Nanotechnology and the Future (of Everything?)

The work of the **Center for Applied Nanoionics**

Michael N. Kozicki
Director, Center for Applied Nanoionics
Professor of Electrical Engineering
Arizona State University

ASU Arizona Institute for Nano-Electronics
ARIZONA STATE UNIVERSITY
CENTER FOR APPLIED NANOIONICS


AT&T
9:42 AM
SMS
Text
Calendar
Photos
Camera
Weather
Maps
Stocks
Settings
YouTube
Notes
iTunes
Calculator
Clock
Phone
Mail
Safari
iPod

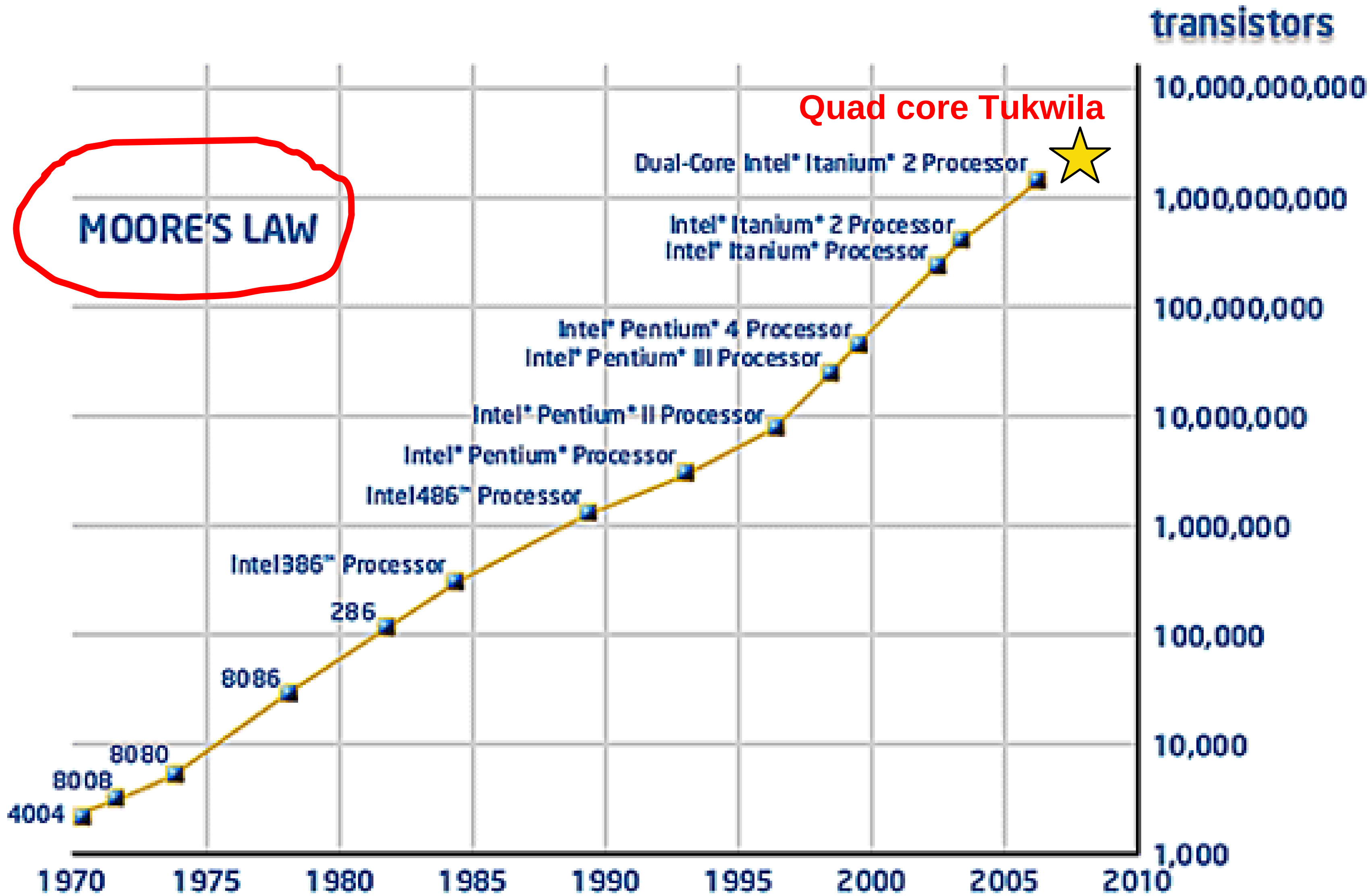
- **Nanotechnology**
  - **control of matter** on the atomic and molecular scale
  - normally **1 to 100 nanometers**
  - **fabrication of devices** within that size range.

http://en.wikipedia.org/wiki/Nanotechnology

- **Two main approaches**
  - **"top-down"**
    - **nano-objects are constructed from larger entities**
  - **"bottom-up"**
    - **materials and devices are built from components which assemble themselves**

http://en.wikipedia.org/wiki/Nanotechnology

Top-down nanotech in action



http://www.intel.com/technology/mooreslaw/index.htm?iid=tech_silicon_research_mooreslaw

What's next?

- The fruits of Moore's "Law"
  - More devices/cm^2 means more performance for less $$
  - The best way to get more devices on a chip is to make them smaller – the cult of *scaling* was established
- Is there a similar evolutionary path to nanoelectronics or will nano*revolution* take place?
  - Looking in the rear view mirror doesn't show us what's around the next bend…

A challenge we are facing…

- **Scaling doesn't work for memory**
  - » **existing memory devices will struggle to meet future industry requirements**
- **We need a technology that will take us to extreme densities**
  - » **for stylish storage-hungry apps**
- **We need a technology that will take us to very low power programming levels**
  - » **for ultra-high density discrete/embedded memory, mobile, wireless apps (RFID, etc.)**
- **By the way, it's a *$60B* market…**

Will Nanotechnology Save Us?

- **Not so fast!**

IEEE SPECTRUM
ONLINE
For Tech Insiders

2007 Technology Winners and Losers Special Issue

Loser: Still Waiting For Nanotube Memory Chip

By Philip E. Ross
First Published January 2008

Nantero's alternative to flash memory has reached its sell-by date

IBM: Materials Will Spur Next Wave of Chip Innovation

Online staff -- *Electronic News*, 11/4/2005

Innovation in materials has replaced scaling as the main source of performance and feature improvements in leading edge CMOS chips.

PROGRESS ARTICLE

Nanoionics: ion transport and electrochemical storage in confined systems

The past two decades have shown that the exploration of properties on the nanoscale can lead to substantially new insights regarding fundamental issues, but also to novel technological perspectives.

J. MAIER

NATURE MATERIALS|VOL 4 | NOVEMBER 2005 |www.nature.com/naturematerials

…the crystallizing field of ‘nanoionics’ bears the conceptual and technological potential that justifies comparison with the well-acknowledged area of nanoelectronics.

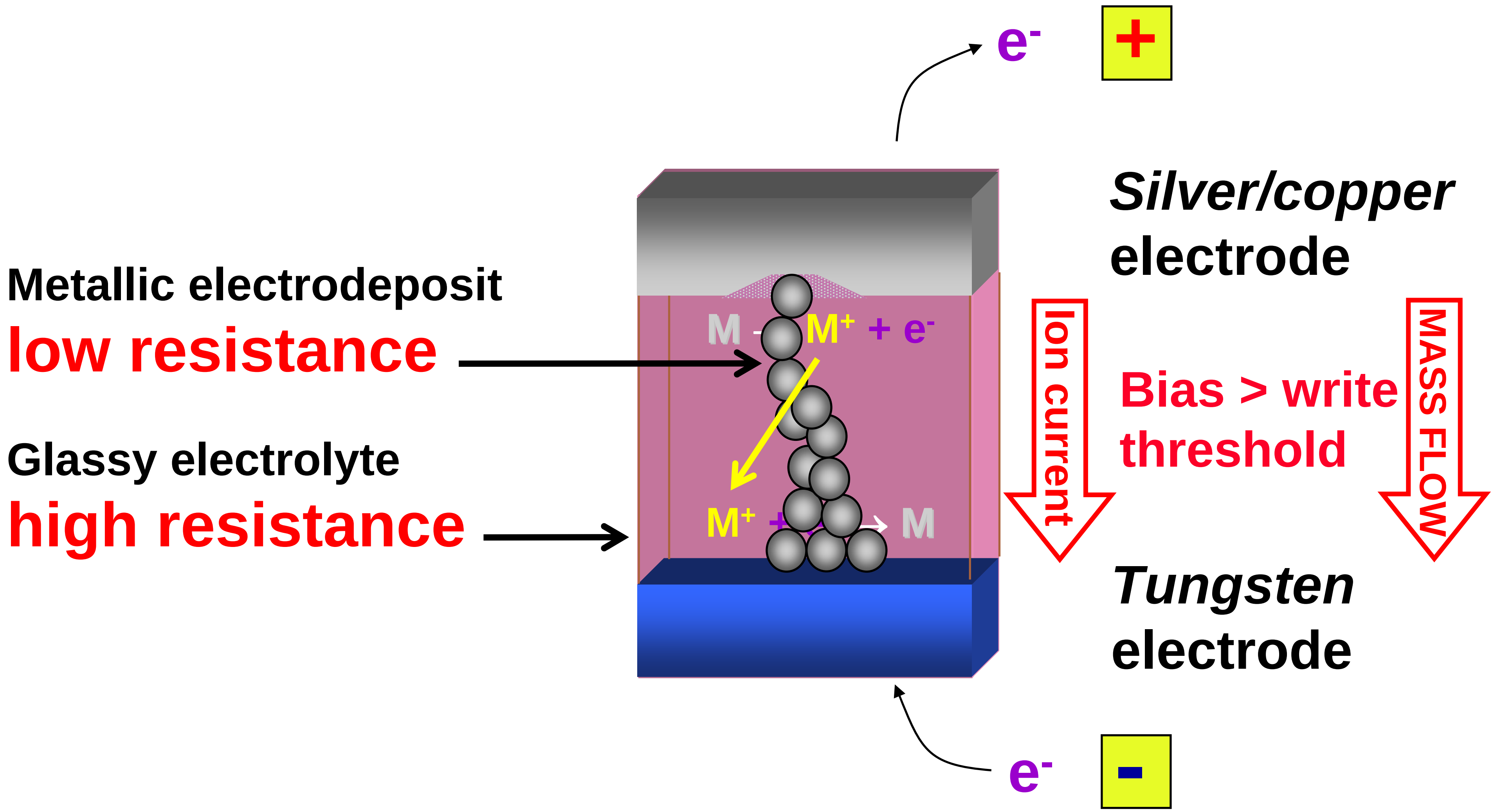
In the words of Masakazu Aono, leader of the first center in the world devoted to nanoscience and nanomanipulation…

- **"(Nobel Prize winner) Heine Rohrer showed five examples of where, if the space becomes small, new phenomena happen… if the distance is very short, diffusion (atomic or ionic motion) is very fast."**

- **"I think the era of electronics has to end. We should move to ionic circuits. We have to produce, maybe at first, electro-ionic or ion-electronic circuits."**

ACS Nano, Vol. 1, No. 5, 379-383 (2007).

Top-down meets bottom-up



Reverse bias dissolves electrodeposit

WIRED

Terabyte Thumb Drives Made Possible by Nanotech Memory

By Alexis Madrigal 10.26.07 | 4:00 PM

Michael Kozicki, director of Arizona State's Center for Applied Nanoionics, has developed a new type of computer memory that he claims is cheaper and more energy-efficient than current technology.

Researchers have developed a low-cost, low-power computer memory that could put terabyte-sized thumb drives in consumers' pockets within a few years. Thanks to a new technique for manipulating charged copper particles at the molecular scale, researchers at Arizona State University say their memory is, bit-for-bit, one-tenth the cost of -- and 1,000 times as energy-efficient as -- flash memory, the predominant memory technology in iPhones and other mobile devices.

http://www.wired.com/gadgets/miscellaneous/news/2007/10/ion_memory

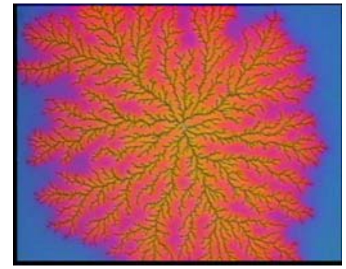
2007 ITRS ERD Chapter

Resistance-based memory technologies

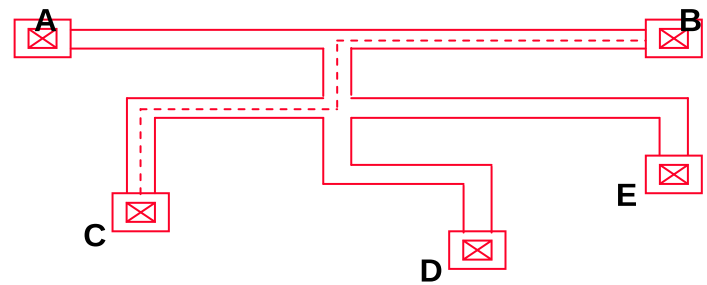
	Nanomechanical memory	Fuse/Anti fuse Memory	Ionic Memory	Electronic effects Memory	Polymer Memory	Molecular Memories
Storage Mechanism	Electrostatically-controlled bi-stable mechanical switch	Multiple mechanisms	Ion transport in solids	Multiple mechanisms	Not known	Not known
Cell Elements	1T1R or 1D1R	1T1R or 1D1R	1T1R or 1D1R	1T1R or 1D1R	1T1R or 1D1R	1T1R or 1D1R
Device Types	CNT bridge CNT cantilever Si cantilever Nanoparticle	M -I-M e.g. Pt/NiO/Pt	1) Solid Electrolyte 2) RedOx reaction	1) Charge trapping 2) Mott transition 3) FE Barrier effects	M-I-M (nc)-I-M	Bi-stable switch

We have developed a technology *platform* that has applications beyond memory and storage…

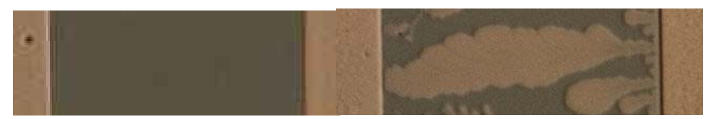
More applications are in the works…



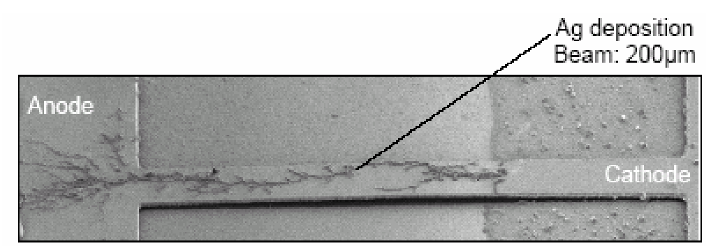
- The ability to move nanoscale quantities of mass leads to a variety of potential applications.
- We have applied this principle to



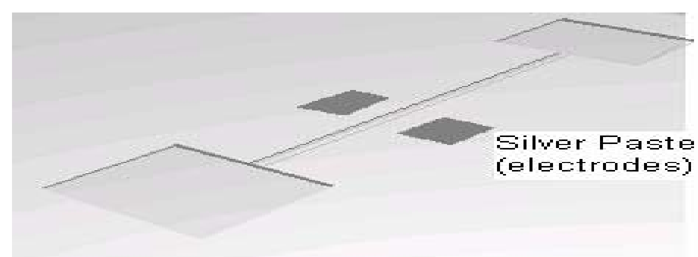
  - Reconfigurable and self-healing interconnect and RF circuitry



  - Optical switches

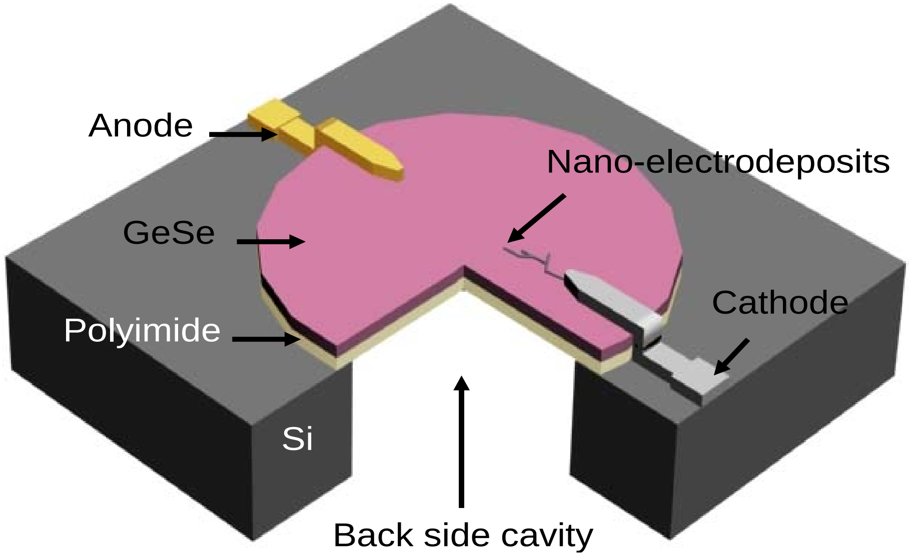


  - Microelectromechanical system (MEMS) resonators



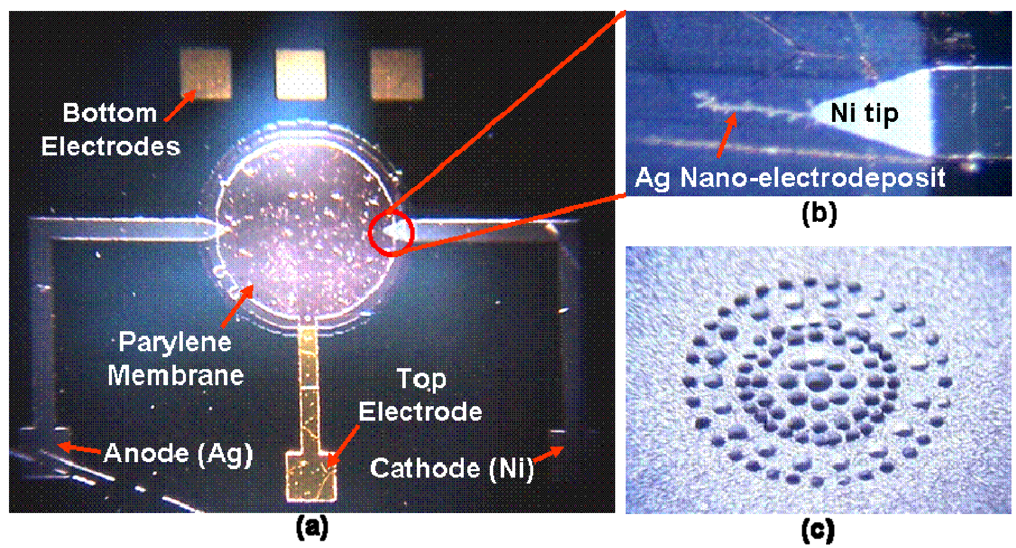
  - Valves for microfluidics

Directional microphone for hearing aids

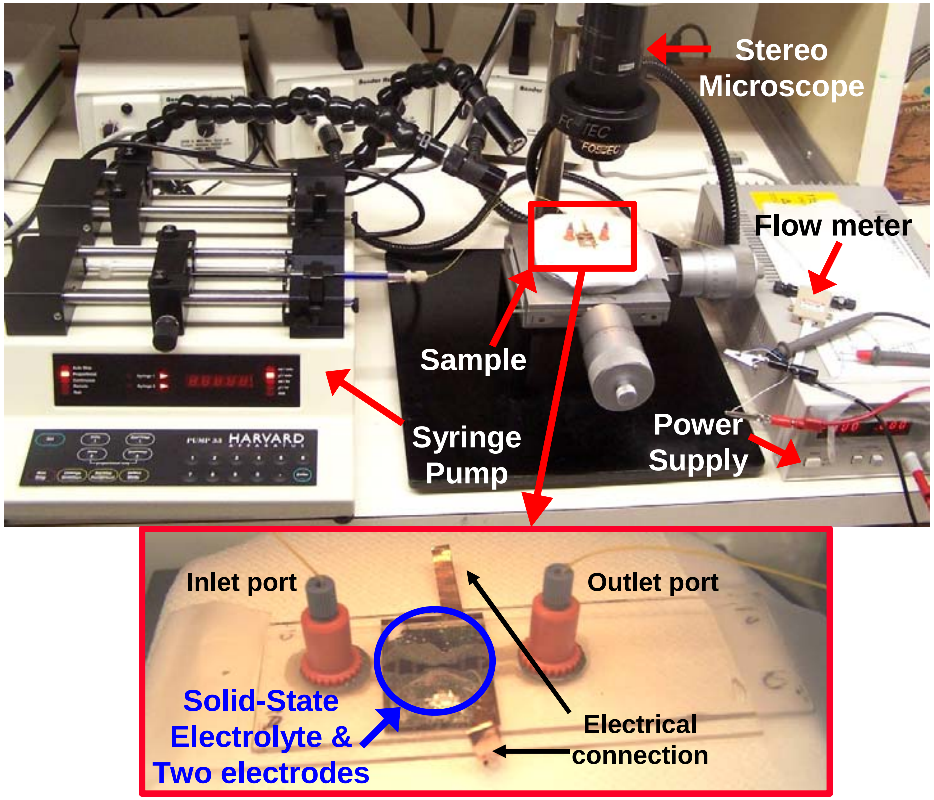


Design parameters	Value
Diaphragm material	Polyimide
Diaphragm thickness	8 µm
Diaphragm radius	0.9 and 1.5 mm
Ag / GeSe film thickness	600 Å / 1400 Å
SiO_2 thickness	1000 Å
Bias voltage	2~10 V

Sang-Soo Je, Michael N. Kozicki, and **Junseok Chae**, "Precise Manipulation of Micro-device Membranes using Electrodeposited Nano-structures", 3rd IEEE International Conference on Nano/Micro Engineered and Molecular Systems (NEMS '08)



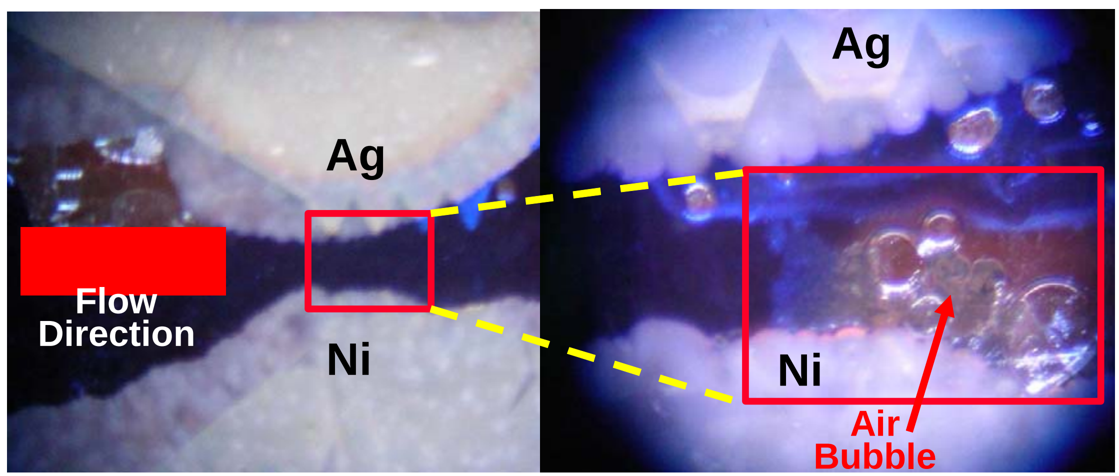
Valves for microfluidics applications



The integration of microfluidic elements onto a single chip enables a range of applications:

- Bio-chip/lab-on-a-chip
- Medical devices
- Micro fuel cells
- Micro cooling systems

Yongmo Yang
Sachin S. Sundar
Michael N. Kozicki
Junseok Chae



ASU Arizona Institute for Nano-Electronics

ARIZONA STATE UNIVERSITY

CENTER FOR APPLIED **NANOIONICS**

Rising interest in nanoionics has been fuelled by the wide range of demonstrated and potential applications. It is this mounting attention worldwide and ASU's role over the past decade in pushing the frontiers of this dynamic field that has led to the foundation of the

Center for Applied Nanoionics (CANi)

within the at Arizona Institute for Nanoelectronics (AINE) at ASU

Active collaborations

- **Very low cost embedded non-volatile memory**
  - **Forschungszentrum Jülich, Germany and Samsung Electronics, Korea.**
- **Physical modeling of solid electrolyte devices**
  - **Politecnico di Milano, Italy.**
- **Fabrication and characterization of tunable MEMS**
  - **University of Edinburgh, Scotland.**
- **Design and testing of RF switches**
  - **NASA Glenn Research Center, USA.**

Active collaborations

- **Materials simulation and characterization**
  - **Univ. of Cincinnati, Ohio Univ., Boise State Univ., USA**
- **Development of commercial chemical vapor deposition techniques**
  - **Structured Materials Industries, USA.**
- **Development of commercial memory devices**
  - **Adesto Technologies, USA; Samsung Electronics, Korea**
  - **+ “others”…**
- **ASU faculty-involved research**
  - **development of flexible memory devices (with the Flexible Display Center),**
  - **MEMS projects - directional microphones and valves for lab-on-a-chip**
  - **materials investigations**
  - ***Nanoionics demo for high schools***

washingtonpost.com
The Washington Post

The 10 Most Disruptive Technology Combinations

Often, even great new technology needs a partner to really change the world. Here are 10 marriages of technologies that have shaken the digital world over the last 25 years.

Dan Tynan, Wednesday, March 19, 2008

5. Cheap Storage + Portable Memory

…a promising new nanotechnology called programmable metallization cell (PMC) could produce drives that are a thousand times more efficient than flash at a tenth of the cost...

Disruption: Where would we be today without cheap, capacious, portable storage? No iPods. No YouTube. No Gmail. No cloud computing.

http://www.washingtonpost.com/wp-dyn/content/article/2008/03/19/AR2008031900134.html?sub=new

CIO
BUSINESS TECHNOLOGY LEADERSHIP

Crackpot technologies that could shake up IT

Eight more technologies that straddle the divide between harebrained and brilliant -- each with a promise to transform the future of the enterprise

Push the envelope of what's possible, or find yourself relegated to wayside. But, to borrow a favored David St. Hubbins Spinal Tap aphorism, there's a fine line between clever and crackpot when it comes to making good on technological breakthroughs in the enterprise.

…emerging nanotechnologies for storage, batteries, and even chip cooling are showing promise, at least in the labs. In the US, Arizona State University's Center for Applied Nanoionics (CANi) has developed insight into nanostorage by examining two leading nanotech solutions simultaneously: tapping special materials and switching from a charge-based to a resistance-based framework.

http://www.cio.com.au/index.php/id;255224966

We now have a duty to *educate*, not just professionals in the field, but those who will work with this disruptive new technology in the not-too-distant future.

If you want to know more…

see reducedion.blogspot.com

memories are made of this

Wednesday, April 2, 2008

Sciart: When science and art become one

There is a fascinating, not to mention groundbreaking exhibition going on right now (26th March to 4th April) at Atelier Färbergasse in Vienna. "*Pask Present*" is an exhibition of work inspired by eccentric British scientist Gordon Pask (1928-1996), one of the forefathers of cybernetics (and a fellow *crackpot*, perhaps). Running concurrently with the 19th European

Blog Archive

- ▼ 2008 (9)
  - ▼ April (1)
    - Sciart: When science and art become one
  - ► March (8)

About Me

Michael Kozicki

I'm a man who has been crushed by the wheels of industry. I started this blog to keep my own thoughts straight as well as to attempt to educate the world on how awful the memory business really is. I'm mad as hell and I'm not going to take it any more...