Nanomaterials Production – Addressing E, H & S Uncertainty

Bradford O. Brooks, Ph.D.
IBM Corporate Environmental Affairs
Toxicology & Chemical Management

Collaborators / Program Managers

Arthur Fong, Ph.D., Tox/Chem Mgmt

Jennifer Gardner, CIH, Integrated Health Services

Environmental Health Collaborative
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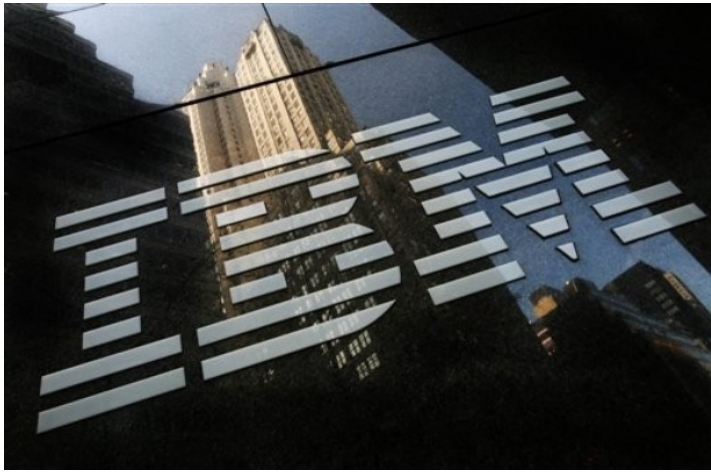
IBM and Nanotechnology??

- Working at nanoscale for 40 years
- Scanning Tunneling Microscope – 1981, Nobel Prize in Physics – 1986
- Atomic Force Microscope – 1986
- 212 nanotechnology inventions since 1997
  - 1247 nanotechnology patents pending or issued globally
- Specifically Engineered Nanomaterials Are Significant Technology Bet for IBM
  - CMOS / End of Scaling
  - Alternative = Molecular Devices (Nanowire FETs, etc)
  - Biosensors
  - Photovoltaics
  - Photonics
  - Spintronics
  - Quantum Computing
  - Storage Devices
  - Battery Technology Improvements
- Significant Investment of Time, Talent, Money



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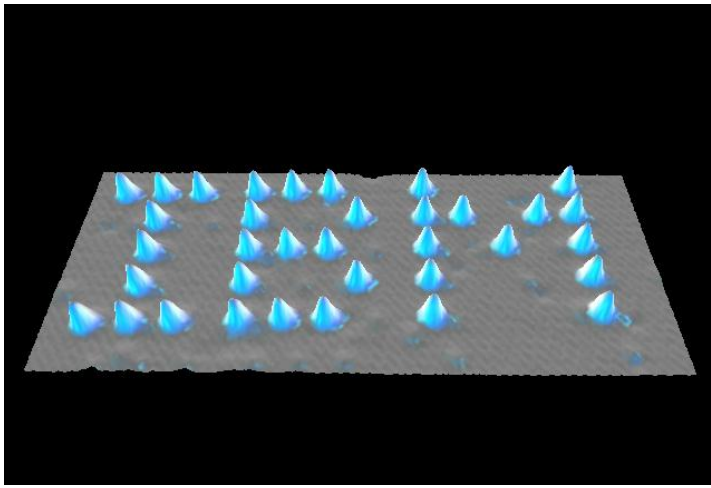
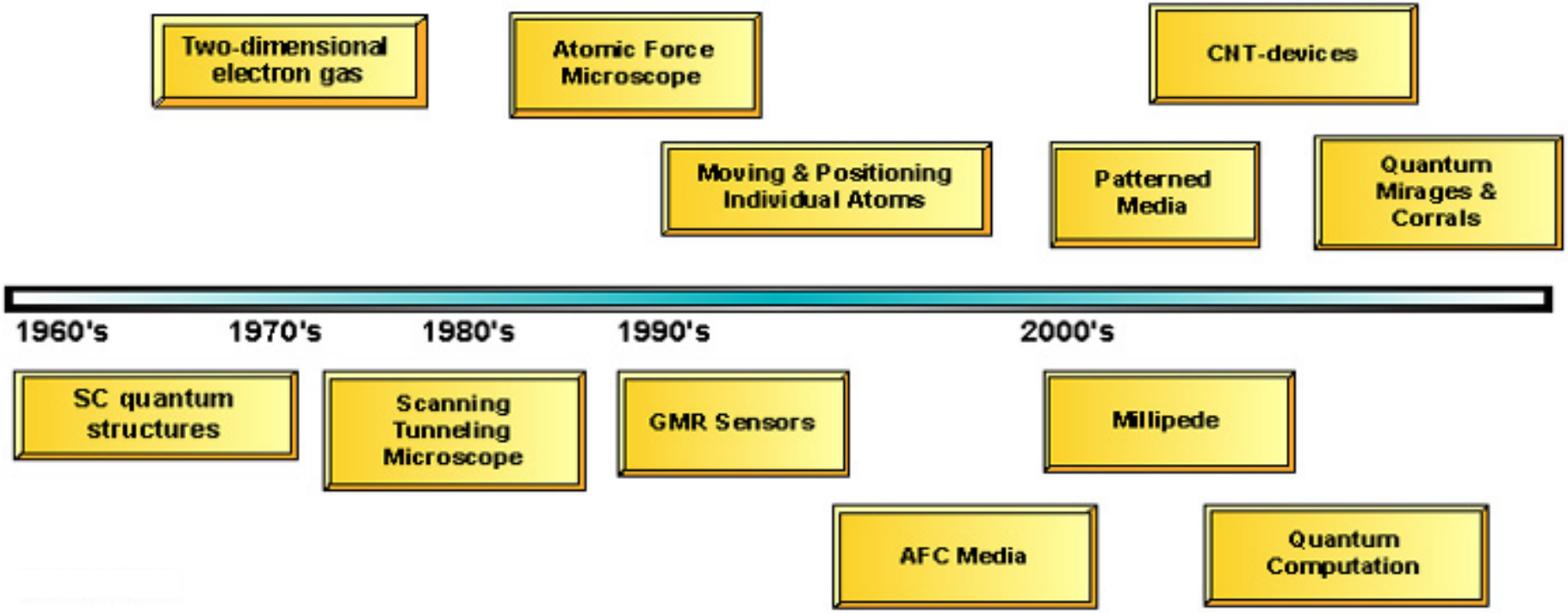
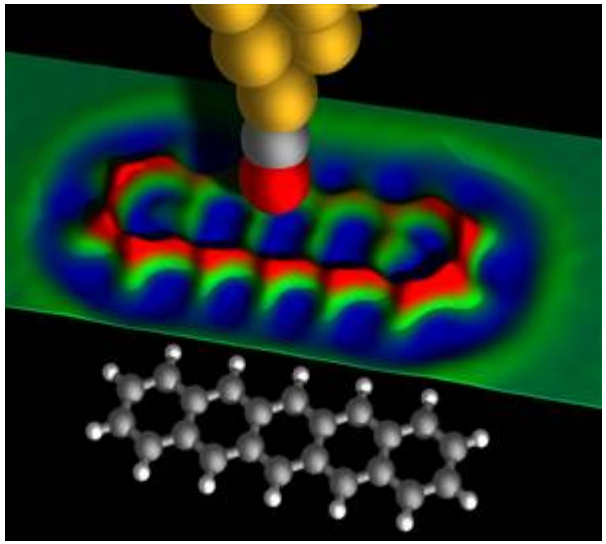


Timeline of IBM Work in Nanotechnology Space

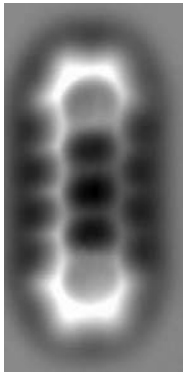


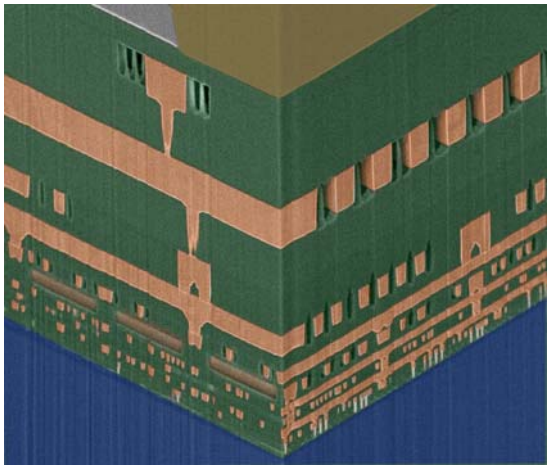
At present, IBM does not incorporate intentionally-engineered nanoparticles into commercial products, but rather, conducts extensive research on nanomaterials, tools to visualize / assess them, and application within the microelectronics realm

Recent IBM Research developments of note

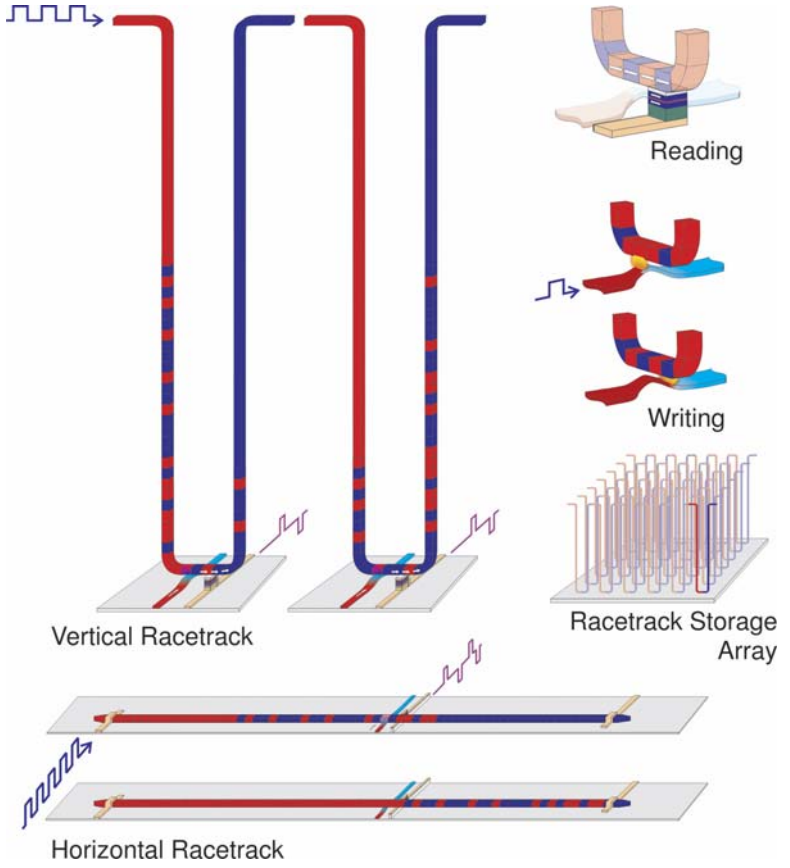


IBM first to image the "anatomy" of a molecule (Science, Aug 28, 2009)





Air Gap Technology (Self-Assembly)



Race Track Memory (Nanowires)

Predicting the Future of Nanotech Development

- Generation 1 – passive addition to more familiar materials
- Generation 2 – active nanostructures, limited self-assembly
- Generation 3 – systems of nanostructures, self-assembly
- Generation 4 – active systems of nanosystems and molecular manufacturing, self-replication

Nanotechnology Issues

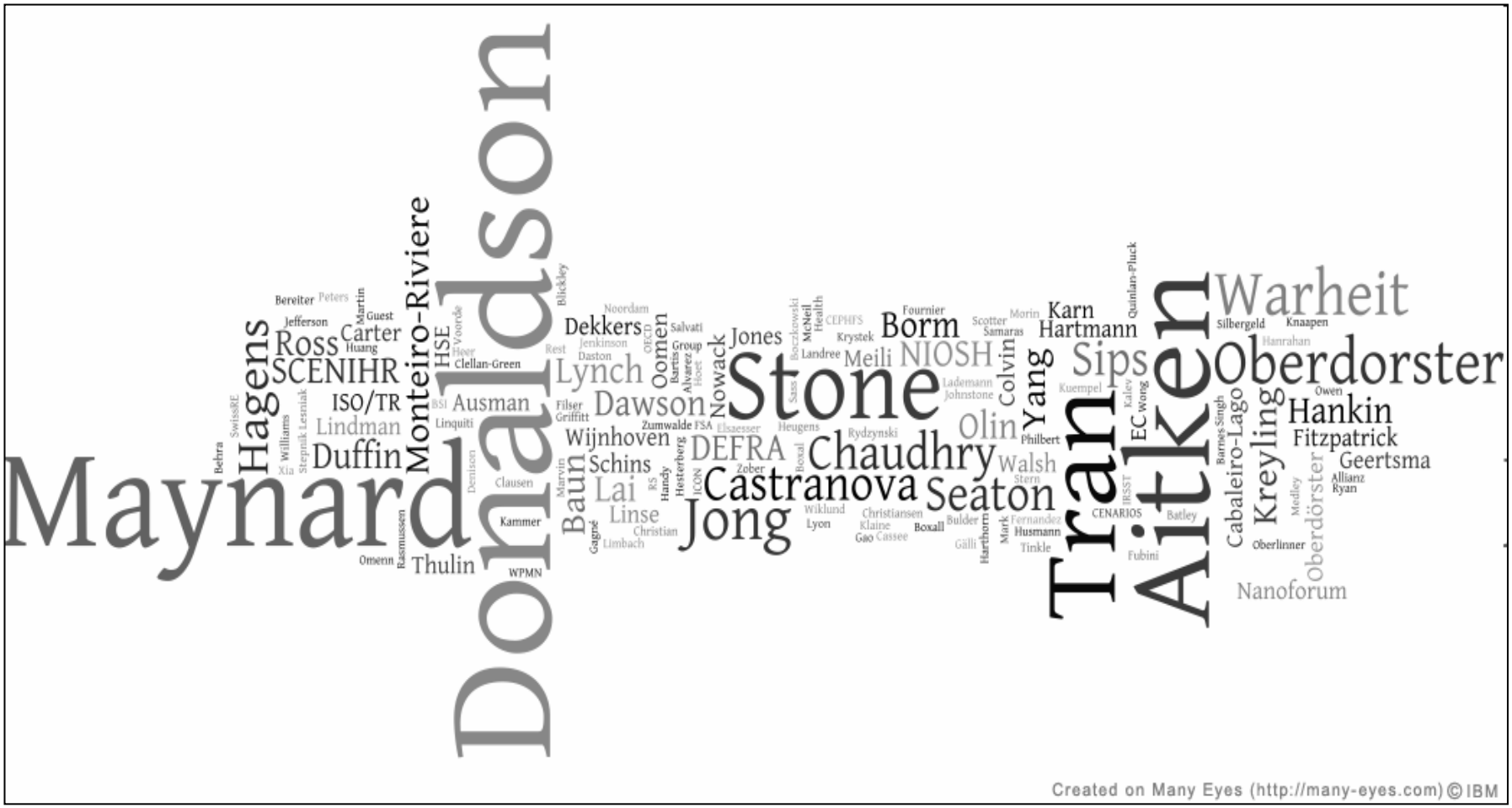
- Technical Issues Associated With Nanotechnology Development
  - Rapid scientific development
  - Vast array of potential nanomaterials – homogenous & heterogeneous
  - Gaps in environmental, health & safety information on nanomaterials
  - Rapid transfer from science to technology – out-driving our headlights?
  - Technical complexity of materials, chemistry, biology involved in nanotechnology
  - Changes in nanomaterials – responsive – permanent or temporary
  - Challenges in risk assessment methods
  - Next-Gen ➔ Self-assembly, Self-replication

Nanotechnology Issues (Cont'd)

- Public Concerns
  - Lack of information / conflicting information
  - Complexity of science, especially nanosciences
  - Broad social impact / moral & ethical beliefs
  - NGO involvement
- Governmental/Regulatory Concerns
  - Are current regulatory systems adequate to oversee nanotechnology development globally?
  - Sufficient headcount and budget to undertake oversight?
  - Are current plans executable and enforceable?
- Corporate Governance
  - Responsible development based upon sound science
  - Ethics of uncertainty – thoughtful, rational dialog and caution

Human / Environmental Toxicology & Nanotechnology

Many Eyes = Many Approaches = Many Views ➔ Gaps left to be investigated



IBM Nanotechnology Profile

- **Production via Vapor-Liquid-Solid and Catalyzed Chemical Vapor Deposition – some etching endeavors**
  - Closed systems, tight controls, no “dry” procedures
  - CNTs, CNWs, Si, Ge, permalloys
- **Slightly less than half of nanomaterials are acquired**
- **“Upstream” Material Reviews / Horizon Material Tracking**
- **Quantities produced or procured tracked and logged**
- **Waste Stream analysis, tracking and logging**
- **Waste Stream disposal via high-temperature incineration**
- **Extensive Collaboration**
  - SEMATECH, SIA
  - NIOSH
  - Environmental Law Institute
  - USCIB ➔OECD
  - CEINT (Duke/CMU)

How Does IBM Address Uncertainty In This Field?

- Single Global Registration of ISO 14001 – Environmental Management System – first company in the world to do so
  - Chemical Management covered extensively in this system
    - Upstream Chemical Review – nanomaterials flagged for further assessment
    - Procurement – MSDS, shipping controls, etc
    - Production – internal assessment of tools, engineering controls, PPE
    - Handling / Storage
    - Disposal – assessment of vendors / facilities
    - Education – required for all employees in user areas
    - Monthly Nanosafe Meetings (Tox + IH + Users)
    - Engineered Nanomaterials Safe Handling Guidelines
      - Based upon an 18-point benchmark
      - Trusted Sources and Informed Treatises
      - Regulatory/Governmental position tracking
      - Collaborative projects

Some helpful tools and sources

- 18-Point Benchmark for Nano EHS
  - General precautionary approach
  - Training / Education
  - Workplace nanoparticle sampling
  - Medical/Health Surveillance
  - Work practices / housekeeping
  - Hygiene
  - Work surfaces
  - Labeling
  - Storage of nanomaterials
  - Using/Working with nanomaterials
  - Engineering Controls
  - PPE Filtration
  - PPE Clothing
  - PPE Gloves
  - PPE disposal
  - Spillage / Accidental releases
  - Clean up – Vacuum
  - Fire Safety / Explosion management

- Six E,H&S Reference Guidelines
  - Approaches to Safe Nanotechnology: An Information Exchange with NIOSH
  - Nanoscale Science Research Center: Approach to Nanomaterials E,S&H
  - Interim Best Practices for Working with Nanoparticles-NSF Nanoscale Science and Engineering Center
  - Nanotechnologies – Part 2: Guide to Safe Handling and Disposal of Manufactured Nanomaterials – BSI British Standards
  - Guidance for Handling and Use of Nanomaterials at the Workplace – German Federal Institute for Occupational Health and Safety + German Chemical Industry Association
  - Are Conventional Protective Devices such as Fibrous Filter Media / Respirator Cartridges, Protective Clothing and Gloves also efficient for Nanoaerosols? Nanosafe

Thoughtful questions regarding the ethics of innovation

- What are the respective roles and responsibilities of government, academia, industry and the public regarding innovation and invention?
  - Who gets to shape the "standards and guidelines“
  - Who should invest, who should benefit, who should profit from these standards and guidelines?
- What is your role, as business owners/managers, scientists and engineers in maintaining the ethos of responsible innovation and invention?
- How important is harmonization of nanotechnology regulatory approaches between regions of the world (e.g. US, EU, etc)?
- Who best should provide E,H&S advice, counsel and recommendations to businesses who engage in nanotechnology endeavors and what format would be the most useful?