Challenges and opportunities for Designs in Nanotechnologies

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What is nanotechnology?

- “Nano” means one billionth.
- Nanotechnology is moving around individual atoms to create lighter and stronger materials, tiny machines and small computers.
- Average human hair is around 50,000 nanometers wide.
- Nanometer: Meter ~ Inch: Half the distance around the Equator.
- A molecule of DNA is only 2.5 nanometers wide.
- Take one millimeter and divide it into 1,000 pieces. Then take one of those pieces and divide it into 1,000 pieces. One of these pieces is a nanometer long.
Nanotechnology: an Interdisciplinary Undertaking

Size of structure

Examples of Size
Tools, Pens, ---
Wire, Screws,
Fibre Glass
Optics, Microprobes
Thick Film, Microsensors
Hair, Skin
Bacteria, CD-bits
64Mb-256Mb-Chip
Thickness of Gold foil, G bit-Chip
Protein
Nanoparticels, width Of DNA
Molecule/Fullerenes
Atom Size

1940 1960 1980 2000 2020 2040
Year
Create materials, devices and systems with fundamentally new properties (because of their small structure) at atomic, molecular levels in the length scale of approximately 1–100 nm range.

» 10 Year vision, 5 years into the program
» 16 US federal agencies involved
» Significant impact on microelectronics expected in the long run
National Nanotechnology Infrastructure Network (NNIN)

An integrated national network of user facilities providing researchers open access to resources, instrumentation and expertise in all domains of nanoscale science, engineering and technology

http://www.NNIN.org
Why do we worry about nanocomputing?

- Major productivity gains in Global economy has been driven by information technology in which microelectronics industry has played a major role in the background.

- $100B US business of which approximately $4B is design (including CAD)

- A technological slowdown may cause a severe downturn in US as well as global economy.

What is the Problem?

- As devices become smaller approaching the atomic scale, new physical phenomena begins to play a role (new technology) – bottom driven

- As billions of transistors are put in a chip new methodologies for robust design verification etc., become imperative (complexity) – top driven
Novel Building Blocks

- Carbon nano-tubes (CNT) as transistors, inteconnects
- Single Electron Transistors (SET)
- Non-charge based devices (spin/photonic devices)
- Quantum dots & QCAs
- Molecular devices
- Still others, FinFETs, RTDs, ....
Some Projections

• Conventional Si - CMOS scaling will continue for the next 10-15 years

• Heterogeneous new technologies will begin to be integrated into Si platforms by 2015

• Novel nanotech devices needed beyond 2015.

• Compatibility with CMOS will leverage production of non-CMOS nano-devices

• Considerable lead time needed
Concerns:

- Will research in nanotechnology lead to the development of more and more fascinating devices that we do not know how to use?

- Can/should the field of nanoelectronics change to one in which the usage models drive device research?
Three Fundamental Questions

- How will we produce **reliable, predictable**, systems from **unreliable components** with unpredictable behavior?

- How will current or **new applications** use the huge numbers of devices made available through **nanoelectronics**?

- How must we modify and improve our **design tools** and methodologies to accommodate terascale designs, nanoscale devices, and radical new ways of computing?
More questions

- Are there revolutionary approaches to parallelism that are more suitable to nanoscale electronics, besides the tried and true parallel computers of the past?

- What kinds of defect/fault tolerance, testing and verification are suitable for nanoelectronics, besides the traditional ones?

- Can computational neuroscience and brain architecture provide us an inspiration for nanoarchitecture?
Emerging Architectures

Departure from von Neumann architecture warranted

- How can use massive parallelism offered by preponderance of tiny devices?
- Asynchronous (GALS)?
- Reconfigurable, self-healing?
- Cross-bar and FPGA-like?
- Hybrid technologies CMOS + nanowires (e.g., CMOL)?
- Neuromorphic, CNN-like?
Understanding of the *computing demands* that models place on tools as well as the physics

- Tools that work with multilevel, multiscale, models
- Hybrid, heterogeneous, hierarchical design tools
- Alternate tools and tool flows matched to new technologies and new computational paradigms
- New tools oriented to atomic scale issues
- Design tools comprehending extreme heterogeneity
- Design tools which “understand” thermal issues of design choices at the nanoscale

- Tools for Reliable Design
  - Fault tolerant insertion through architectural synthesis
  - Explore connection between defect testing and reconfiguration
Success in the SNB Era Requires Cooperation at All Levels
Epilogue

- It took 50+ years for transistors to make a real difference in computing. We are at the beginning of the age of nano-scale computing.

- Exponential progress is manifested today in many aspects of scientific endeavor - the most impactful of which is bio-nano technology, which has the potential to change our lives for ever.

- We live in the most interesting of all times, and are probably at the cusp of a technological revolution.