California Nanotechnology Initiative Symposium V

An Industry Perspective

16 NOV 2009

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Agenda

1. Intel Corporation Overview
2. Nano-Electronics and Use of Nanomaterials
3. Responsible Use of Nanomaterials
   - Internal Activities
   - External Activities

Intel Corporation:

The World's Largest Semiconductor Manufacturer

Leading Manufacturer of Computer, Networking & Communications Products

300 Facilities in 50 Countries

Over $37B in Annual Revenues from Customers in Over 120 Countries

22 Consecutive Years of Positive Net Income

Approximately 80,000 Employees

43,000 technical degrees, 12,000 Masters in Science, 4,000 PhD's, 4,000 MBA's

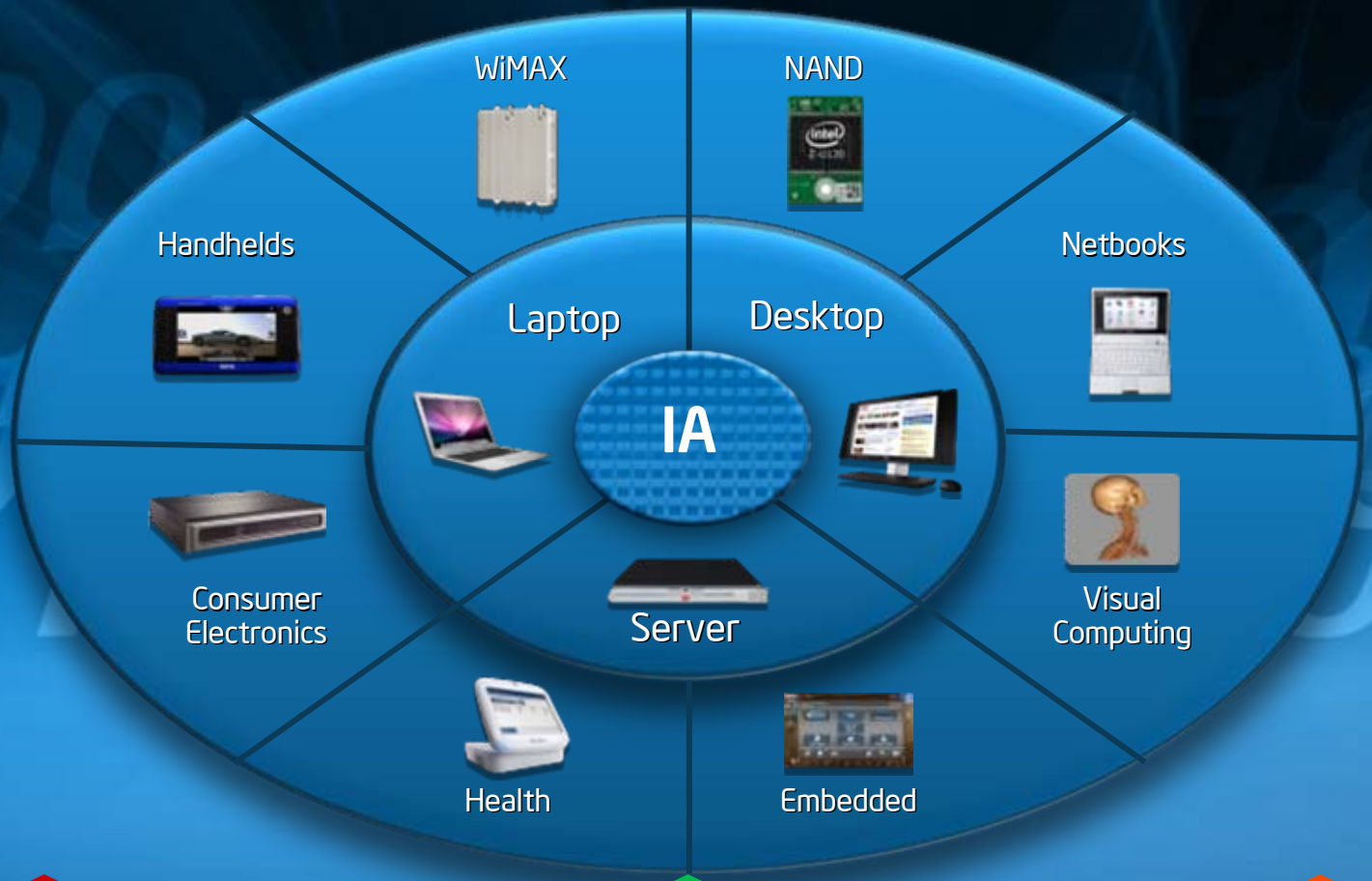
One of the Top Ten Most Valuable Brands in the World for 10 Consecutive Years

Invests $100 Million Each Year in Education Across More than 50 Countries

The Single-Largest Corporate Purchaser of Green Power in the United States

One Million Hours of Volunteer Service in Our Communities in 2008

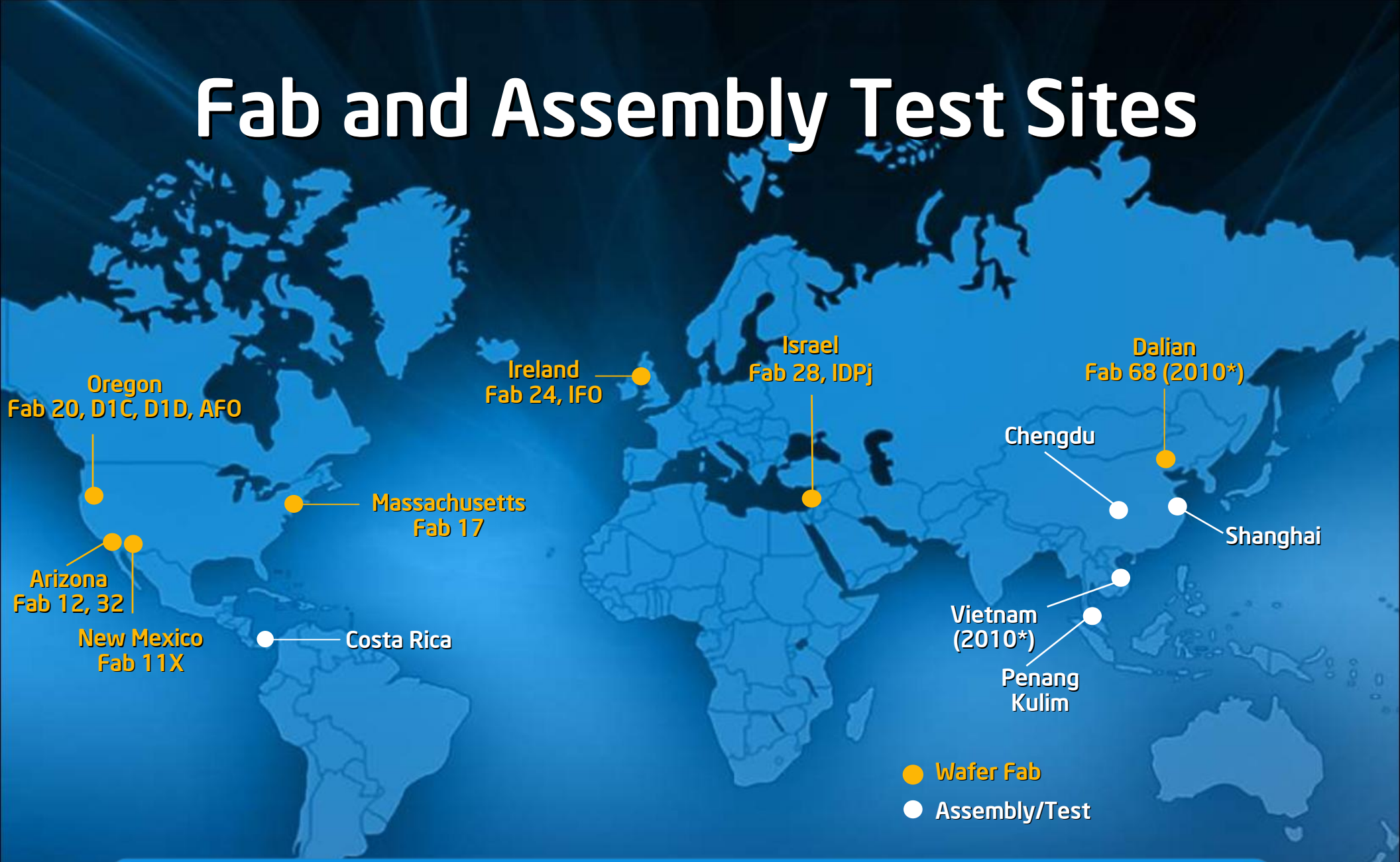
What We Do



Silicon Process | **Platform Architecture** | **Market Creation**

Intel Employees

Fab and Assembly Test Sites



10 fabs operating in the United States, Ireland, and Israel with 1 more under construction in China

* Projected

32nm Investment

$7 BILLION

Over 2 Years

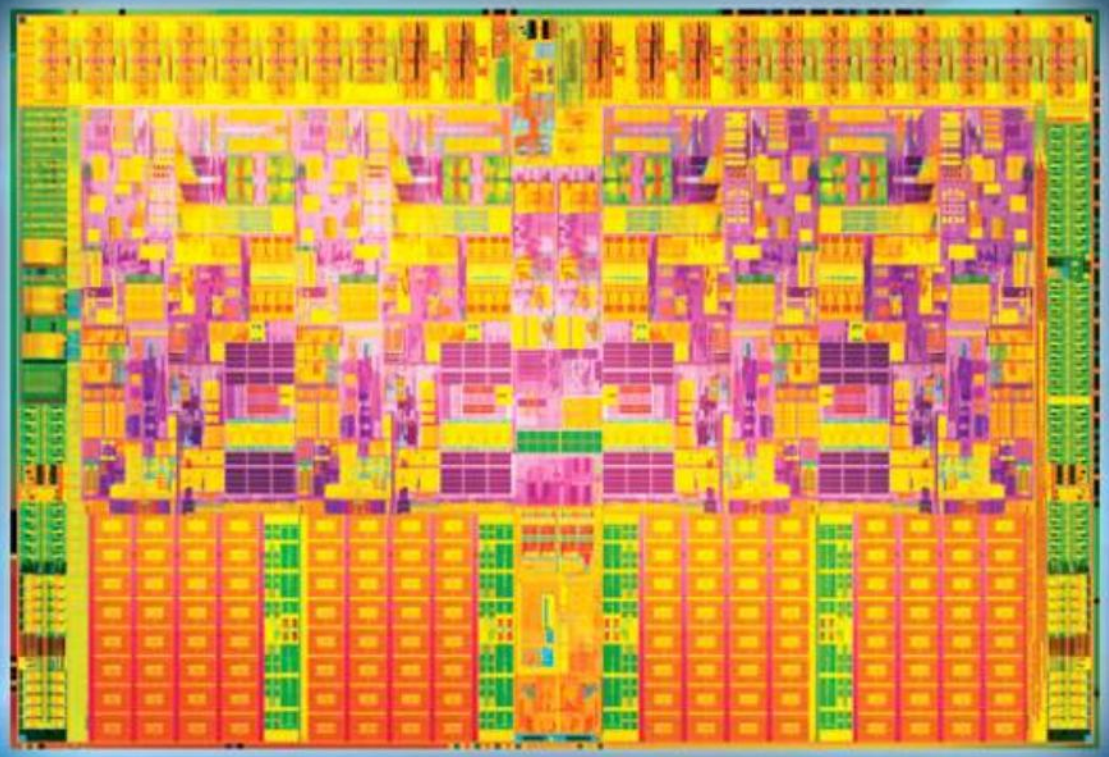
D1D Oregon

D1C Oregon

Fab 32 Arizona

Fab 11X New Mexico

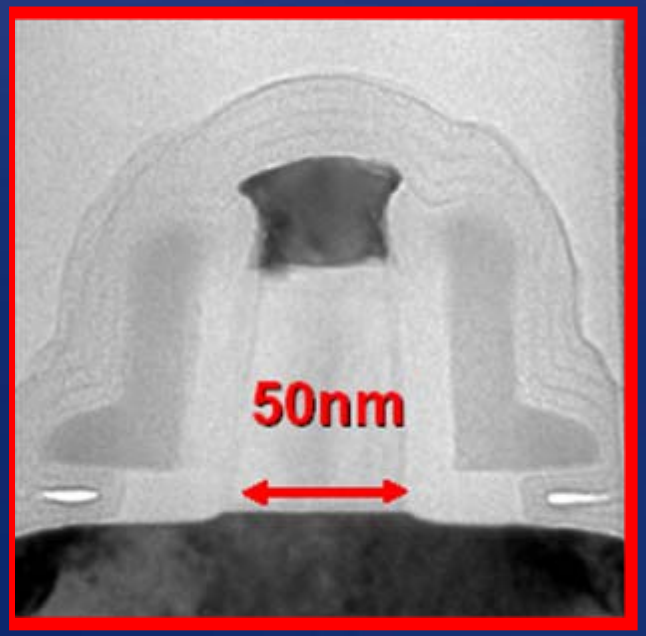
Less Power, More Powerful



Shipped over 200 Million Microprocessors with 45nm High-K Metal Gate Transistor Technology

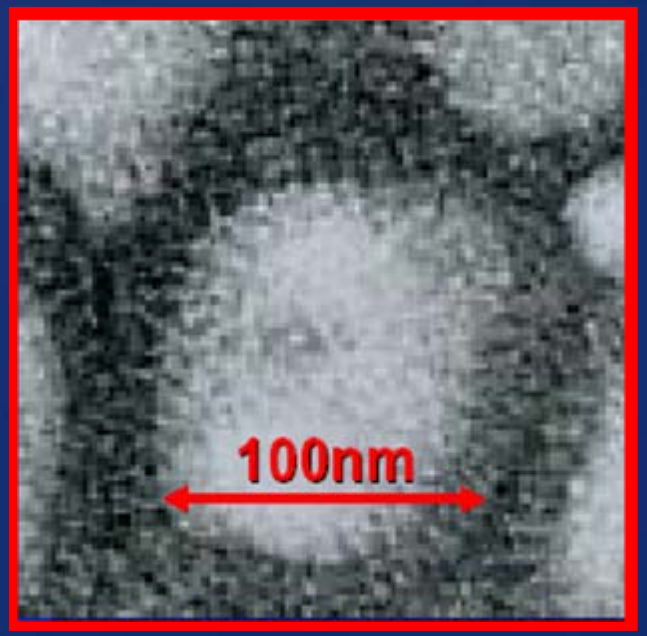
Current Silicon Technology

50nm transistor is ~2000x smaller than diameter of human hair



Transistor for 90nm Process

Source: Intel

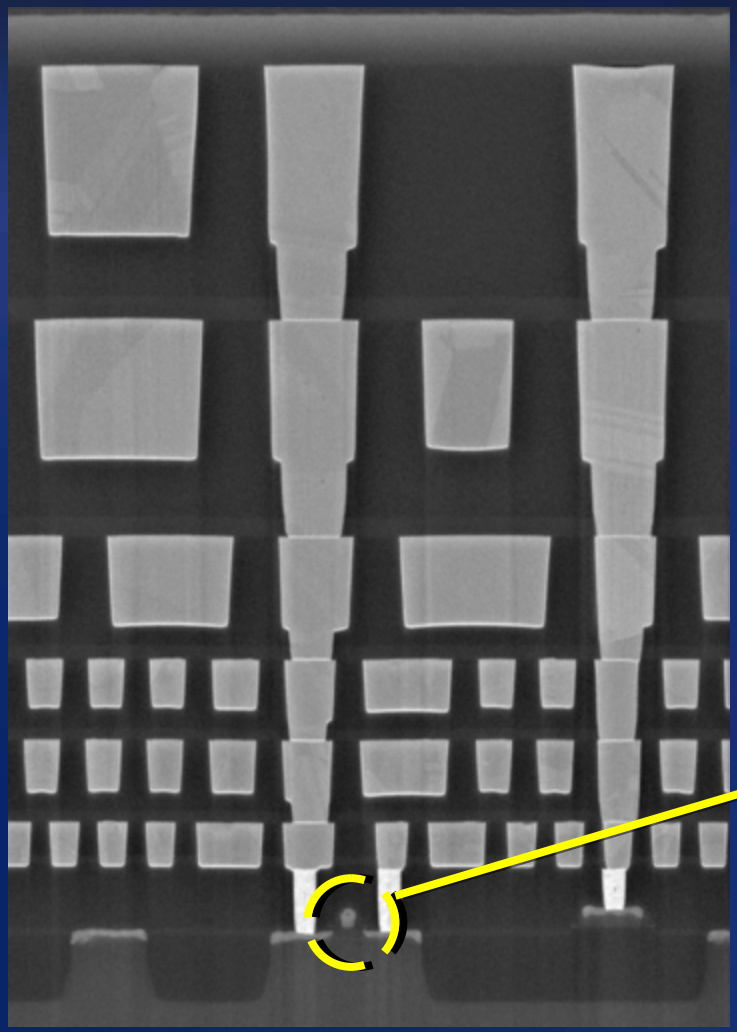


Influenza Virus

Source: CDC

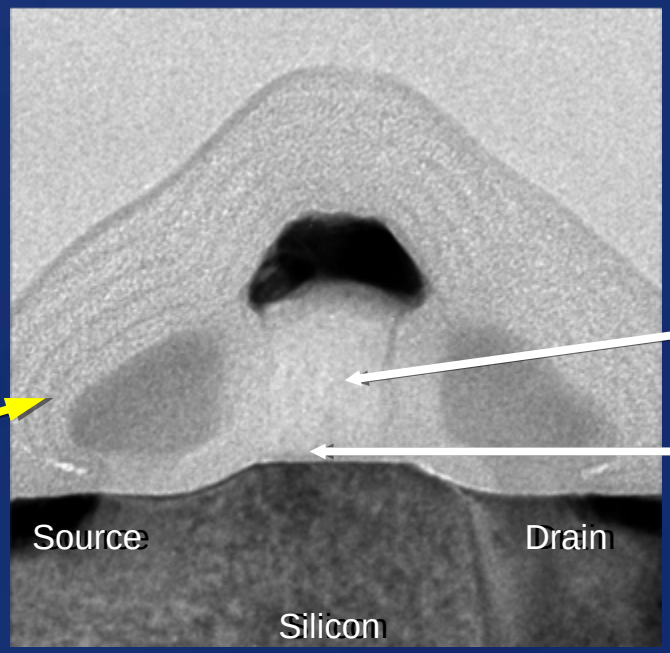
Intel has been manufacturing sub 100 nm transistors since 2003

Integrated Circuit Technology



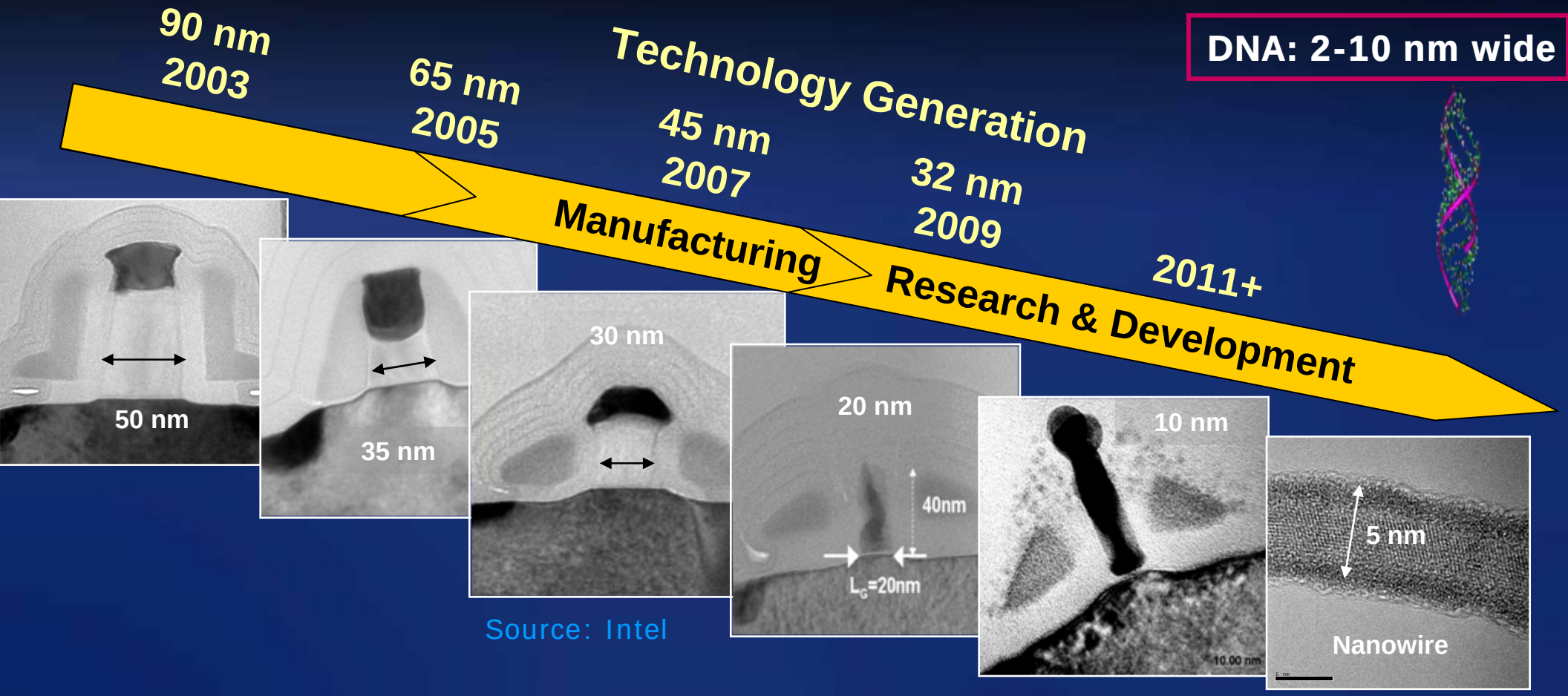
Many electrically isolated transistors connected with defined interconnects

Individual Transistor



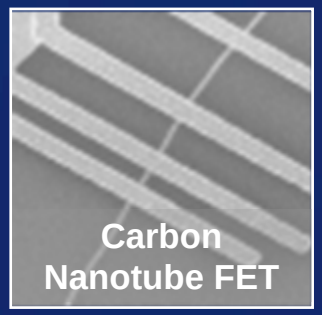
Fabrication without defects is critical…

Transistor Nano-Electronics Research



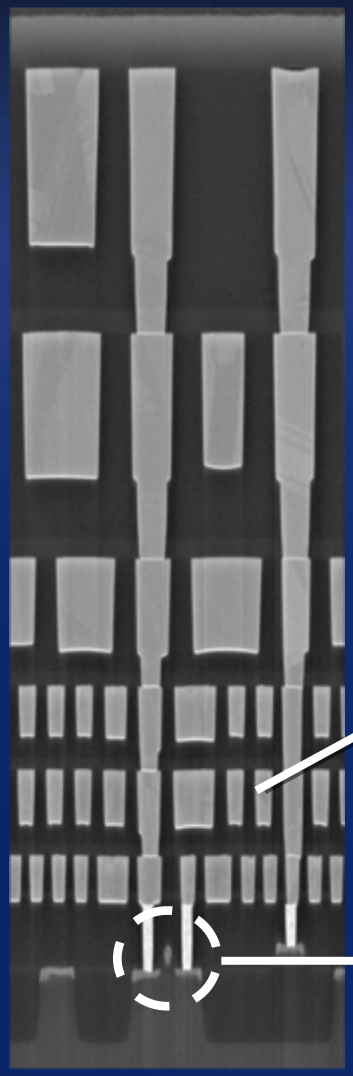
Source: Intel

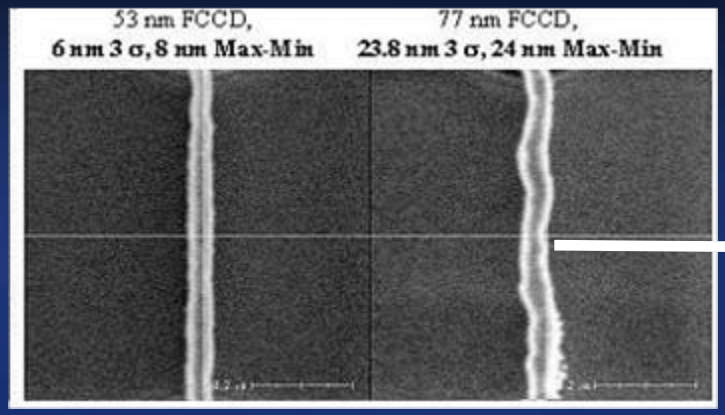
Miniaturization of transistors allows for continuation of Moore's law (doubling of number of transistors every two years).



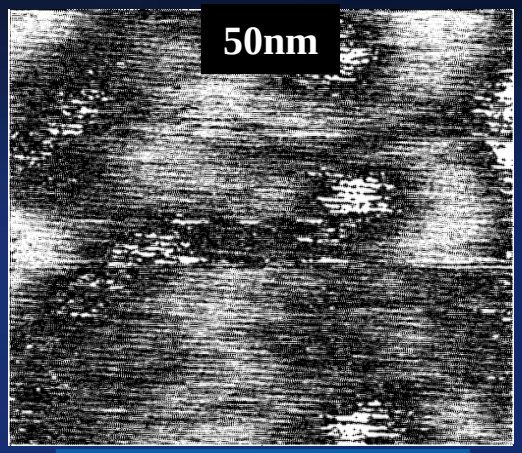
Future options subject to change

Nanomaterial Opportunities/Challenges

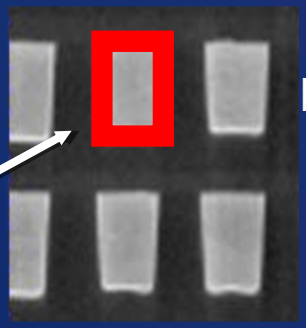




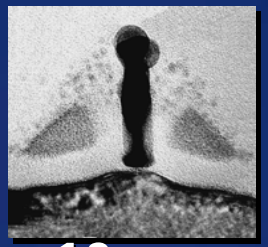
Lithography Line Edge Roughness(LER)



Resist Nano-domains



Barrier Layer ~20nm



10 nm

What Materials?
How to Assemble?

Source: Intel

Materials Challenges Everywhere

Nanomaterial Opportunities

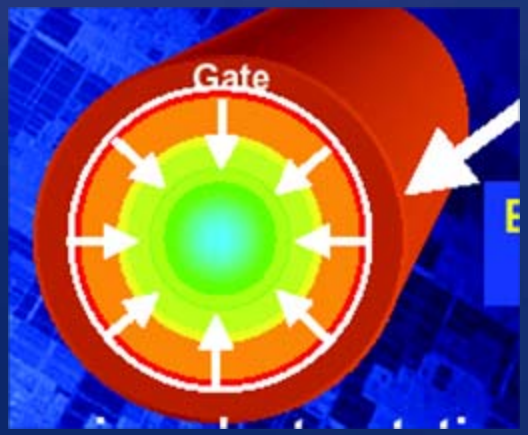
Extending CMOS (*Complementary Metal Oxide Semiconductor)*

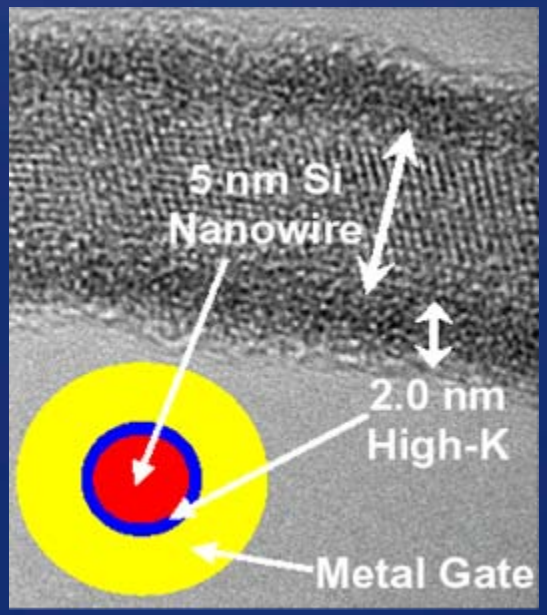
- Nano-silica or Nano-clays
- Nano metal oxides
- Self assembled dielectrics
- Carbon Nanotubes for thermal materials?
- Silicon Nanowires or Carbon Nanotubes

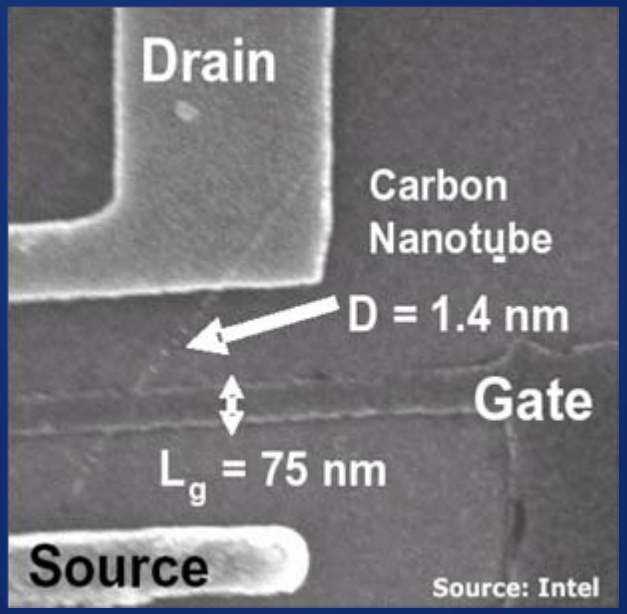
Beyond CMOS

- Nanodots
- Nanowires…

Future Nanomaterial Transistors?



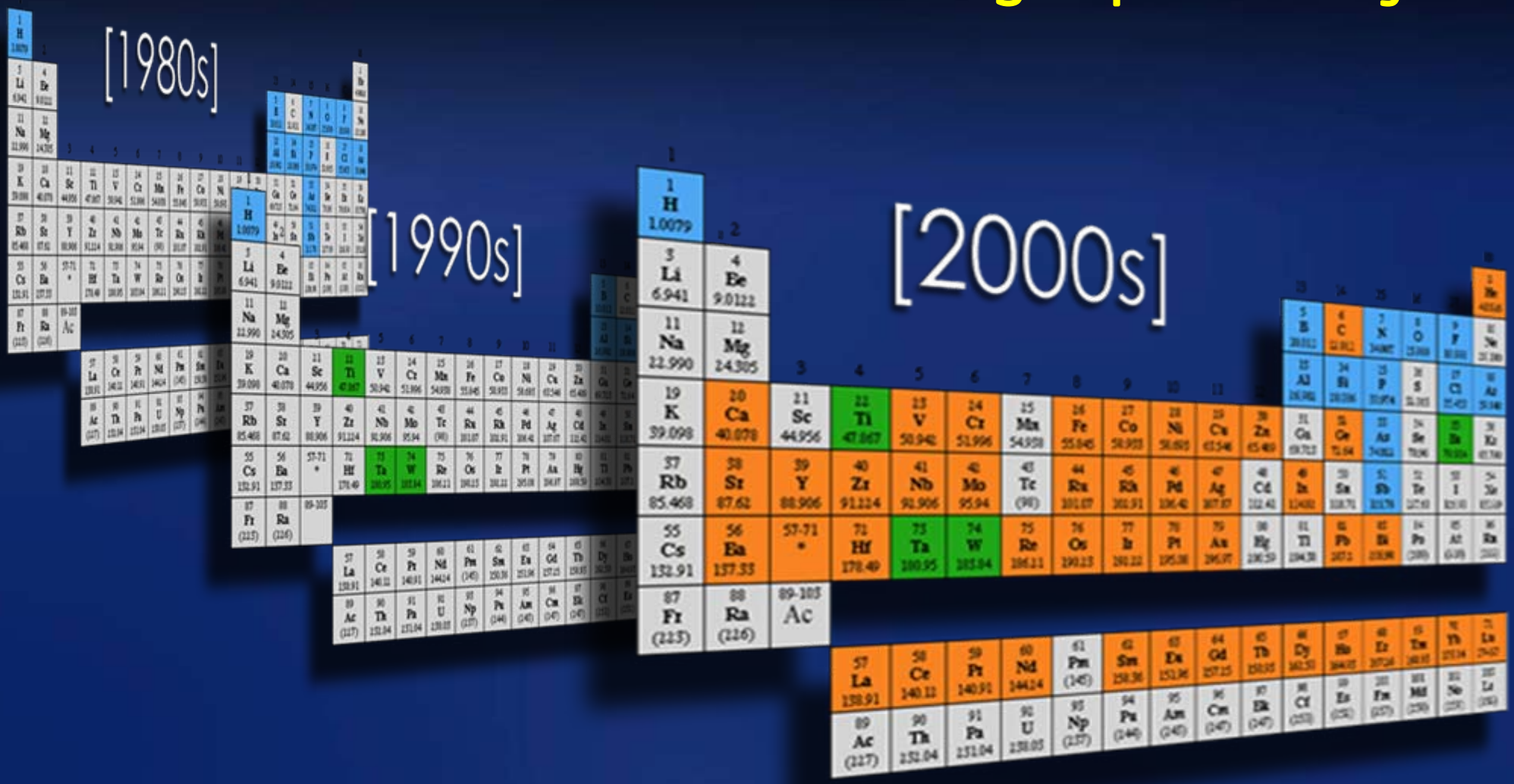




Options for sub 10nm technologies

Challenges: Placement and property control

Use of New Materials Increasing Exponentially



NOTE - Nanomaterials are small subset of future materials being investigated for future use in manufacturing

Intel's Nanomaterial Safety Program

How does Intel safely introduce new nanomaterials and nanotechnologies into existing and future manufacturing processes?

Intel Policy: Nanotechnology

"Intel will manage and handle nanomaterials in a safe and environmentally responsible manner using state of the art exposure control technologies based on the currently available toxicology information."

Program Elements

- Formed Nanotechnology EHS Management Review Committee with representatives from Public Affairs, Government Affairs, Technology Development and EHS to establish nanomaterial policy and direction
- Developed internal guidelines/policy for nanoparticles
- Establish precautionary principle as bases of EHS controls
- Utilize existing control philosophy for handling materials with unknown toxicity
- Utilize existing protocols for assessing environmental impacts of any potential nanomaterial emissions

Practices to Control Exposure to Nanomaterials

In accordance with our existing new chemical use requirements, all use of nanomaterials (R&D and manufacturing applications) must be reviewed and approved by Intel EHS prior to use

- Toxicologist
- Industrial Hygienist
- Environmental Engineer

Appropriate EHS controls are determined based on potential hazards of material; in absence of hazard data, conservative handling guidelines are established

Prohibited handling of unbound nanoparticles with out engineering controls or process enclosures

Effective Engineering Controls

For most processes and job tasks, the control of airborne exposure to nanomaterials can be accomplished using a engineering control techniques similar to those used in reducing exposures to more common airborne particulates, gases, and/or vapors.

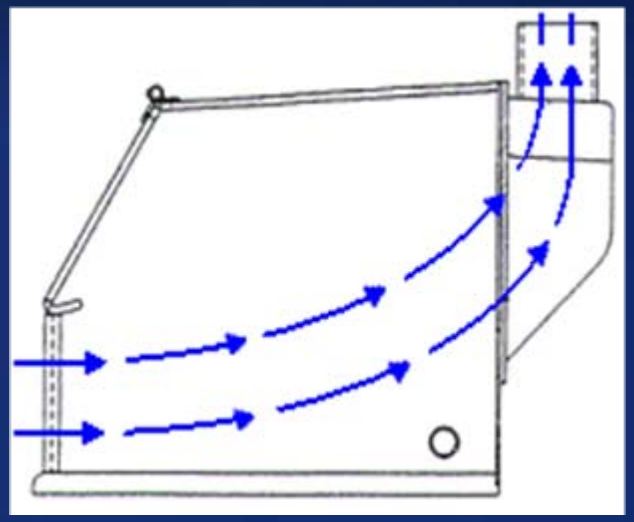
Based on what is known of nanoscale particle motion and behavior in air, control techniques such as source enclosure (i.e., isolating the generation source from the worker) and local exhaust ventilation systems should be effective for capturing and containing airborne nanomaterials.

General examples from industry include ventilation systems, process enclosures, sealed process piping, robotic applications of hazardous materials and process enclosure interlocks.

Nanoparticle Containment Controls

No open or dry manipulations of nanomaterials

Production process enclosures



"Laminar-flow" Fab environment

Laboratory fume hoods for R&D nanomaterial applications

The Silicon Wafer Fabrication Environment

Highly automated processing

Clean room conditions with HEPA filtered down draft airflow

Wafer processing tool

Chemicals & gases enclosed in process chambers or exhausted enclosures

Nanomaterial Environmental and Product Content Issues

Information about releases / emissions, transport distribution, and transformation is necessary to estimate environmental impact or product content issues.

Relevant environmental-fate questions

- By what means could manufactured nanomaterials enter the environment?
- Could nanomaterials be released from products during normal use or disposal?
- What are the modes of dispersion for nanomaterials in the environment?
- Do manufactured nanoparticles undergo transformation in the environment?
- Are they persistent and/or do they bio-accumulate?

Life Cycle Analysis of Nanomaterials

Understanding of Life Cycle of nanomaterials is critical to control environmental risk

- Understanding of Manufacturing Process
- Emissions / Releases
- Uses /Applications
- Product & Article Aging studies
- Disposal

Support EHS related research on Nanomaterials

Science Foundation Ireland (SFI) BioNanoInteractions

- Strategic Research Cluster proposal to SFI, a 5 year work program to determine interactions of engineered nanoparticles with biological systems

U of Az Nano Research Project Environmental, Safety, and Health Impact of Nano-Materials in Electronics and Photonics Nano-Manufacturing

- The objective of this seed project is to form a multi-disciplinary university/industry team to formulate and conduct a preliminary study of the uniqueness of the health effect of *nano-particles* and *nano-structures* in manufacturing of electronics and photonics devices

International Alliance for Nano EHS Harmonization

- Develop reproducible, reliable nanobio/tox testing protocols and get them widely adopted

UCLA Center for Environmental Implications of Nanotechnology

- The mission of the UC CEIN is to insure that nanotechnology is introduced and implemented in a responsible and environmentally-compatible manner

EU NanoInteract

- Development of a platform and toolkit for understanding interactions between nanoparticles and the living world

Nanotechnology Occupational Safety & Health (NOSH) Consortium (completed)

- Develop nanoparticle generation techniques for toxicological inhalation assessments
- Determine effectiveness of various media (respirator filters, HEPA Filters) to filter nanoparticles
- Develop portable instrument for occupational nanoparticles detection

Actively promote and support the development of nanotechnology EHS standards

- Lead development of ASTM E2535-07 Standard Guide for Handling Unbound Engineered Nanoscale Particles in Occupational Settings.
- Convener of ISO Technical Committee 229 WG3 on EHS aspects of nanotechnologies
  - USA selected to lead ISO TC229 Work Group on EHS standards
  - 9 EHS standards and/or technical reports under development
- ISO TC#229 WG3 liaison to OECD Working Party on Manufactured Nanomaterials
- Participate in Governmental Workshops on Nanomaterial regulatory development activities (NIOSH, US EPA, Malaysia EPA, etc.)

Support dissemination of EHS nanomaterial information

- Founding member of International Council on Nanotechnology (ICON)
  - Mission: Assess, communicate and reduce environmental and health risks associated with nanotechnology while maximizing benefits to society
- Member of International Semiconductor Manufacturing Initiative (ISMI)
  - Presentations at ISMI/Sematech Symposiums on nanomaterial EHS programs
  - Participation on ISMI EHS research on use of nanomaterials within the semiconductor industry
- Present Nanotechnology EHS information at public forums, symposiums to share knowledge and promote sharing and open communications
  - NIOSH - International Nanotechnology Symposium
  - Malaysian Office Science and Technology – Nano Awareness Seminar
  - Italy Ambiente Lavoro Convention

Thank You For Opportunity to Share Information

The World Ahead

Access

Connectivity

Education

Content

Connecting the Next Billion People to Uncompromised Technology Around the World