Simulation of Bio-molecular Microsystems (Simbiosys)
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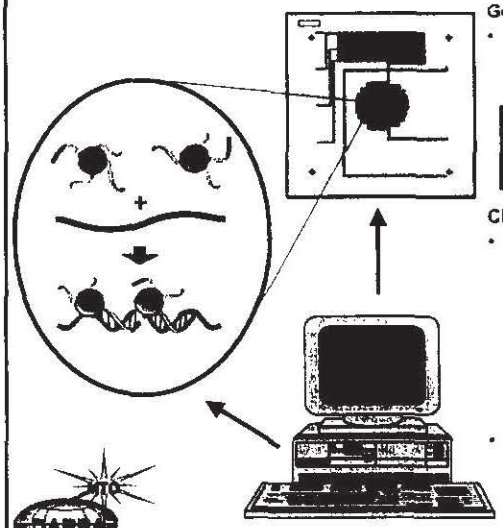

Goal

- **Develop and demonstrate the capability to simulate and design high performance integrated Bio-Molecular Microsystems**

Develop phenomenological models, scaling laws and design rules for Bio-Microdevices
DEVICE MODELS

Challenges

- **Experimental/Theoretical Characterization of the elements of a Bio-Molecular System :**
  - **Molecular Recognition Elements (sensitivity, selectivity and speed)**
  - **Signal Transduction Elements (Signal Amplication with High SNR)**
  - **Bio-Fluidic Transport Elements (High Efficiency, Low Power Pumping, Valving and Mixing Methods)**
- ***Demonstration of device models on design of* Bio-Microsystems**

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- Motivation for Program
  - Lack of Quantitative Characterization of the Interface Between Biology and Micro/Nano Technology is the Single Biggest Roadblock in Designing High Performance Bio-Chips
  - Current practice of cut-and-try approach is unable to transform good ideas into reliable/robust bio-chips within a reasonable amount of time
- Military Impacts
  - Program will develop the Device Models (Scaling Rules and Phenomenological Models) to enable the design of high performance, re-configurable, portable bio-molecular microsystems for sensing and detection applications

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- Start Date: FY01 End Date: FY04
- Program Status:

  New Start
  - BAA 01-07 released Oct. 2000, Closed Feb. 2001
  - 80 Proposal abstracts received, 16 recommended for full proposals
  - 30 Full proposals received, 15 selected for awards
  - Joint BioFlips/Simbiosys Kick-off Meeting was Held 8-10 August, 2001
- Management Issues:
  - DARPA/AFRL/SPAWAR/AFOSR Program Management Team
  - Close collaboration with DARPA/BioFlips program, several jointly funded projects
- Interactions with other DARPA Offices:
  - Focus 2000 workshop with DSO & ITO on the future of interfacing BIO-INFO-Physical Systems

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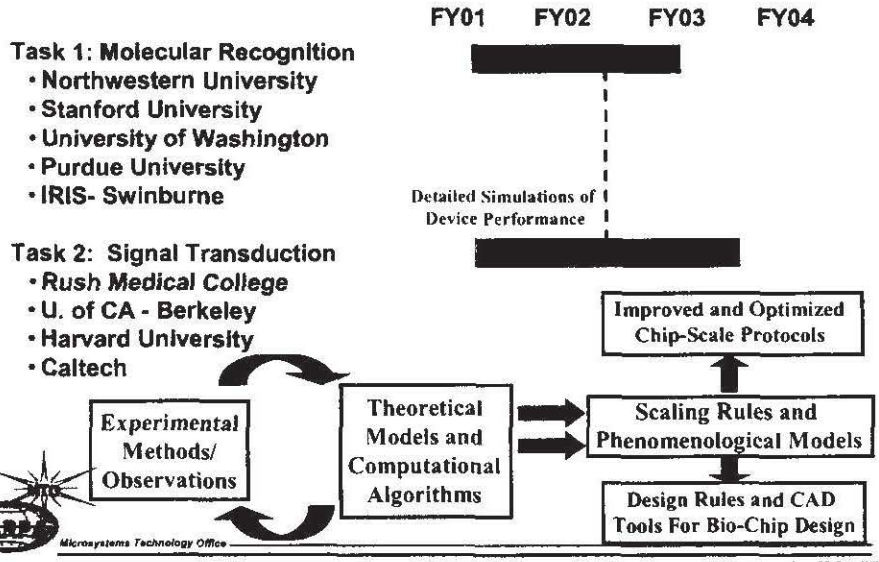
Programmatics



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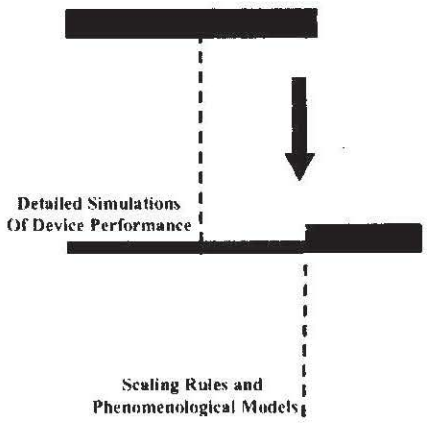
Programmatics

FY01 FY02 FY03 FY04

Task 3: Bio-Fluidic Transport
- U. of Pennsylvania
- SRI International
- Northwestern University
- Ohio State University
- LLNL
- Johns Hopkins University

Task 4: Design of LoC Systems
- SRI International
- Coventor
- Carnegie-Mellon University
- U. of Wisconsin (w/BioFlips)
- U. of Cincinnati (w/BioFlips)
- U. of Texas (w/BioFlips)



Technology Transfer through Coventor, CFDRC, SRI, Cleveland Clinic Foundation and BioFlips Members (Aclara, Motorola, Honeywell, ...)

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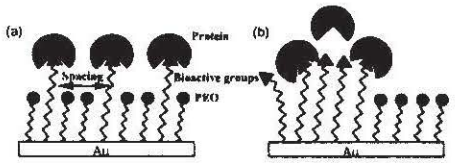
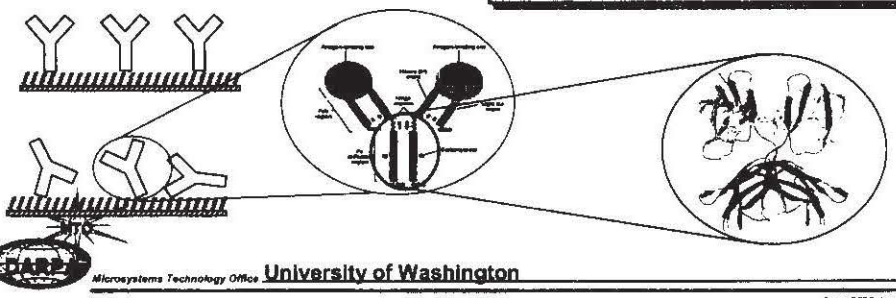
Device Models for Probe Surfaces, Quantification of Surface Probe Sensitivity and Selectivity on Molecular Scale Properties; Enable Design of Optimal Surface Probes



Surface Probe Sensitivity/Selectivity = F(Target Molecule Properties, Probe Molecule Orientation/Distribution on Surface, Probe Molecule Properties)



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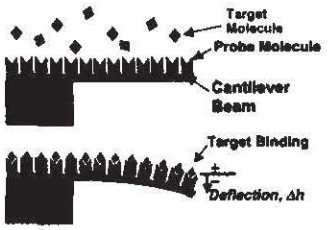
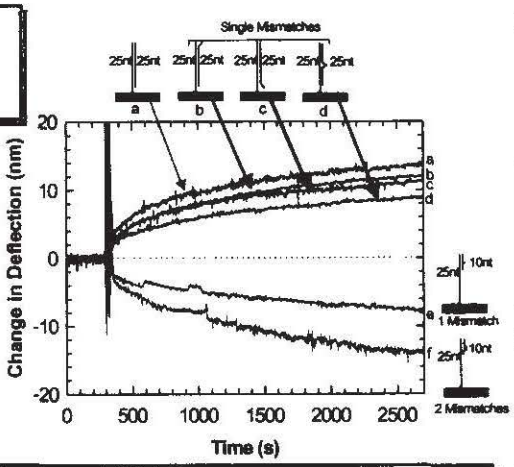
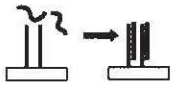
Device Models of Micro-Cantilevers for High SNR Transduction of Molecular Signals ; Enable Signal Processing Based on Micro-Cantilevers







Cantilever Deflection = F(Surface Coverage, Molecular Binding, Molecular Properties, Cantilever Properties/Dimensions)

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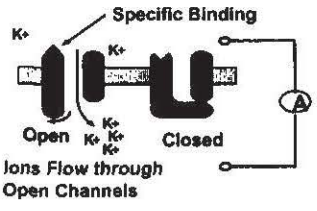
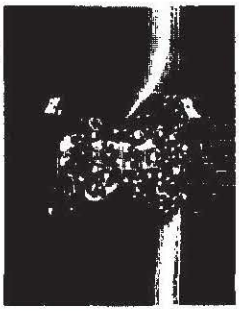
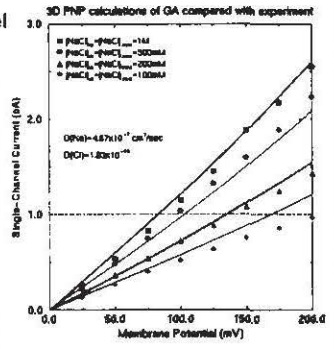
Device Models for Ion Channel Behavior; Quantify Sensitivity and Selectivity of Ion Channels; Enable Engineering of Channels



Gramicidin Ion Channel



Current voltage relations



Ion Channel Transduction | Spectral Element PDE Solver | Device Model for Channel

Ion Channel Sensitivity, Selectivity and Amplification = F(Ion Properties, Channel Charge Distribution/Electric Field, Channel Properties, Molecular Binding/Properties)

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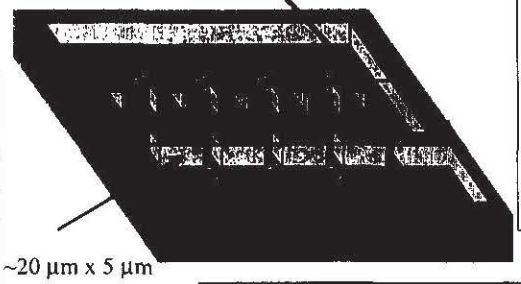
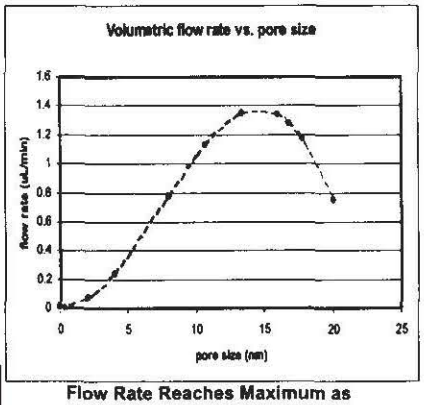
Device Models for Micro and Nano Flow Channels, Enable Optimization of Fluidic Transport in Microfluidic Systems

Parallel Nanochannels



~20 μm x 5 μm



Flow Rate Reaches Maximum as Edges of the EDL Merge

Pumping Power = F(Channel Size and Properties, Fluid Properties, Applied Pressure and/or Electric Fields)

Early Results : Electrically Driven Flow Leads to Significant Power Reduction Below 1 micron channel size !!

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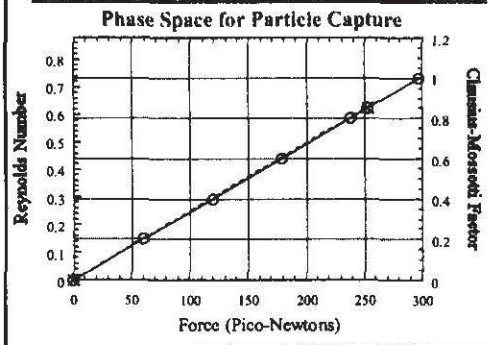
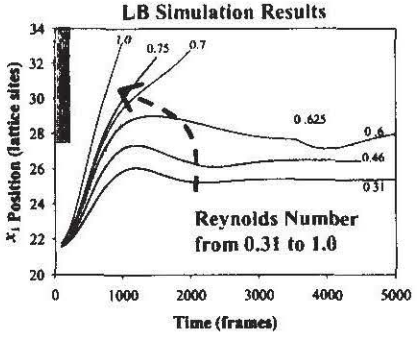
Device Models for Dielectrophoresis in Microfluidic Systems for Particle Sorting and Trapping

Electrode width and gap = 30 μm
Applied voltage = 5 Vrms
Particle radius = 3 μm





Particle Trajectory Control = F(Electrode Size/Position, Applied Field, Particle Size/Density, Flow Properties)

Early Results : Scaling Rules for Particle Trapping Using DEP

Microsystems Technology Office **Lawrence Livermore National Laboratory**

Program Manager Introduction
Anantha Krishnan

- Vice-President, Advanced Technology Group, CFD Research Corporation
- Sc.D., MIT, Mechanical Engineering, 1989

  M.S., Marquette University/Medical College of Wisconsin, Bio-Medical Engineering, 1986
- Technical Interests :

  Intersection of Biology and Engineering at the Molecular Scale

  Computer Aided Design (CAD) Tools for Mixed Technology Systems (MEMS, Microfluidics, Mixed Signal Electronics and Photonics, …)