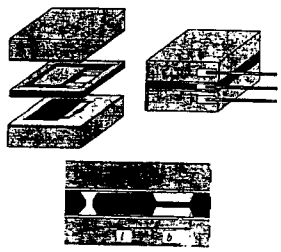
### Micro fluidic pump

- Microfluidic devices need "fluid movers"/pumps to move fluids
- Several designs available
  - "positive displacement" PZT or electrostatically actuated membranes with passive (flap type) or dynamic valves used to rectify flow
  - electrophoresis, electroosmosis, surface tension
- Complex physics with multi-disciplinary coupled effects
  - flow + structures, flow+thermal+structures, electrostatics, surface tension
- High-fidelity multi-physics, computational tools can impact the design process
  - assess individual components as well as assembled devices
  - predict performance of different designs prior to fabrication, save testing and development time
- Ultimate aim is to generate numerical "virtual" models
  - "virtual" numerical manufacture and testing of devices
  - reduce/eliminate need for actual testing prior to device manufacture

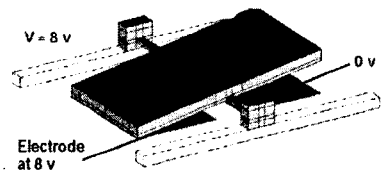
## MEMS and μ-Fluidics applications in CFD-ACE+

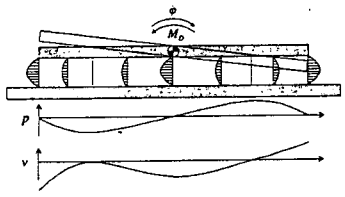
### FSI, Air damping

**Accelerometers**

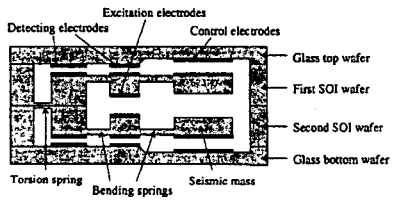


**Tilting Mirrors**



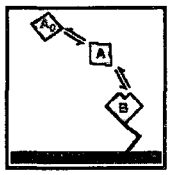

**Gyroscopes**



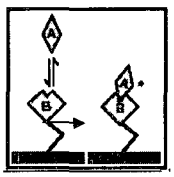
## MEMS and μ-Fluidics applications in CFD-ACE+

**Bio-chemistry** capability

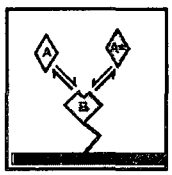
- Mass Transport or Kinetics-Limited Antigen-Antibody, Ligand-Receptor Binding
- Surface & Bulk Flow Reactions
- Multi-Protein, Multi-Receptor, Competitive Binding
- DNA Hybridization
- Surface or Volume-Immobilized Enzyme Catalysis (Michaelis-Menten)
- Microsphere-based Detection (Immunoassays)



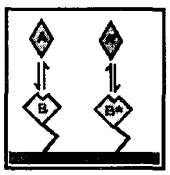
Transport Limited



Conformation Change



Competitive



Non-competitive

## Conclusion

- **Realistic Multi-Physics, Multi-Disciplinary simulations are becoming feasible and viable.**
- **No major technology (hardware or software) barriers**
- **Rate of Success =**
  ***f* (Management Perception, Conviction, adequate Commitment)**

**Active collaborations and partnerships can accelerate rate of success and are strongly recommended.**