Measurements and Standards for Nano-electrotechnologies: Progress and Challenges

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Outline

- Why Standards Are Important
- IEC TC 113 Scope, and Working Groups
- Examples of Progress
- Grand Challenges
- Invitation to Contribute

Significance of International Standards for Nanotechnologies

- **Global competition is intense.**
- **Standards are significant enablers for commercial success at all stages of innovation - from R&D to recycling/disposal.**
- **Successful innovation in nanotechnologies requires standards based on the best of each nation's science and engineering.** Standards not so based may constrain innovation and entrench inadequate technologies.
- **Documents for standards on consensus specifications advance the field.**
- **Standards influence R&D and business models.**

"Standards enable innovative products and new markets." –
Patrick Gallagher, NIST Director, November 2009

Nanotechnology: Converging and Emerging of Many Technologies

Challenges:

Involve relevant players and stakeholders in international standards and associated measurements – Global collaborations and cooperation will be key.

Establish decision making procedures.

Build consensus and priorities to accommodate limited resources.

Account for varying national and regional priorities.

IEC TC 113 on Nano-electrotechnologies

Scope

Established in 2007

The scope of TC 113 is "Standardization of the technologies relevant to electrical and electronic products and systems in the field of nanotechnology in close cooperation with other technical committees of IEC and of the International Standards Organization (ISO) TC 229 on nanotechnologies."

Topics include terminology, measurement, characterization, performance, reliability, durability, environment, health, and safety.

Scope (continued)

The standard deliverables will focus on components or intermediate assemblies that are created from nano-scaled materials and processes for electrical or electro-optical applications.

Nano-electrotechnologies will be used in a wide variety of applications. Potential applications include: electronics; optics; magnetics; electromagnetics; electroacoustics; multimedia; telecommunications; and energy production (direct conversion into electrical power as in fuel cells, photovoltaic devices and storage of electrical energy).

IEC TC 113 Working Groups

- **JWG 1: Terminology and Nomenclature**

Scope: Define and develop unambiguous and uniform terminology and nomenclature in the field of nanotechnologies to facilitate communication and to promote common understanding.

- **JWG 2: Measurement and Characterization**

Scope: The development of standards for measurement, characterization and test methods for nanotechnologies, taking into consideration needs for metrology and reference materials.

JWG 1/JWG 2 are Joint Working Groups with ISO TC 229 on nanotechnologies.

IEC TC 113 Working Groups (continued)

- **WG 3: Performance Assessment**

Scope: To develop standards for the assessment of performance, reliability, and durability related to the nanotechnology-enabled aspects of components and systems in support of continuous improvement at all stages of the value adding chain. WG 3 considers market demand and technology pull with an emphasis on fabrication, processing and process control, disposal, and recycling.

Six stages of the linear economic model – technical research, technology development, initial deployment, commercialization (large-scale, high-volume manufacturing), end of first use, and end-of-life (disposing and recycling)

Terms of Reference for IEC TC 113 WG3 on Performance Assessment

Nano-Device/ Structure		Nano-Subassembly/ Component		Product/System
KCCs	→	Figures of Merit	→	Specifications

To develop standards for the assessment of performance, reliability, and durability related to the nanotechnology-enabled functionality of components and systems in support of innovative electrotechnical products at all stages of the value added chain:

Raw and/or Recycled Material → Process → Subassembly →
System Integration → Product → End of First Use
→ End-of-Life → (Disposing and Recyling)

KCC = Key Control Characteristics

An Example:
NIST-Energetics-IEC IEC TC 113 Survey

Goal and Objectives: **Build an international consensus among members of the nano-electrotechnologies community for developing standards and related measurements to guide IEC TC 113 WG3 program priorities with its limited resources.**

- **Establish procedures for ranking new documents for comment (DCs) and new work item proposals (NWIPs) in priority order.**
- **Respond to new work item proposals from IEC National Committees.**
- **Identify experts for working groups to improve DCs and complete high-priority NWIPs.**

http://www.nist.gov/eeel/semiconductor/upload/NIST_Energetics_Survey.pdf

Survey Results - Priorities

Survey on nano-electrotechnologies was online from May 10, 2008 to December 15, 2008. 459 respondents from 45 countries ranked in priority order the items listed below for the five taxonomy categories.

Products

1. Energy
2. Medical Products
3. Computers
4. Telecommunication
5. Security/Emergency
6. Consumer Electronics
7. Household Applications
8. Transportation

Cross-Cutting Technologies

1. Sensors (chemical, physical, mechanical, etc.)
2. Fabrication tools for integrated circuits
3. Nano-electromechanical Systems
4. Performance and reliability
5. Analytical equipment for properties
6. Environmental, Health, and Safety (bi-modal)
7. Instrumentation for Process Control
8. Optical Technologies

Properties

1. Electronic and Electrical
2. Optical
3. Biological
4. Chemical
5. Radio Frequency
6. Magnetic

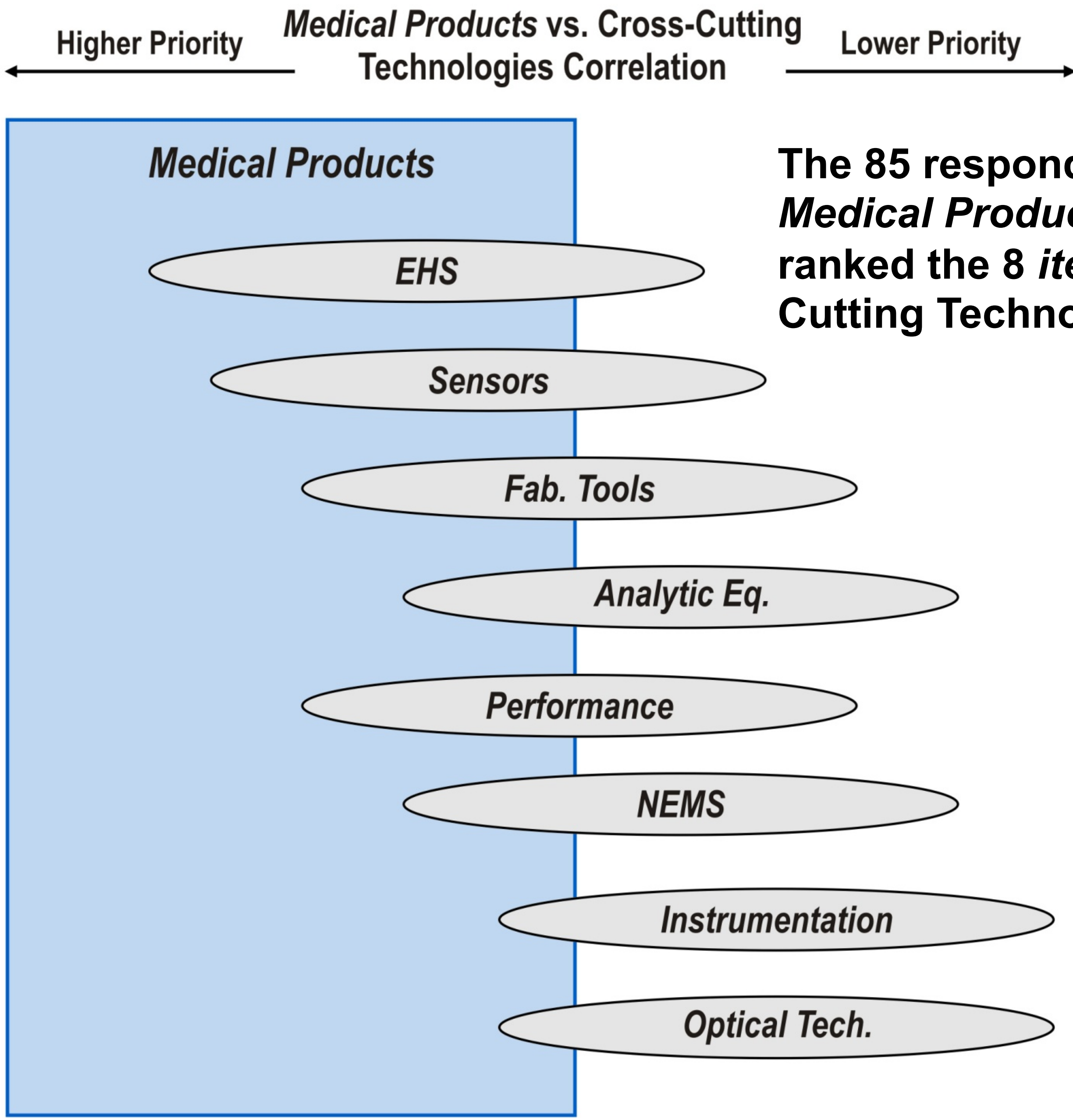
IEC Discipline Areas

1. Measurement /Performance
2. Design/Development
3. HSE
4. Dependability/Reliability
5. Electromagnetic Compatibility
6. Terminology/Symbols

Stages of the Economic Model

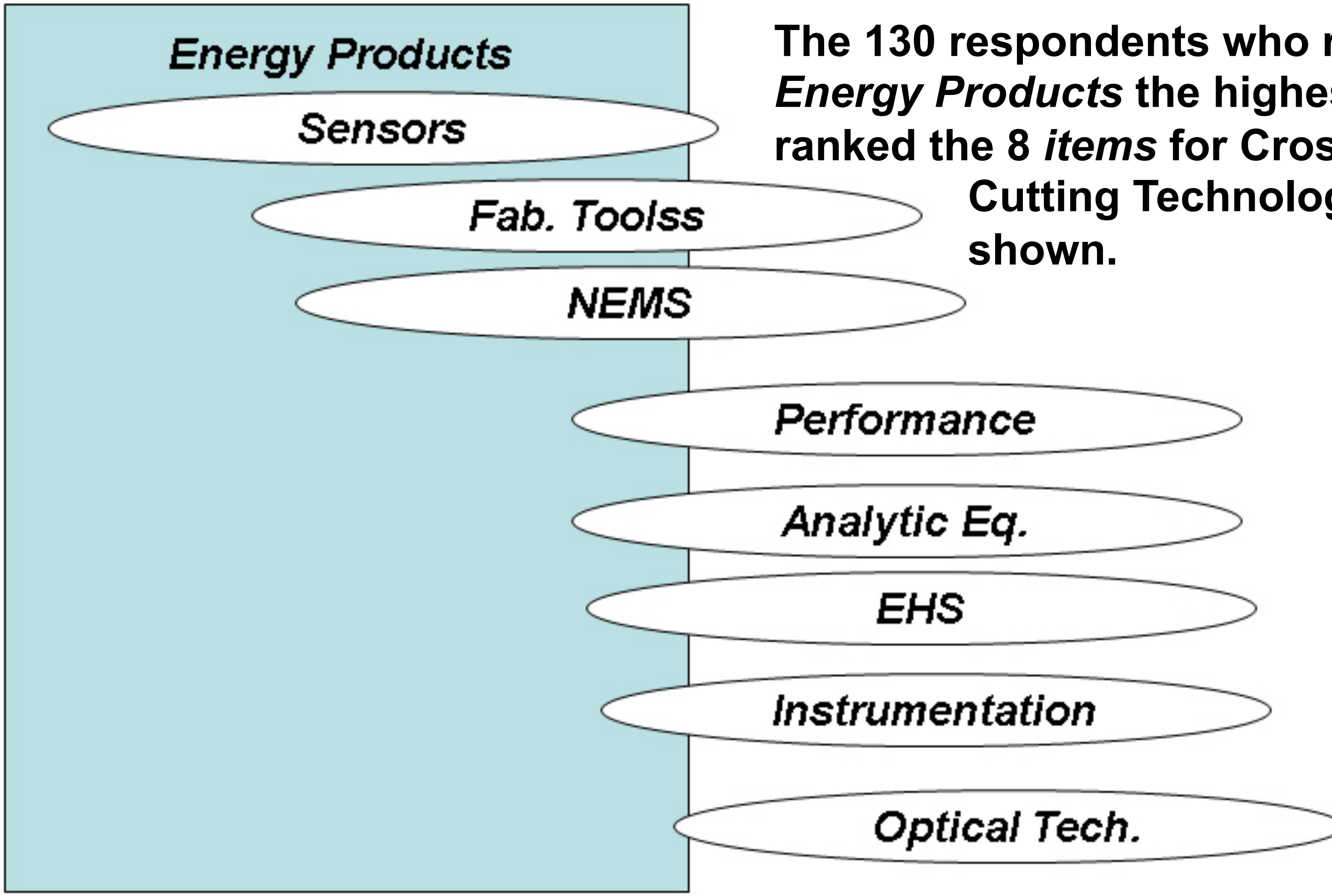
1. Basic Research
2. Technology Development
3. Initial Deployment
4. Commercialization
5. Initial End-of-Use
6. End-of-Life (Recycle/ Disposal)

http://www.nist.gov/eeel/semiconductor/upload/NIST_Energetics_Survey.pdf



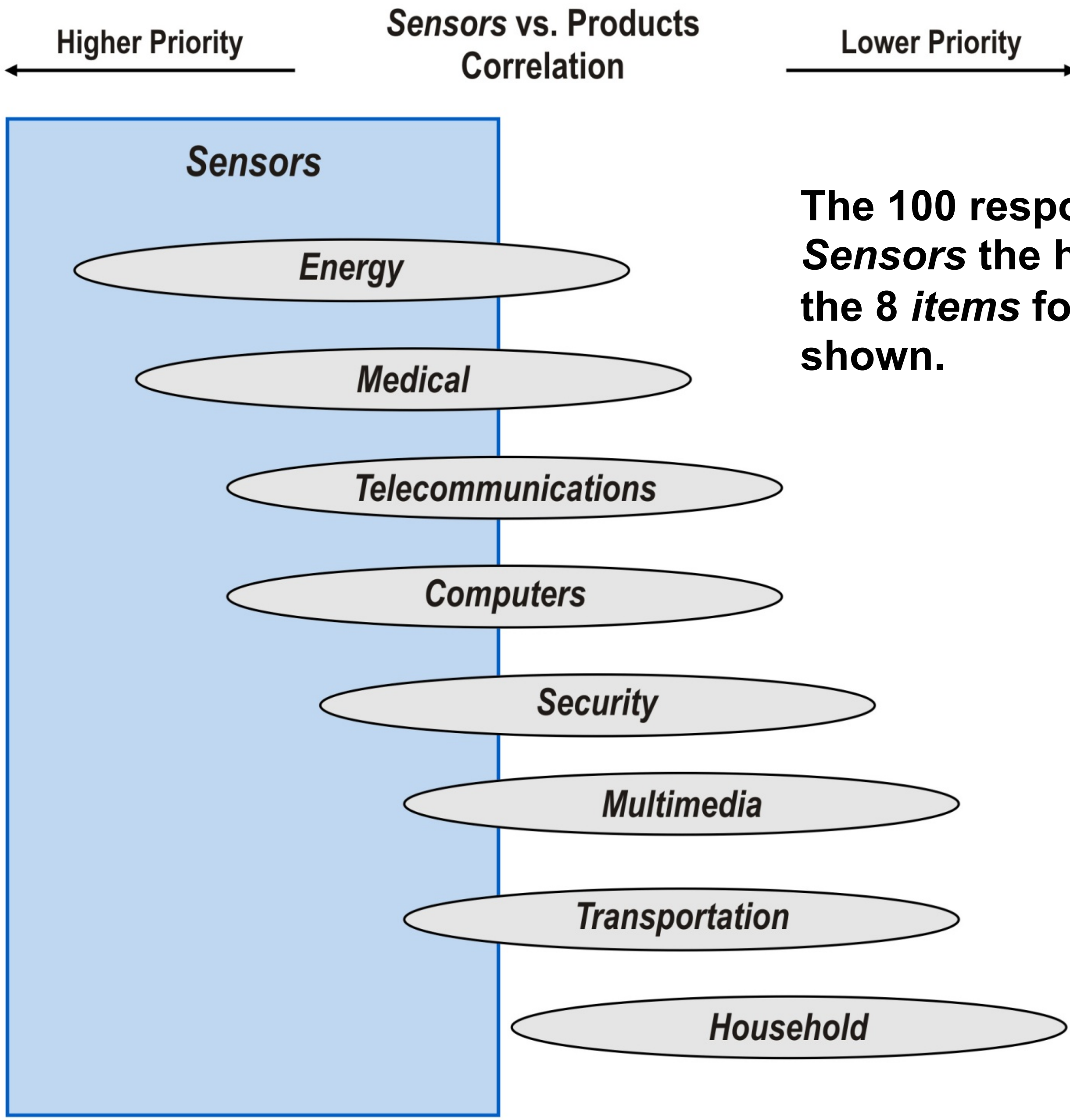
The 85 respondents who ranked *Medical Products* the highest also ranked the 8 *items* for Cross-Cutting Technologies as shown.

Higher Priority *Energy Products* vs. Cross-Cutting Technologies Correlation Lower Priority



The 130 respondents who ranked *Energy Products* the highest also ranked the 8 *items* for Cross-Cutting Technologies as shown.

H. S. Bennett, et al., *Priorities for Standards and Measurements to Accelerate Innovations in Nano-electrotechnologies: Analysis of the NIST-Energetics-IEC TC 113 Survey*, NIST Journal of Research, Volume 114, Issue 2, March-April 2009, and on the Web at http://www.nist.gov/eeel/semiconductor/upload/NIST_Energetics_Survey.pdf



The 100 respondents who ranked *Sensors* the highest also ranked the 8 *items* for Products as shown.

Complete Analysis of the Survey

Priorities for Standards and Measurements to Accelerate Innovations in Nano-electrotechnologies: Analysis of the NIST-Energetics-IEC TC 113 Survey

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Published in the NIST Journal of Research, Volume 114, Issue 2, March-April 2009, and on the Web at http://nvl.nist.gov/pub/nistpubs/jres/114/2/V114.N02.A03.pdf

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Survey Result

The global consensus prioritizations for ranked items in the 2009 Survey of taxonomy categories suggest that the IEC TC 113 should focus initially on standards and measurements for electronic and electrical properties of sensors and fabrication tools that support performance assessments of nano-technology enabled sub-assemblies used in energy, medical, and computer products.

IEC/TC 113 Published Standards

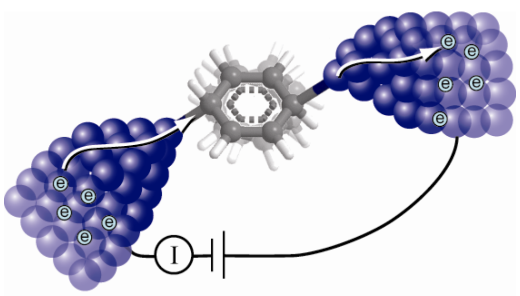
IEC/IEEE 62624: Test methods for measurement of electrical properties of carbon nanotubes (First published by IEEE-SA in 2005; now in maintenance cycle under IEC/IEEE dual logo).

Examples of IEC/TC 113 Projects in Progress

IEC/IEEE Technical Specifications 62659, Large scale manufacturing of nanoelectronics. This is an approved new work item. Development work will begin in 2010.

IEC/IEEE 62xxx, Technical Report for the TC 113 on nanoelectronics standardization roadmap. Begins in 2010.

IEC 62xxx, Technical Report on nanoscale electrical contacts and interconnects. Development work will begin in 2010.



A benzene molecule junction spans platinum atomic point contacts.
Figure from L. Venkataraman, Viewpoint – *Benzene provides the missing link in molecular junctions*, Physics 1, 5 (2008) at http://physics.aps.org/articles/v1/5
http://dx.doi.org/10.1103/Physics.1.5
Reprinted with American Physical Society permission from Physics, 1, 5 (2008); illustration by Alan Stonebraker.

The Diffuse TC113/TC229 Moving Boundary

Terms of Reference for
IEC TC 113 WG3 on Performance Assessment

IEC TC 113 WG3 -- MARKET PULL

→ **Nano Product Attributes**

- **Performance**
- **Reliability**
- **Durability (end-of-use)**
- **Disposing and Recycling (end-of-life)**

Diffuse Moving Boundary

ISO TC 229 ↘

JWG2 -- TECHNOLOGY PUSH

IEC TC 113 ↗

→ **Nanotechnology moving towards innovative commercialization**

Work-in-Progress DRAFT - Subject to change.

Bone Tissue Engineering [1]

Single-walled carbon nanotube scaffolds promote differentiation of progenitor osteoblast cells into functional mature osteoblast cells – increase bone mineral density in patients with osteoporosis

Carbon nanotubes promote bone cell proliferation, show excellent affinity for cell adhesions, carry neutral charge sustain the highest bone cell proliferation and production of hydroxyapatite crystals; and chemically functionalized SWCNTs with negatively charged surface control the orientation of the nuclei of hydroxyapatite and promote the crystal growth.

Establishes direct relationships among SWCNTs, their electronic charge distributions, and bone health biomarkers.

[1] Xiaomin Tu, et al., Department of Chemistry, University of Arkansas Little Rock,
Paper presented at MRS Spring Meeting 2007, San Francisco

Environmental, Health, and Safety (EHS) International Opportunities and Challenges

One randomly selected example from *NanoToday*, October 2007, Volume 2, Number 5, page 10:

Carbon nanotubes show germ-fighting promise

Toxicology and Environment - Researchers from Yale University have provided the first direct evidence that highly purified single-walled carbon nanotubes (SWNTs) exhibit strong antibacterial activity [Kang et al., Langmuir (2007) 23, 8670]. This has implications for both useful antimicrobial filtering processes, tissue engineering scaffolds based on nanostructures, and possible harmful environmental effects. … contact with nanotubes results in the death of the bacteria. … After exposure, loose DNA and RNA were found floating in the solution, …., causing this genetic material to float out.

What is the mechanism that leads to leakage of genetic material? – local inflammation, puncturing, etc. ?

More-than-Moore (MtM) Domains

MtM applications are vast. MtM examples include the domains of:

- **RF and Analog/Mixed-Signal Technologies, (e.g., wireless communications)**
- **Energy (e.g., solar, photovoltaic cells, smart grid, and storage-batteries)**
- **Imaging (e.g., quantitative medical imaging)**
- **MEMS/NEMS - Sensor/Actuators (e.g, biosensors)**
- **Bio-Chips (e.g., bioelectronics)**
- **3D Heterogeneous Integration.**

Recent News on More-than-Moore Applications

From ATA Telemedicine and e-Health News Alert, 26 October 2010: According to Kathy Calvin, Chief Executive of the United Nations Foundation, mobile phones have the potential to "have as big an impact on global healthcare as Sir Alexander Fleming's 1928 discovery of penicillin."
– involves the MtM domains of RF, AMS, bioelectronics, MEMS based biosensors, and actuators.
http://www.liebertpub.com/products/product.aspx?pid=314

Recent News on More-than-Moore Applications

From in-Pharma Newsletter 10 November 2010: Novartis says it plans to submit its microchip containing ‘smart-pill’ technology to European regulators within 18 months. The silicon and metal digestible sensor within the tablet, which is activated by stomach acid upon ingestion, is able to transmit data via wireless and Bluetooth connections to a patch worn by the patient, and from there, to a smartphone or a doctor’s computer.
– involves the MtM domains of RF, AMS, bioelectronics, MEMS based biosensors, and actuators.

http://www.in-pharmatechnologist.com/Materials-Formulation

Invitation to Contribute

The quality of the those portions of roadmaps and international standards and labeling that pertains to medical products enabled by nanotechnologies will depend in part on the contributions from the medical community (e.g., healthcare providers, researchers, manufacturers, regulators, and insurers) for all stages of the economic cycle - from R&D to recycling and/or disposal.

Common Theme Among Recent Workshops on Nanotechnologies and NanoManufactruring#

- Limited resources and knowledge for developing the critical science- and engineering-based metrology.
- Support for all sages of the economic and materials cycles from research to recycling and eventual disposal.
- Challenges are :
  - Characterizing, understanding, modeling, and controlling the key properties and processing parameters of nanomaterials.
  - Assessing the performance (figures of merit) of products that have added value and functionalities enabled by nanotechnologies.

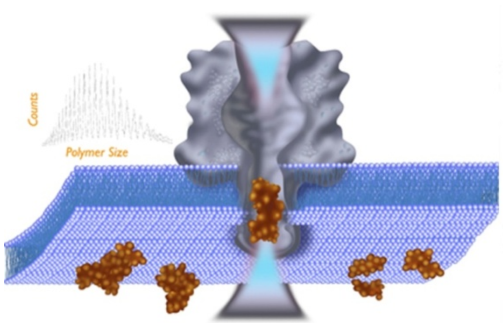
See for example, http://www.nist.gov/cstl/upload/nano_small_web-4.pdf

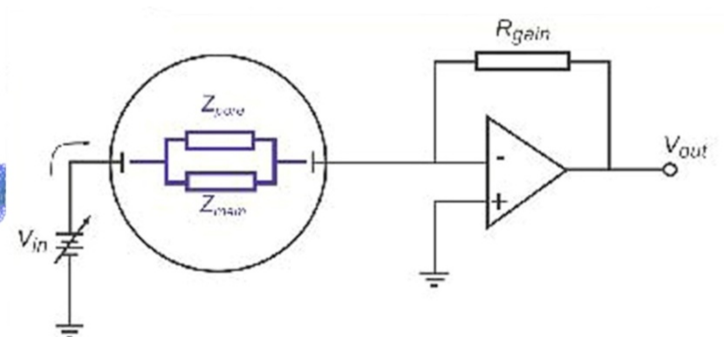
Opportunities for Additional Collaborations

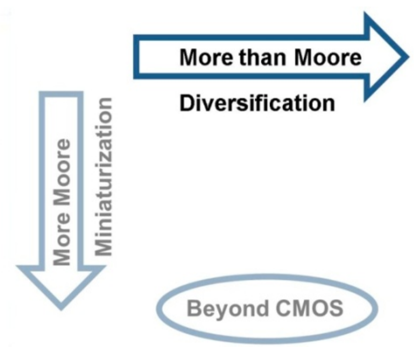
Are *more than Moore* applications of electronics appropriate now for international standards and metrology efforts?

Will the past business models for standards and metrology in support of the semiconductor industry be optimum for the diverse applications of nanotechnologies?

From where will the essential resources come?







A GRAND CHALLENGE

Sustaining effective communication, cooperation, and collaboration among all the global stakeholders – essential to avoid the overload of overlaps or *who is doing what*?

In nanotechnologies, TCs for ISO and IEC co-exist with:
OECD
JEDEC JC-14 Quality and Reliability – before 2001
ASTM International Committee E56 on Nanotechnology – 2005
IEEE Standard Test Methods for Measurement of Electrical Properties of Carbon Nanotubes - 2005
IEEE NTC Nanoelectronics Standards Roadmap – 2007
SEMI
ANF
CEN 352 on labeling
And this list goes on and on and on ……. .

The IEC TC 113 invites you to contribute to its standards and associated measurements activities.

To join the IEC TC 113

Please contact the TC 113 secretary
Dr. Norbert Fabricius at norbert.fabricius@kit.edu

For more information **on the IEC, please visit** http://www.iec.ch/about/mission-e.htm

THANK YOU