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Overview of Emerging Technology - nano

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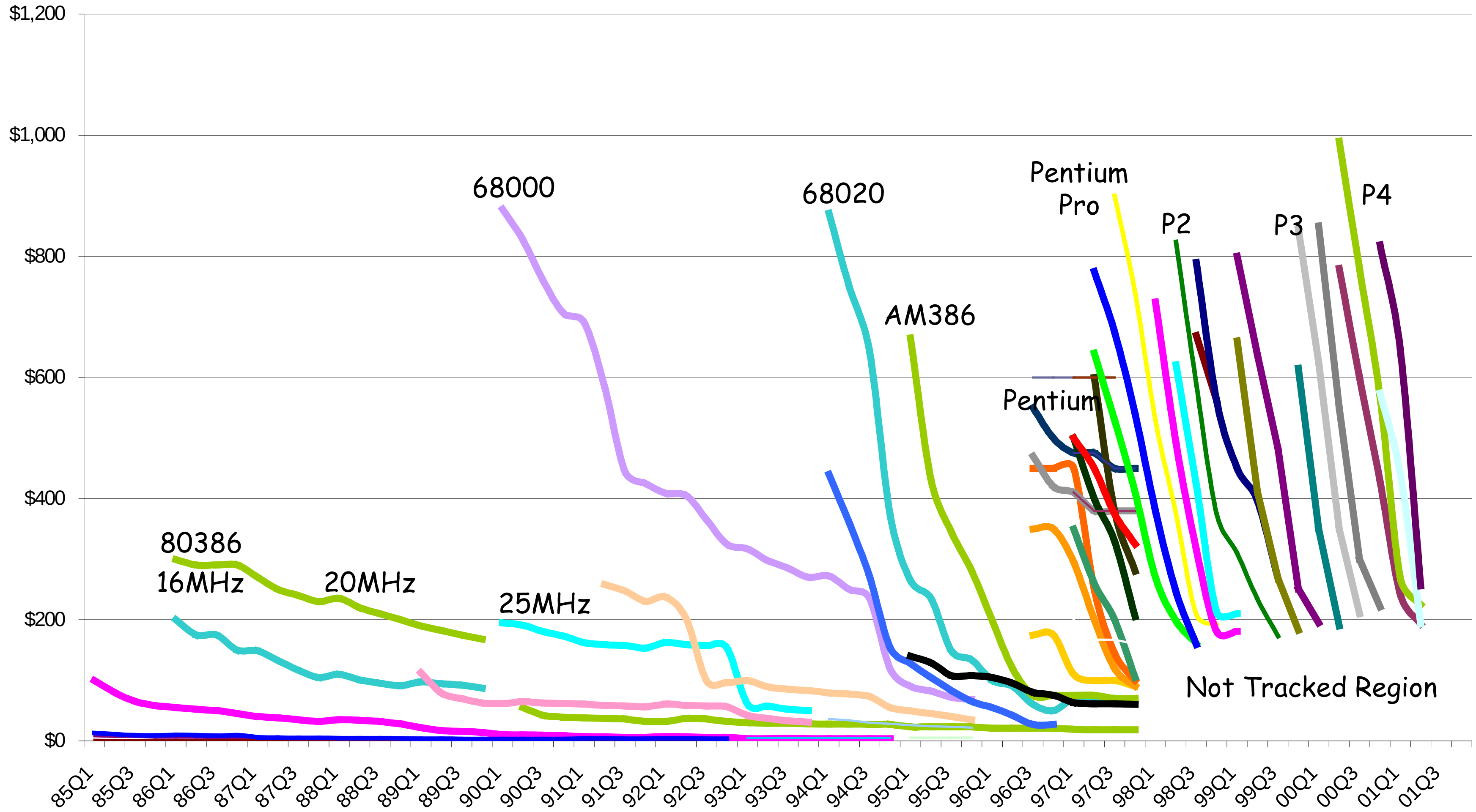
Structure of Presentation

- **Background – the technologies**
  - Technology Driven
  - Economic Driven
  - Health Benefits Driven
- **Tale of Technologies**
- **Nano Technology Example**
- **Business Implications**

Background

- **There are many reasons for an industry to change but it is response to market pressures and customer needs**
- **Evolutionary changes are common**
  - Improving efficiency of air conditioners requires advances in chemistry, but these are developments that are planned
  - Even substituting Carbon Nano Tubes (CNT) in epoxy in order to replace metal bumpers on cars is evolutionary.
- **Revolutionary changes tend to occur infrequently in traditional industries, but rapidly in high tech industries where product life cycle tends to decrease over time**
  - Semiconductors have a rate of change that is driven by the doubling of transistors per unit area over an 18 month period – Moore's Law
  - Even a large portion of the changes are evolutionary, but major shifts occur
  - The changing of wavelengths for lithography was evolutionary but required revolutionary developments.
- **The ability to manage the technology development and the potential applications into successful products will be key to maintaining profitability for companies.**

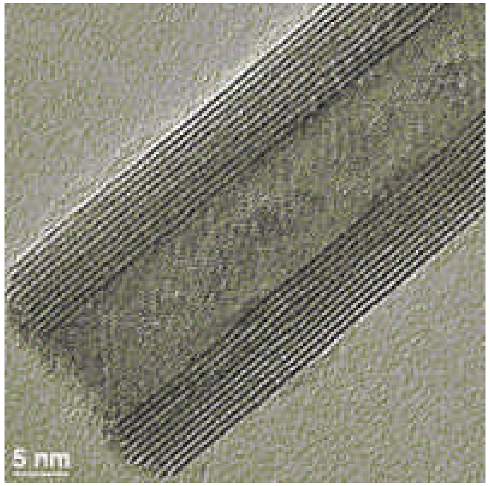
Hyper-Competitive Industry
MPU Selling Price over Time



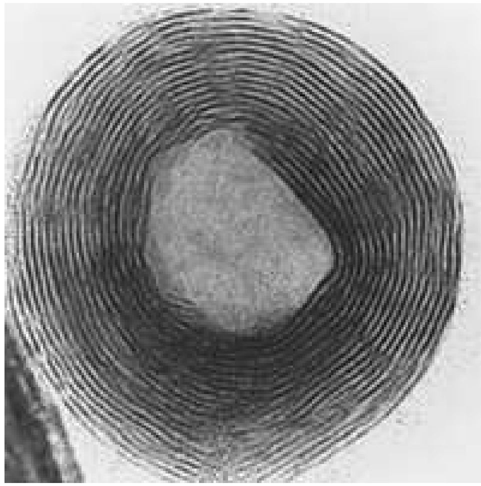
Based on information from DataQuest and MicroDesign Resources.

Stronger materials

IsraCast has recently tested one of the most shock-resistant materials known to man. Five times stronger than steel and at least twice as strong as any impact-resistant material currently in use as protective gear.



Certain inorganic compounds such as WS_2, MoS_2, TiS_2 and NbS_2 that normally occur as large flat platelets can be synthesized into much smaller nano-spheres and nano-tubes which they named inorganic fullerene-like nanostructures (IF)



The "Onion like" nano-structure of the IF materials, is the result of a sophisticated manipulation on the original layered material. This unique structure is responsible for its remarkable strength and durability

The material withstood the shock pressures generated by the impacts of up to 250 tons per square centimeter. The rendering above is of a possible armor vest. (Material production is currently a few kilograms per day.

Ref. http://www.isracast.com/tech_news/091205_tech.htm

Quantum Dot Rainbow
Source: Andrey Rogach
References:
Yu. P. Rakovich, J. F. Donegan, S. A. Filonovich, M. J. M. Gomes, D. V. Talapin, A. L. Rogach, A. Eychmüller. "Up-Conversion Luminescence via a Below-gap State in CdSe/ZnS Quantum Dots." *Physica E* , 17, 99-100.2003

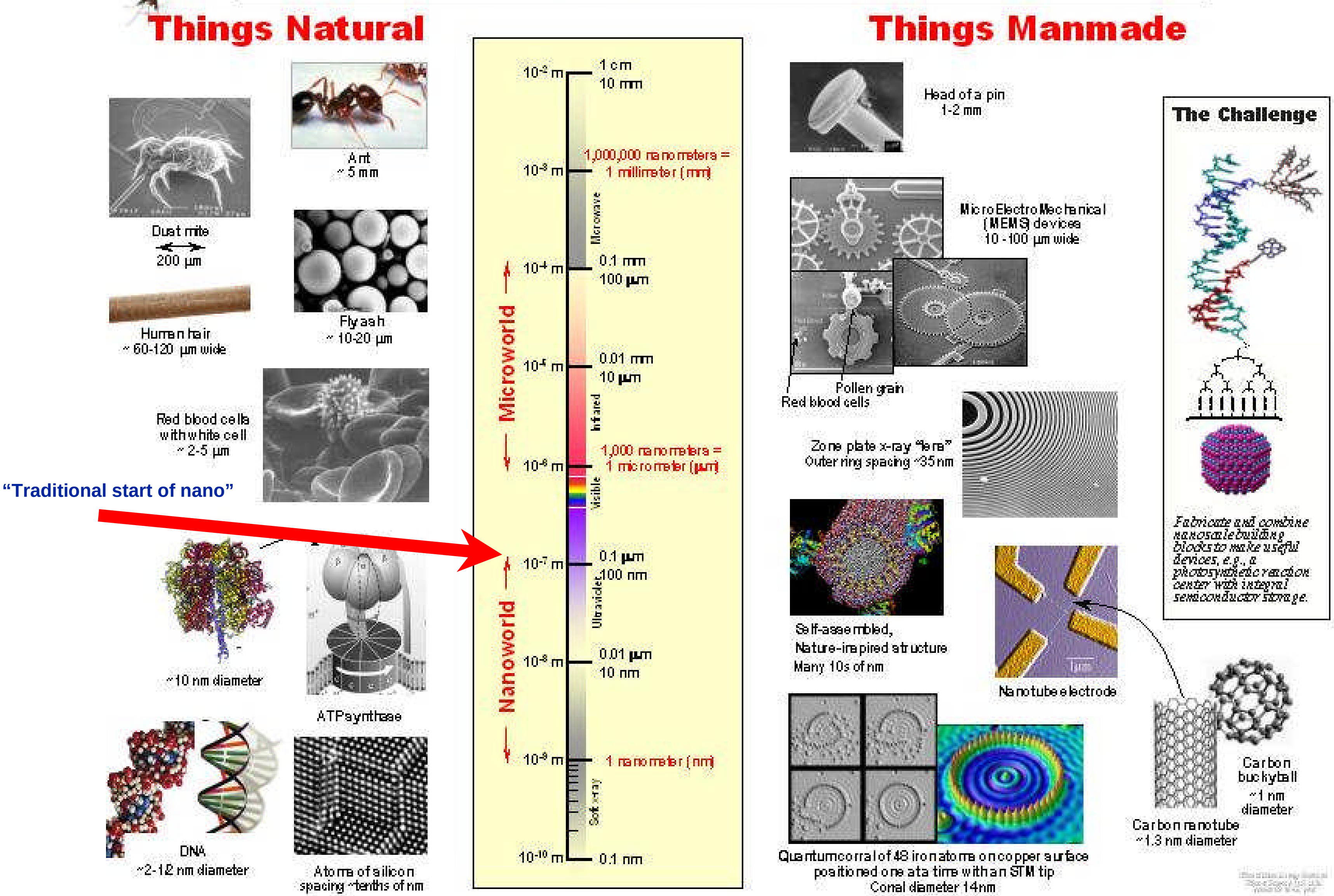
Description:
Semiconductor nanocrystals, also called colloidal quantum dots, typically have a size between ~1 and 10 nm and lie in the transition regime between bulk solids and molecules. They are fascinating objects for studying basic novel properties of matter, generally described by the term "size quantization effect". A famous demonstration of the size-dependent properties of semiconductor nanocrystals is the continuous change of their emission color. Shown is an example of the range of CdSe nanocrystal emission spectra.
Most nanocrystals are highly luminescent, and the emission is tunable through the whole visible and the near-IR spectral range by controlling the composition and size of quantum dots. Highly luminescent semiconductor nanocrystals are interesting for different applications, ranging from thin film optoelectronic devices to fluorescent labels. The incorporation of luminescent semiconductor nanocrystals into photonic crystals and microcavities has attracted considerable attention as a promising pathway to novel light sources with controllable spontaneous emission.

Nano Technology

All promise but no substance?

or the "new" plastic?

The Scale of Things – Nanometers and More

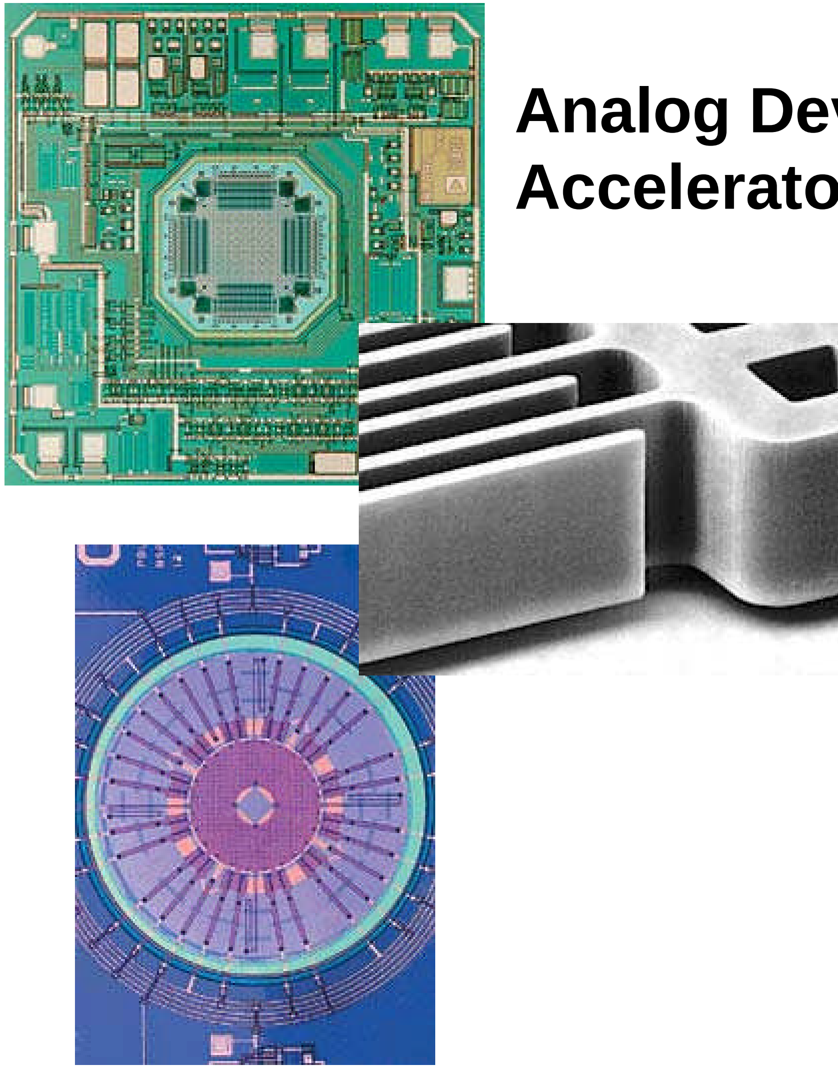


Courtesy Office of Basic Energy Sciences,
Office of Science, U.S. Department of Energy

Examples of MEMS

TI DLP

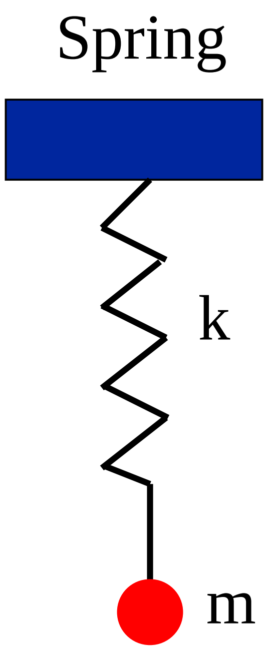
Analog Devices Accelerometer



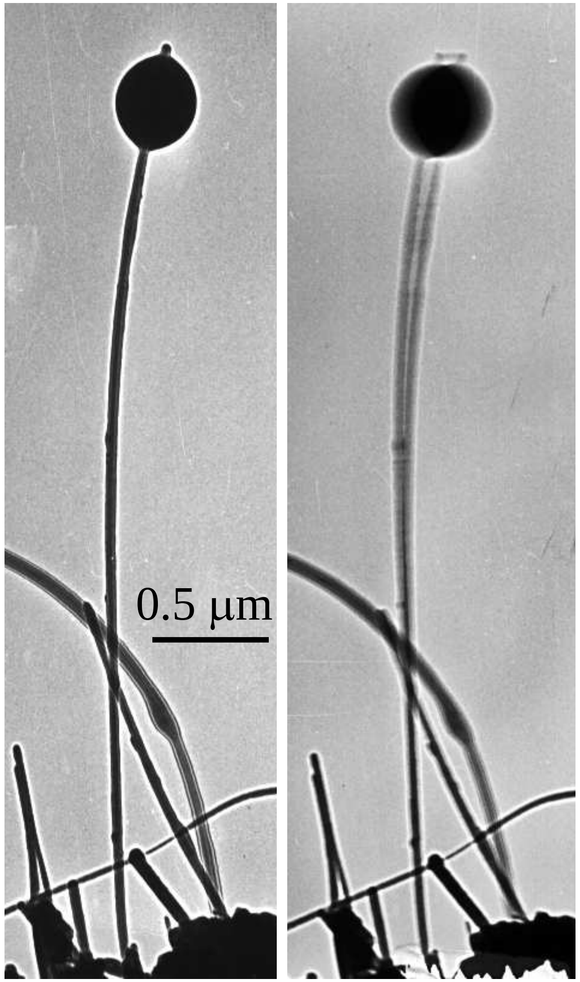
NEMS

Femtogram Nanobalance

Smallest in the world



$f = (k/mg)^{1/2}$



$\nu = 0$ $\nu = 968$ kHz

Weighting individual nanoparticles, such as a virus

Bending modulus:

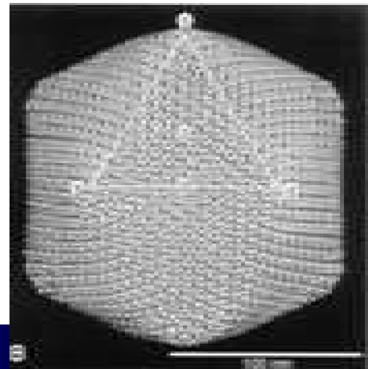
$E_b = 90$ GPa for D = 42 nm

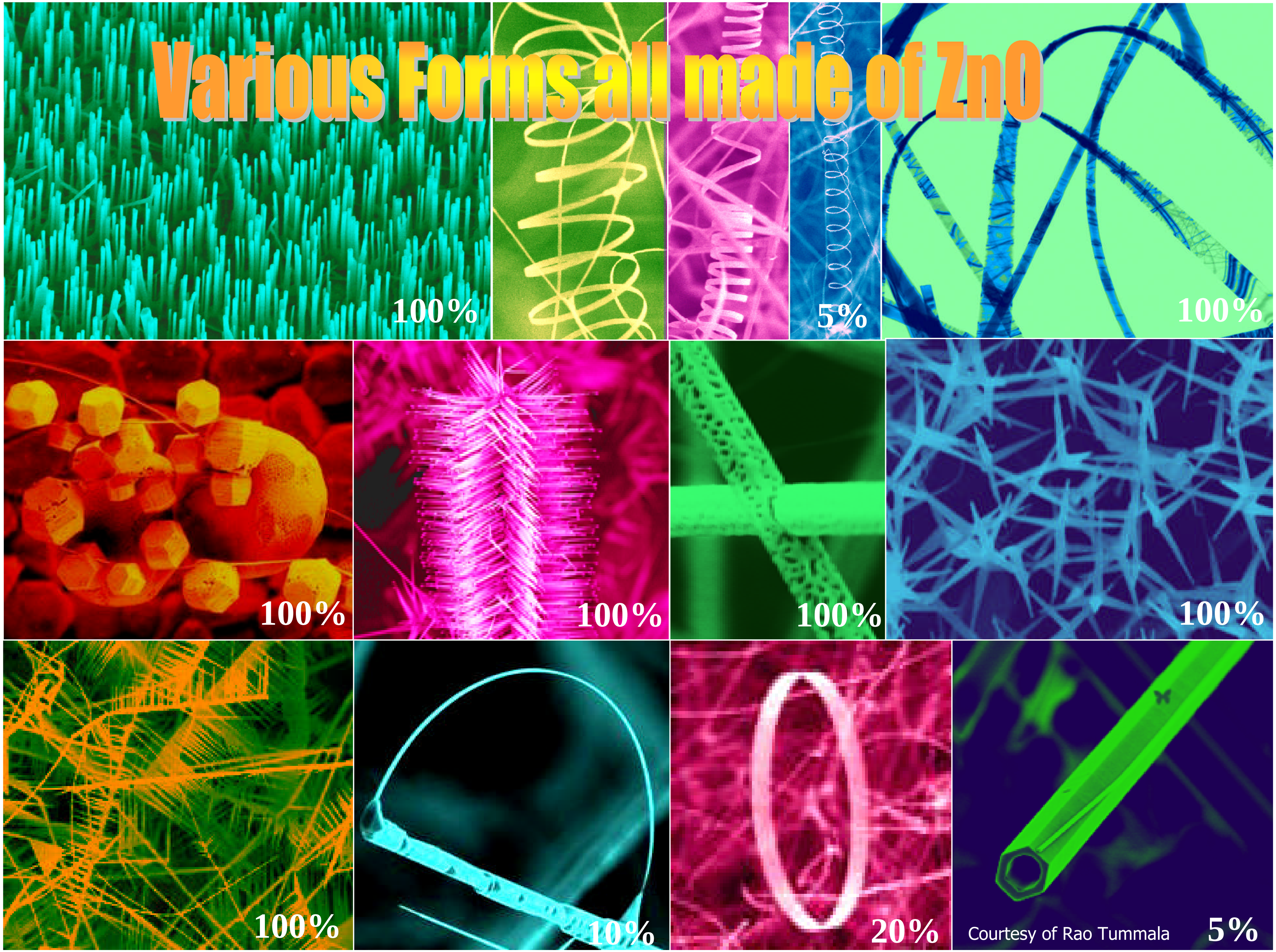
Mass of the particle = 22 ± 6 fg

(1f = 10^{-15})

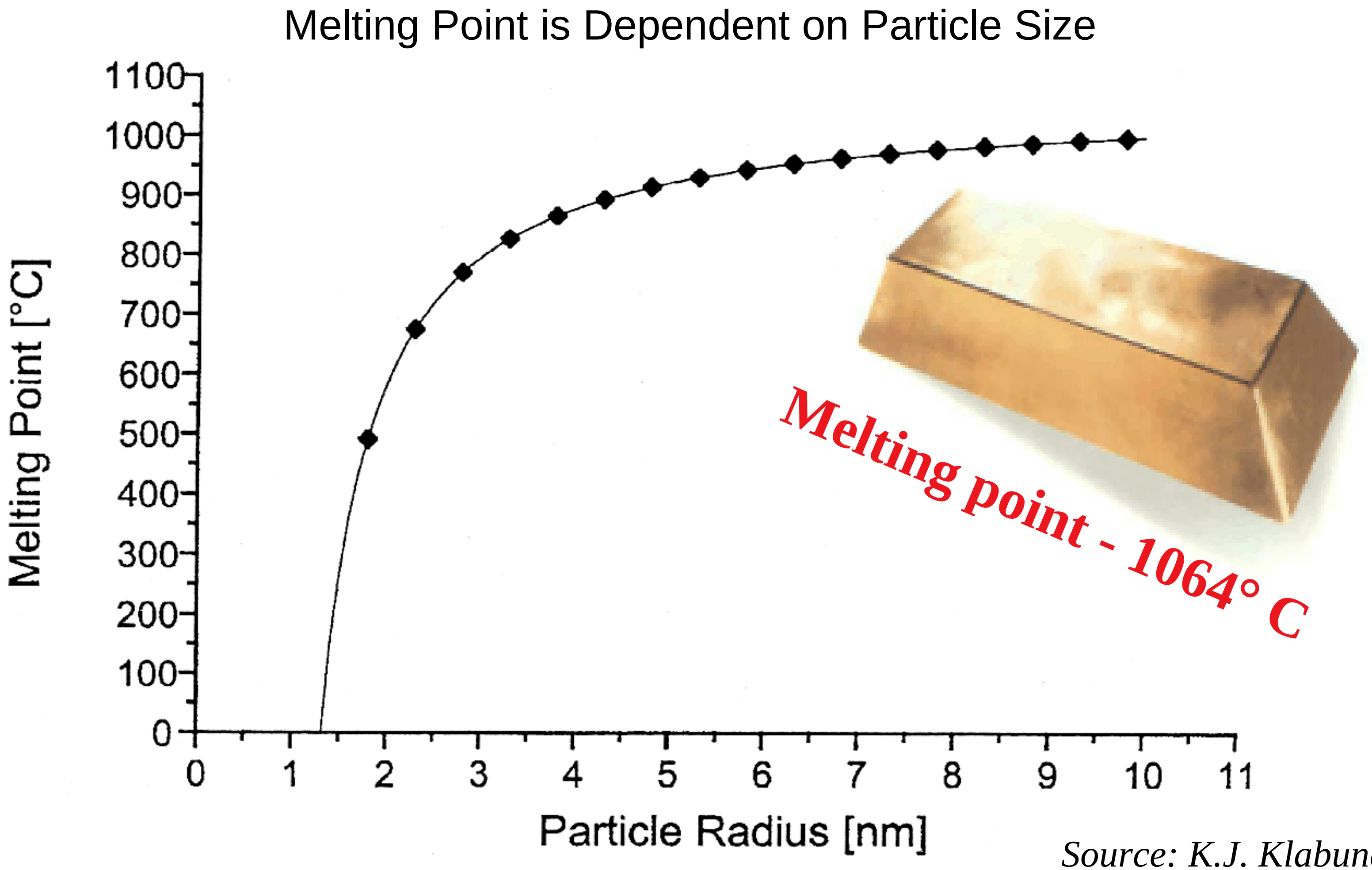
Calculated mass = 30 fg

Algal virus




Various Forms all made of ZnO
100%
5%
100%
100%
100%
100%
100%
100%
10%
20%
Courtesy of Rao Tummala
5%

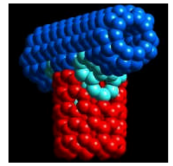
Melting Point is not Constant!



Source: K.J. Klabunde, 2001

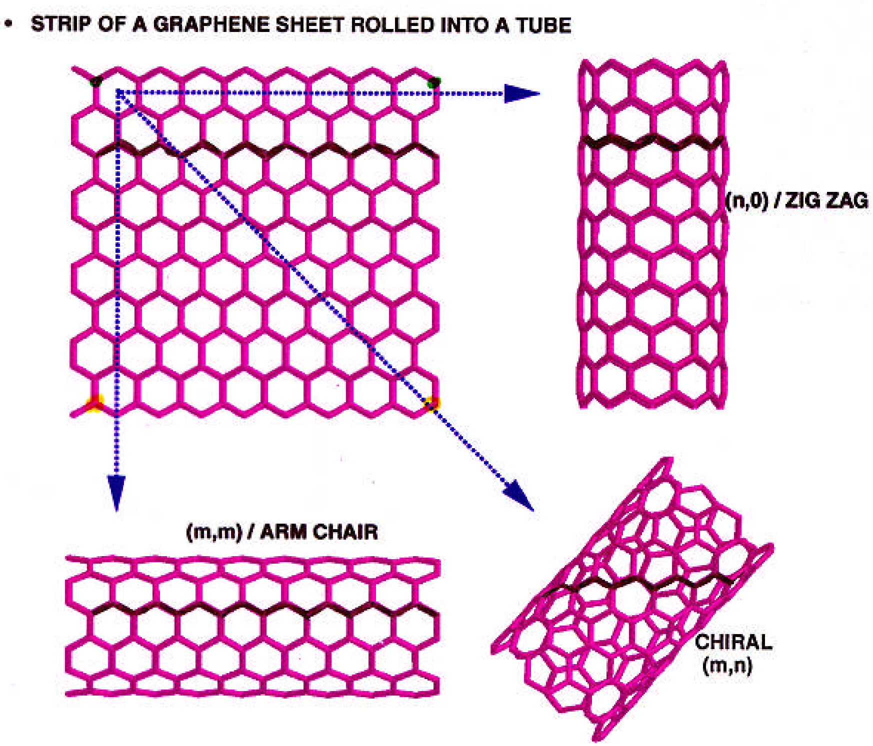
NASA Ames

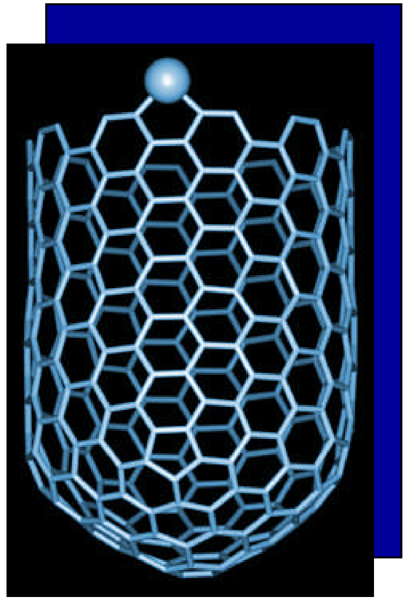
Carbon Nanotube



CNT is a tubular form of carbon with diameter as small as 1 nm.
Length: few nm to microns.

CNT is configurationally equivalent to a two dimensional graphene sheet rolled into a tube.



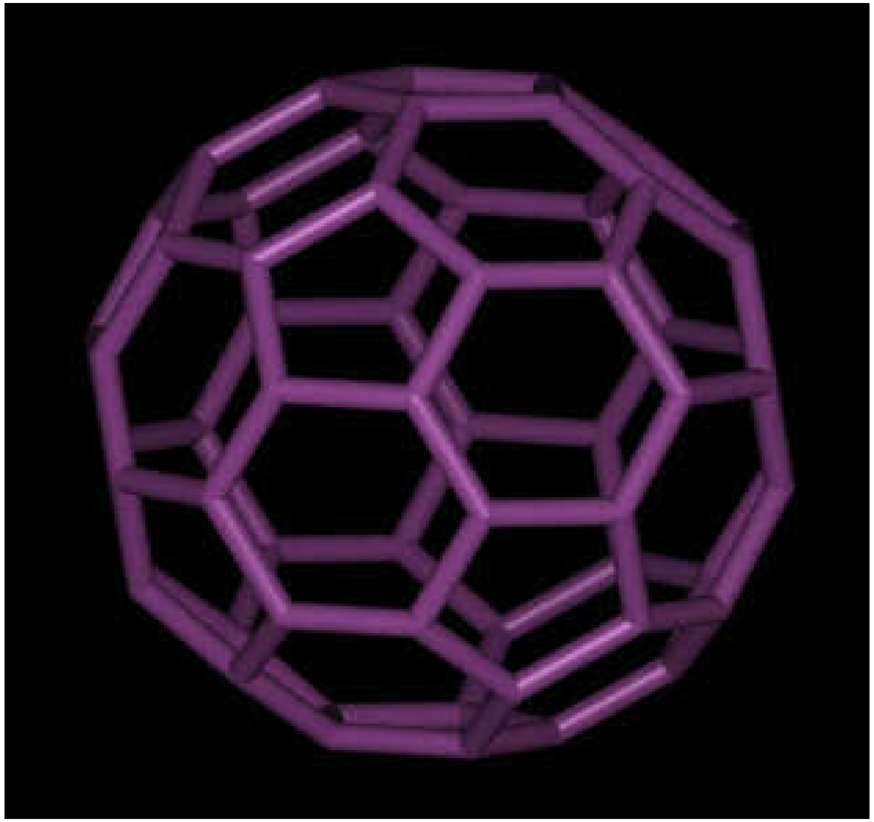


CNT exhibits extraordinary mechanical properties: Young's modulus over 1 Tera Pascal, as stiff as diamond, and tensile strength ~ 200 GPa.

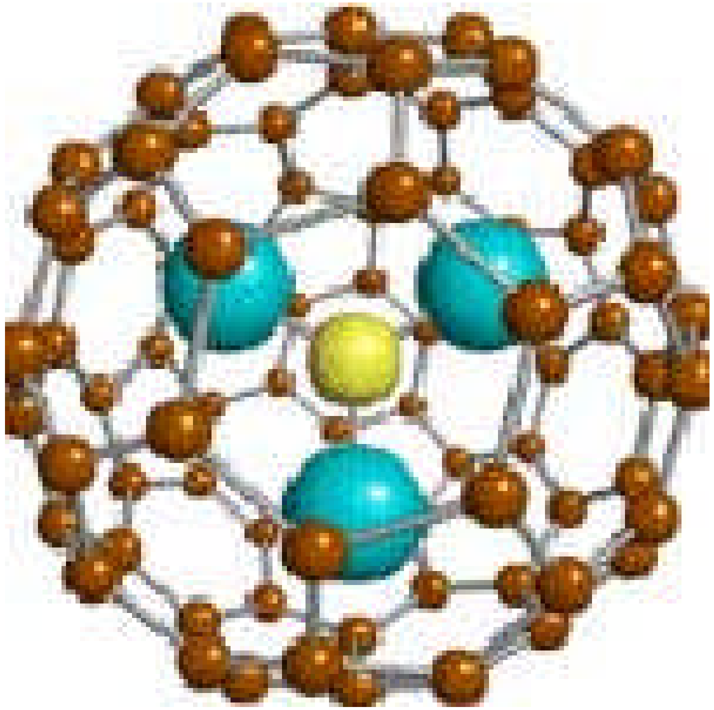
CNT can be metallic or semiconducting, depending on chirality.

Courtesy of M. Meyyappan

Novel Material Properties



A Carbon60 Buckyball (Courtesy CNI)



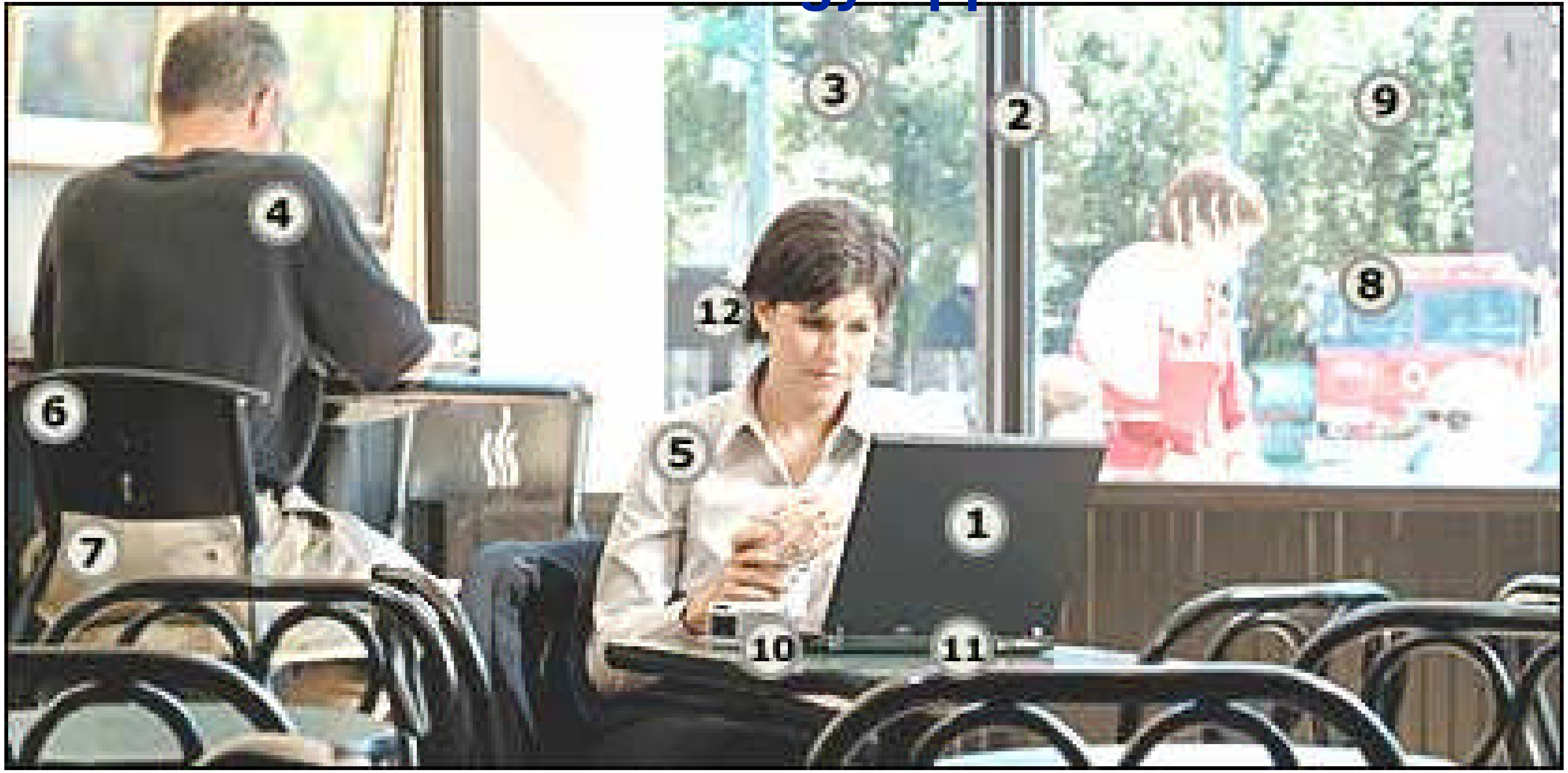
Luna's trimetasphere buckyball.

Small Times

Nano Everywhere

- **There are hundreds of available consumer products being spawned as companies manipulate matter at the atomic level, according to The Project on Emerging Nanotechnologies, a Washington, D.C. initiative associated with the Woodrow Wilson International Center for Scholars.**
- **The group released a products inventory containing descriptions of more than 200 consumer goods purportedly made with some type of nanotech process or nanomaterial.**
- **Link to Nanotechnology Consumer Products Inventory - http://www.nanotechproject.org/index.php?id=44&action=view**

Nano Technology Applications



1 - Organic Light Emitting Diodes (OLEDs) for displays

2 - Photovoltaic film that converts light into electricity

3 - Scratch-proof coated windows that clean themselves with UV

4 - Fabrics coated to resist stains and control temperature

5 - Intelligent clothing measures pulse and respiration

6 - Bucky-tubeframe is light but very strong

7 - Hipjoint made from biocompatible materials

8 - Nano-particle paint to prevent corrosion

9 - Thermo-chromic glass to regulate light

10 - Magnetic layers for compact data memory

11 - Carbon nanotube fuel cells to power electronics and vehicles

12 - Nano-engineered cochlear implant

Compiled by Jo Twist, BBC News On-Line, July 28, 2004

Business Implications

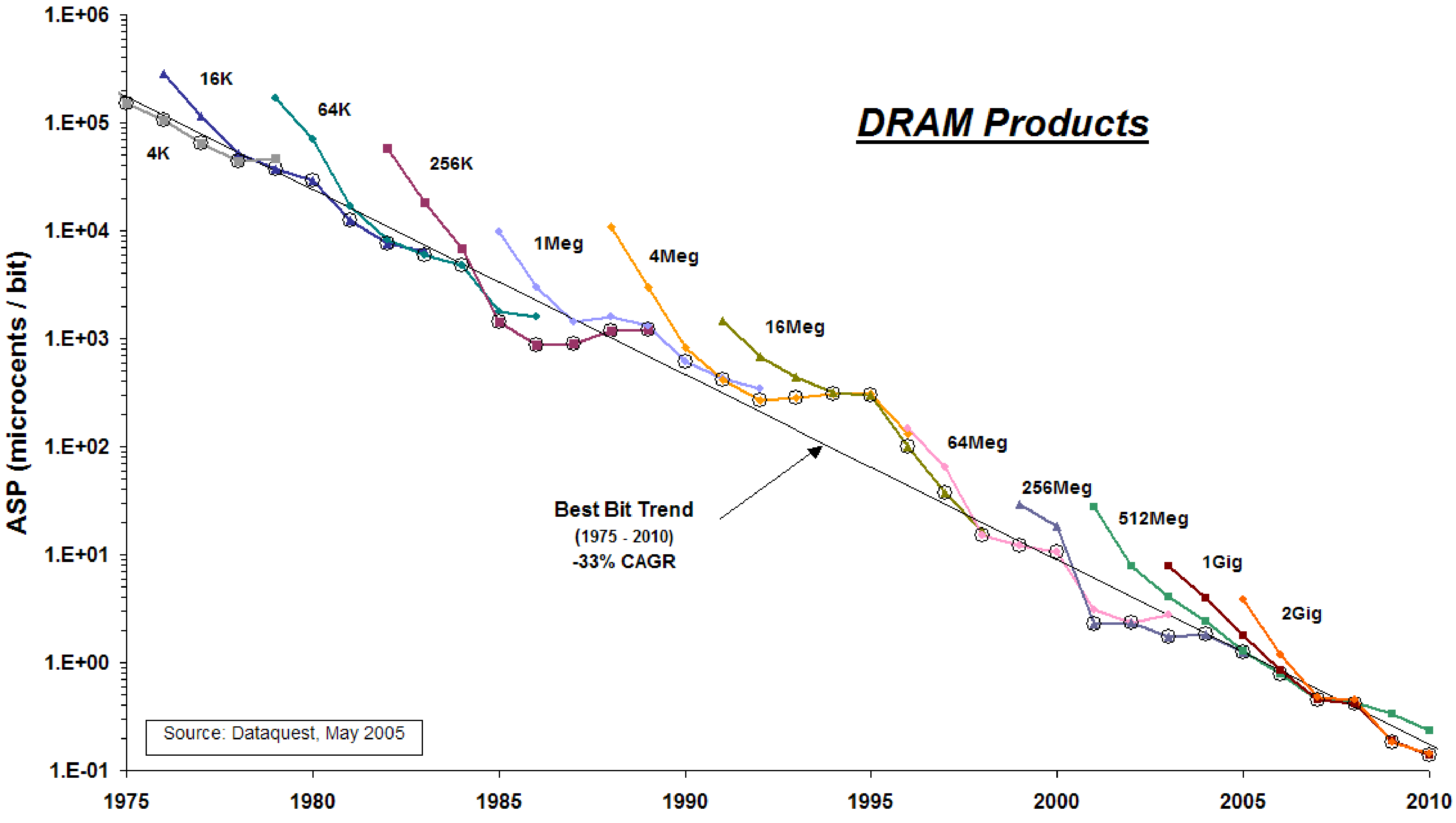
- **There will be many new opportunities**
  - Some will be successful
  - And, some will not
- **Development in the “nano” region does not refer to the investment required**
- **Leveraging existing industry will facilitate the development of the nano community**

Semiconductors: First Nano Industry

- **Model of early nanotech adoption, foundation for other nano industries**
  - People, capital, technology, infrastructure, experience, and culture will enable the transformation of nano into the advanced technology economies of the future
- **Lessons learned that will apply to follow-on nano industries**
  - Meeting technical challenges
    - New requirements in nano region; issues do not just scale
    - Operating environment is critical
    - Complete infrastructure must be ready (development interdependency)
  - Meeting economic/business challenges
    - High barrier to entry
    - Each new generation costs more
    - Shorter and shorter life cycles
    - Development issues and technology acceleration can crash infrastructure
    - Greatest benefits come to earliest successful entries
      - Being late means losing leading edge capabilities

Productivity Sustains the Industry

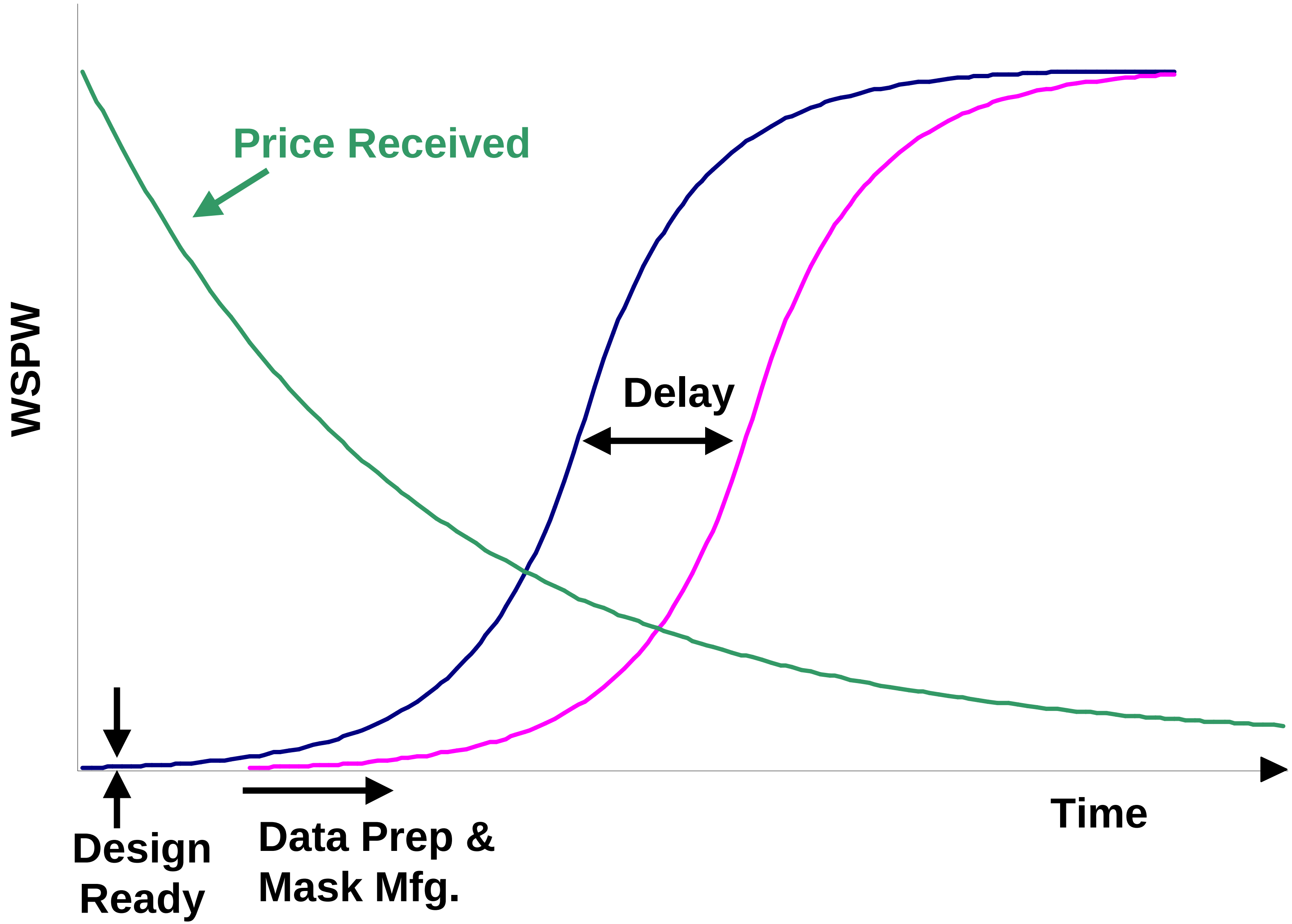
Example: DRAM Value Trends



←75-100mm 150mm 200mm 300mm 450mm→

Cost to process 1 cm^2 is about the same over this period (a few dollars)

Start Up Delay Impact



The Nanotech Challenge

- **Learnings from semiconductor industry can assist in coordinating industry, university, government, and infrastructure roles as nano industries develop**
- **In advanced technologies, companies and countries that want to control their own destiny must be at the leading edge**
  - Advanced technologies will drive the economy for the next 50 years
    US Dept. of Commerce
  - Enabler for national security and competitiveness
  - But competition is global and severe and already upon us

Key Points

Mis-applied technology costs businesses $Ms each year. Focused evaluation ensures compatibility and expedites time to market.

Businesses are good at what they do. Introducing a new technology can become a financial nightmare. Compatibility of business and technology does not magically happen.

Technology costs are easy to underestimate. Traditional tools may not Provide sufficiently accurate information.

Engineers love their technical developments and don't understand why business people can't see the value. Businesses what to see the return; engineers don't focus on the enumeration of the business, but on the beauty of the technology.

The semiconductor industry developed 248nm lithography tools in 1991, but these tools did not enter manufacturing until 1995! Infrastructure!

Points are listed at http://www.tryb.org/entry-pg1.html

Key Points

The dot.com bust was driven by people, who did not understand technology, believing the developers, who loved the technology

The semiconductor industry investigated, evaluated, and committed to Immersion lithography after a 14 month industry R&D effort.

The semiconductor industry spent over $2B on developing 157nm lithography only to decide that it was not manufacturable in sufficient quantities.

Business people do not truly understand the engineering mindset. Engineers rarely understand the business implications of their efforts. Incompatibility Provides for an interesting relationship.

Points are listed at http://www.tryb.org/entry-pg1.html

Summary

- **Technology is interesting, but it is the application to products that generates jobs.**

- **Intelligent people can make incorrect decisions, but correcting these choice enables progress. "You have to know when to fold'em."**

- **Focusing on "your" expertise provides the ability to make correct decisions. Core competencies.**

- **There will be many technology "losers", but the successful will <u>understand</u> the technology and how to drive development to satisfy a consumer need.**