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SRC/NSF Forum on Nano-Morphic Systems

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Semiconductor Research Corporation

Stanford University, November 8 & 9, 2007

Introductory Remarks

- A trend, synergistic with scaling, is the use of semiconductor technologies for diverse integrated systems applications
  - Called Functional Diversification (FD)
  - SRC member companies have asked SRC to investigate basic research opportunities in FD
  - We appreciate your willingness to provide input to our research needs identification process

Functional Diversification (FD)

- FD embraces the expansion of semiconductor technology applications to new domain
- FD requires integration of non-CMOS devices (sensors, actuators etc.) with traditional CMOS and other novel information processing devices
- FD is empowered by continued traditional scaling
- FD is fundamentally cross-disciplinary

How do we define research issues associated with FD?

- Specific technology requrements are driven by the chosen application
- Requrements contain elements of
  - system architectures,
  - energy sources/conservation
  - SoC and SiP configurations
  - sensing etc
- Can we extract a set of broadly applicable, generic research needs for Functional Diversification?
- One approach, adopted by the forum, is to consider an extreme case of a functional integrated system; e.g. *Nanomorphic Systems*

Morphic architectures

- Having a specified form or shape
- Conveys that the computational structure is inspired by the physics, biology, etc. of the problem being addressed.
  - Morphic systems sense, filter, extract features, characterize, and report/take action
  - Example: *Vision Chip, Electronic Cell etc.*

Forum Focus

- Forum Focus is on Extremely Scaled Microsystems
  - We have chosen a ‘thought problem’ from bioelectronics to focus thinking
  - We must comprehend the physical limits that govern what might be achieved at the scale of the living cell

Desired Outcome

- Definition of Research
  - What are the research pathways and timelines that enable the design and realization of extreme microsystems within fifteen years?
- If SRC were to decide to engage in basic research in the Semiconductor Bioelectronic (SBE) systems area, what domains offer the best opportunities for SRC university research to make substantial contributions?
- While the forum is focused on long term horizons, we are also interested in research opportunities in shorter term time frame
  - Can we suggest a sequence of steps?
  - Semiconductor Bioelectronics Roadmap

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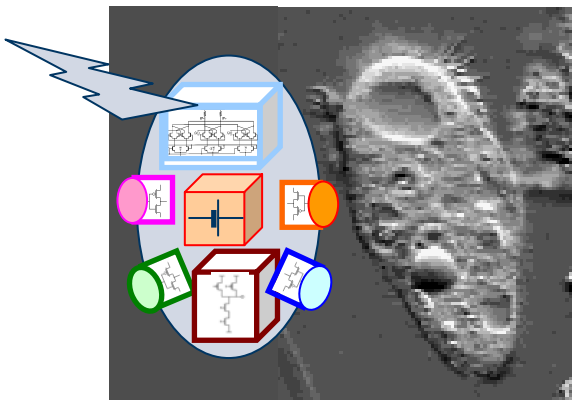
Prototypical example of a nanomorphic architecture:

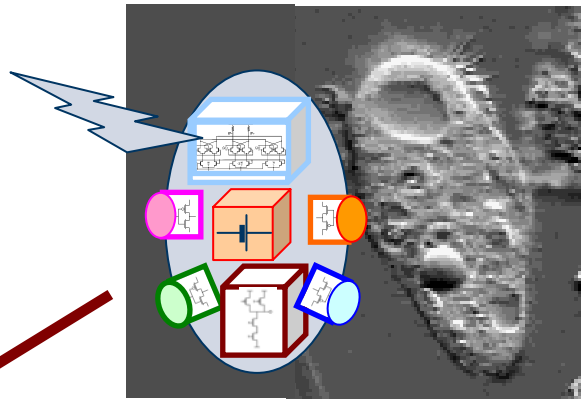
Autonomous Micron-Scale Systems

Goal: Sense the state of single living cell



In vivo Cell State Measurements

Examples of important cell's states to detect



I. Alive or Dead?

Important for stem cell research

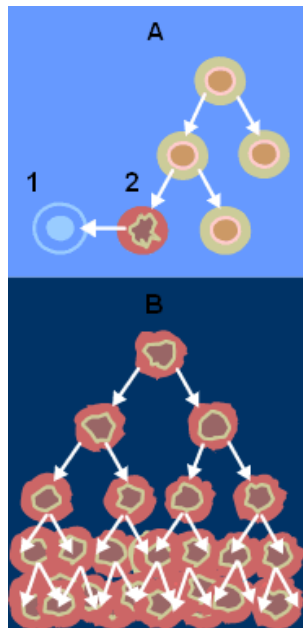
II. Normal or Cancer Cell?

Normal Cells:

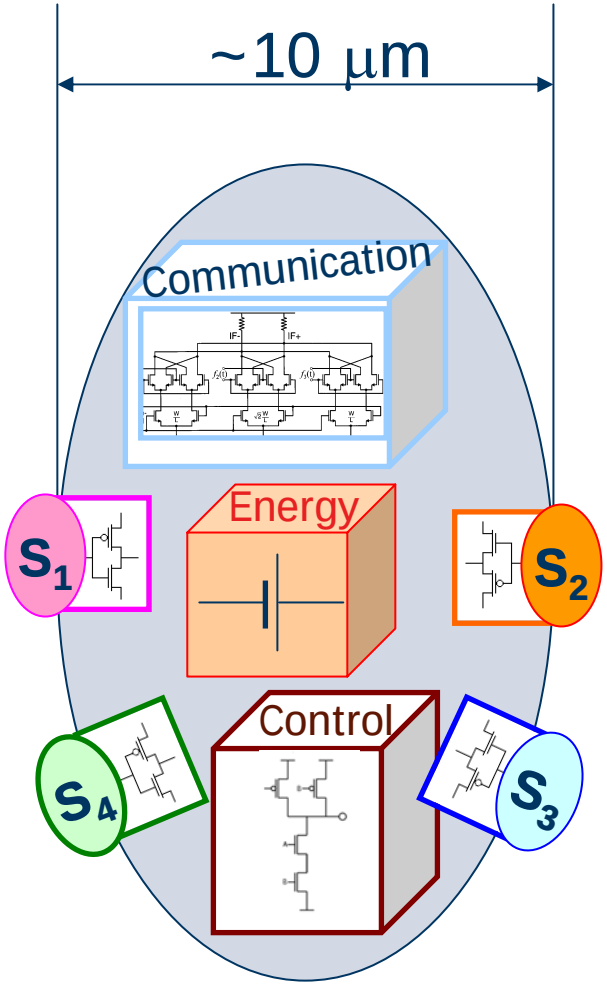
Programmed cell death

Cancer cells:

Do not stop reproducing
Do not obey signals



Electronic Cell



Major functional blocks:

- Sensing
- Communication
- Control
- Energy

Technology Convergence

Constraints and Trade-offs:

Very limited space needs to by divided between

- sensors
- power supply
- electronic components

Scaling Limits need to be Understood

Extreme scaling needed

Thermal Limits !

Layout:

3D microcircuits

Prototypical Semiconductor Bioelectronics Roadmap

Research Goal

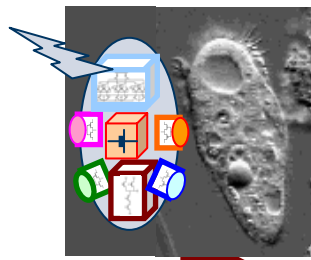
2D arrays of pressure sensors with sub10 μm resolution

On-chip integrated energy sources

Tablet PC

Sub10μm probe electrodes

A two-way interface between neurons and transistors



Bio-FET

2007

e.g. artificial eye

2XXX

Sensing state of individual cell

Clinical Assistant

High-resolution tactile imaging for palpation

Implantable microsystems

Application

Agenda – 11/8/2007

9:00A - 9:15A	Welcome and Forum Overview - Steve Hillenius, SRC	
		Topic
9:15A - 10:00A	Presentation: Wentai Liu, UC/Santa Cruz	Bio-Interfaces
10:00A - 10:45A	Presentation: Steve Downey, Cymbet Corp.	Small Energy Sources
10:45A - 11:00A	Break	
11:00A - 12:30P	*Panel I: BioFET Sensors for Living Cell*	
	Gregory Timp, Univ. of Illinois/Urbana-Champaign	Biosensing
	Moritz Voelker, M. Planck Institute-Germany	BioFET
	Zhiyong Li, Hewlett-Packard	Si NW for Intracellular Sensor
	Robert Westervelt, Harvard	'Pseudo-cell' Nanofactories
	Mark Reed, Yale University	Si NW FET
12:30P - 1:30P	Lunch	

Agenda – 11/8/2007 (con't)

1:30P - 2:15P	Presentation: Joshua Smith, Intel	Wirelessly Powered Platform for Sensing and Computation
2:15P - 3:00P	Presentation: Ralph Cavin, SRC	Emerging Research Architectures for Micro-Systems: Limits and Trade-offs
3:00P - 3:15P	Break	
3:15P - 4:45P	*Panel II: Autonomous Micron-Scale Systems*	
	David Cumming, Univ. of Glasgow-Scotland	Wireless Telemetry/Lab-in-a-Pill
	Kensall Wise, Univ. of Michigan	Wireless Microsystems
	Jan Rabaey, UC/Berkeley	PicoNode
	Carlotta Guiducci, Univ. of Bologna-Italy	Wireless Sensor Networks/Embedded Microsystems
5:00P - 7:00P	Reception (heavy hors d'oeuvres)	

Agenda – 11/9/2007

8:00A - 9:45A	*Panel III: Integrated Power Sources*	
	Henry Hess, Univ. of Florida	Caged ATP Energy Sources
	Woonsup Shin, Sogang Univ.-Korea	Mini-biofuel Cell (& Zn-AgCl batt)
	Amit Lal, Cornell Univ. / DARPA	Radio-isotope Energy Sources
	Gleb Yushin, Georgia Tech	Integrated Supercapacitors
	Paul Wright, UC/Berkeley	Vibration-based Energy Sources
9:45A - 10:00A	Break	
10:00A - 11:45A	*Panel IV: Emerging Research Devices for Micron-Scale Systems*	
	Jim Hutchby, SRC	ERD for Added Functionality
	Stan Williams, Hewlett-Packard	Molecular Electronics
	Meyya Meyyappan, NASA Ames	NW Memory
	Victor Zhirnov, SRC	Ultra-low Power Devices
11:45A - 12:30P	**Brainstorming System Integration - Facilitator: Dan Herr, SRC**	
12:30P - 1:30P	Lunch	
1:30P	Adjourn	