Nanoelectronics and the Environment

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CONTENTS

- Nanotechnology and the environment – A life cycle approach
- Specific environmental issues of nanotechnology and nano-products
- Application of the methodology to Nanoelectronics
- Key issues along the electronic product life cycle and involvement of stakeholders
- Conclusions

INTRODUCTION

- Nanotechnology and production of nanomaterials rapidly evolving field with many innovation opportunities
- As for any new emerging technology:
  - Need to assess and control environmental impacts
- Specific issue:
  - Number of uncertainties and concerns in regard to impact mechanisms on environment and human health

DEFINITIONS

- Nanotechnologies:
  "the [purposeful] design, characterization, production and application of structures, devices and systems by controlling shape and size at nanometer scale"
  (Royal Society & Royal Academy of Engineering 2004).

Royal Society 2004

- Nanomaterials:
  - Materials with unique structural features of the order of 1-100 nm
  - They can be aggregates of nanoparticles as well as composites containing nanoparticles

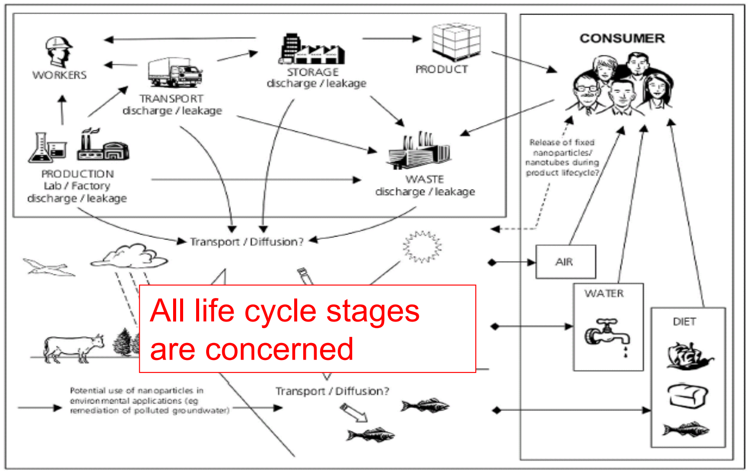
NEED FOR ENVIRONMENTAL ASSESSM

- New technologies may mean new risks to health, safety and the environment
- Responsibility to anticipate, address and minimize risk to workers and users
- Understanding and managing risk is essential:
  - To protecting people and the environment
  - To the economic viability of emerging technologies
  - To beneficial nanotechnologies reaching their full potential
- A holistic perspective on potential impact is essential
  - Life Cycle Assessment

NANOTECHNOLOGY AND LCA

- Recent joint US/EU expert workshop in Washington DC, Oct 2-3, 2006
- “Nanotechnology and Life Cycle Assessment”, W. Klöpffer, M.A. Curran, P. Frankl, R. Heijungs, A. Köhler, S.I. Olson, (forthcoming)

POTENTIAL IMPACT ROUTES



[adopted from The Royal Society & Royal Academy of Engineering 2004]

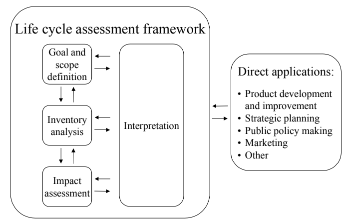
POTENTIAL IMPACT ROUTES

- **SOURCE → pathway →RECEPTOR**
- Direct:
- Inhalation
  - eg. workplace
  - Emissions from vehicles, combustion, etc
- Dermal exposure;
  - eg. sun-screens; cosmetics
- Ingestion;
  - eg. In water
- Indirect: primarily via food chain

[Source: R. Clift 2006]

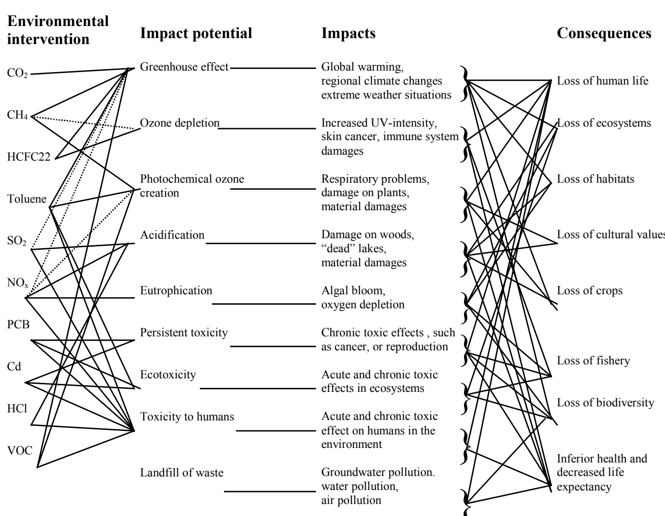
LIFE CYCLE ASSESSMENT (LCA)

- LCA is a methodological framework for estimating and assessing the environmental impacts attributable to the entire life cycle of a product,
  - from raw material extraction and acquisition,
  - through energy and material production and manufacturing
  - to use
  - and end of life treatment and final disposal (ISO 14040:2006)



(Source: ISO 14040:2006)

LC IMPACT ASSESSMENT (LCIA)



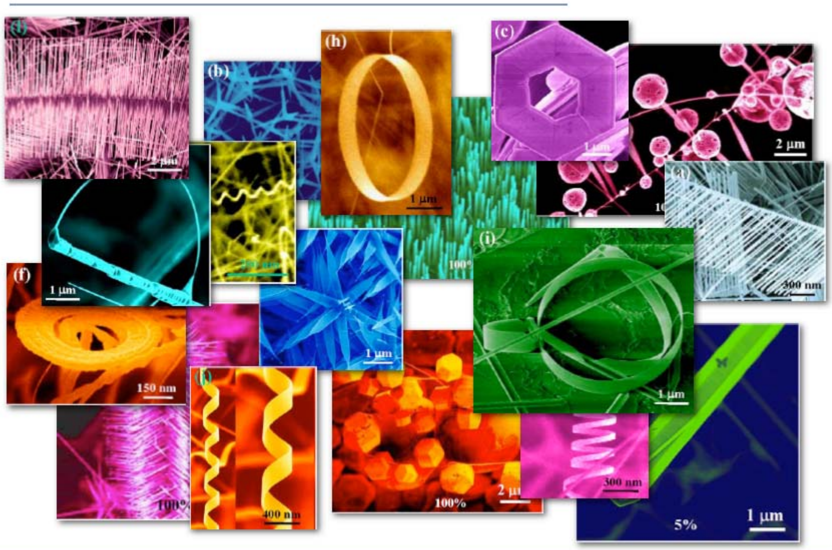
(Source: Wenzel et al., 1996)

SPECIFIC ISSUES - NANOTECHNOLOGY

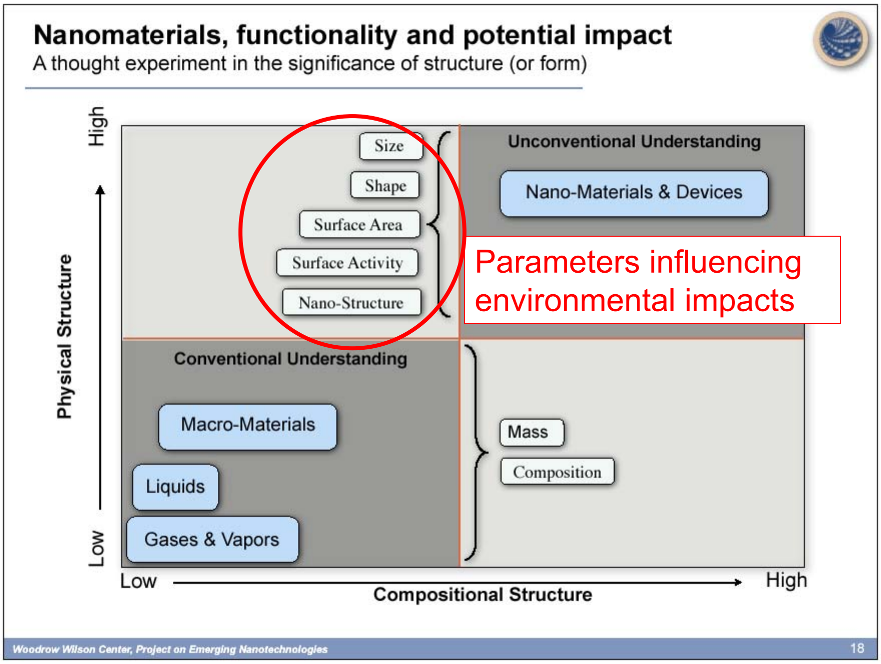
- Toxicological impacts
  - Do not just depend on mass and chemistry
  - Significantly depend on other parameters at the nano-scale
- Size and surface matter!
- How are persistence and bioaccumulation affected?
- Abiotic depletion
  - Large-scale diffusion of products → Dissipative use of scarce resources (e.g. Indium)

The Significance of Structure (or Form)

ZnO: One chemistry, many shapes - Courtney of Prof. Z.L. Wang, Georgia Tech



[Source: Maynard 2006]



[Source: Maynard 2006]

ASSESSMENT FRAMEWORK

- UNEP/SETAC assessment framework appropriate in principle (Dec2006)
- *But* to be taken into account:
  - Nanoparticle-specific parameters
- Combination LCA + Risk Assessment needed

CATEGORIZATION

- Define categories of Nanomaterials and products for the purpose of LCIA:
  - **Dispersive** vs. **non dispersive** uses (intentional and non-intentional)
  - **Chemical composition**
  - **Form** and **structure**
  - **Mobility** (or not) of releases in the different environmental compartments (air, water, soil) at each life cycle stage
  - **Transformation** from one life cycle stage to another

APPLICATION TO NANOELECTRONICS

- Mainly technology at the nanoscale rather than nanoparticles
  - few exceptions possible/envisaged, e.g.
    - Carbon nanotubes
    - Ag nanowires for Pb-free soldering
- Strict control procedures in manufacturing processes
- No dispersive use
- In principle, low particle mobility
- Potential challenge: behaviour and transformation in the end-of-life stage

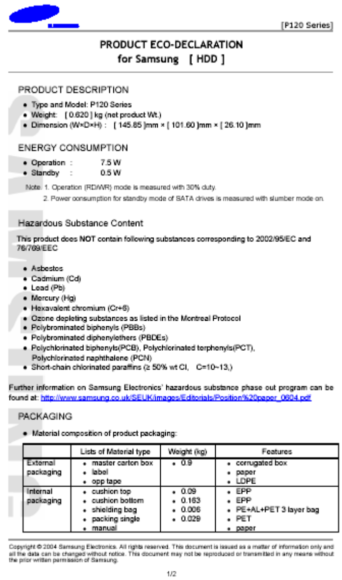
NANOELECTRONICS & LIFE CYCLE

Life Cycle Stage	Environmental issue	Current Status
Manufacturing	Avoid accidental release	Clean rooms Strict control
Use	Ensure non-dispersive use and low particle mobility	OK
End of Life	Ensure recovery and appropriate treatment Electronics in billions of products Stability or transformation of nanoparticles?	How to involve stakeholders? Role of electronic industry to be further defined

ELECTRONIC INDUSTRY ROLE

- Pro-active behaviour
- Regulation trigger – e.g. WEEE, RoHS
- Involve down-stream stakeholders along the entire product life cycle chain
- Provide information to clients and users regarding
  - Materials contents
  - Potential challenges and risks
  - Guidelines for correct use and EoL treatment
- Existing examples
  - Environmental Product Declarations in Japan, Sweden and Korea
  - IT “ISO-type II” environmental claims and labels

EXAMPLE OF LC COMMUNICATION



[P120 Series]

PRODUCT ECO-DECLARATION
for Samsung [HDD]

PRODUCT DESCRIPTION

- Type and Model: P120 Series
- Weight: [0.620] kg (net product Wt.)
- Dimension (W×D×H) : [145.85]mm × [101.60]mm × [26.10]mm

ENERGY CONSUMPTION

- Operation : 7.5 W
- Standby : 0.5 W

Note: 1. Operation (RD/WR) mode is measured with 30% duty.
2. Power consumption for standby mode of SATA drives is measured with slumber mode on.

Hazardous Substance Content

This product does NOT contain following substances corresponding to 2002/95/EC and 76/769/EEC

- Asbestos
- Cadmium (Cd)
- Lead (Pb)
- Mercury (Hg)
- Hexavalent chromium (Cr+6)
- Ozone depleting substances as listed in the Montreal Protocol
- Polybrominated biphenyls (PBBs)
- Polybrominated diphenylethers (PBDEs)
- Polychlorinated biphenyls(PCB), Polychlorinated terphenyls(PCT), Polychlorinated naphthalene (PCN)
- Short-chain chlorinated paraffins (≥ 50% wt Cl, C=10~13,)

Further information on Samsung Electronics' hazardous substance phase out program can be found at: http://www.samsung.co.uk/SEUK/images/Editorials/Position%20paper_0604.pdf

PACKAGING

- Material composition of product packaging:

	Lists of Material type	Weight (kg)	Features
External packaging	• master carton box • label • opp tape	• 0.9	• corrugated box • paper • LDPE
Internal packaging	• cushion top • cushion bottom • shielding bag • packing single • manual	• 0.09 • 0.163 • 0.006 • 0.029	• EPP • EPP • PE+AL+PET 3 layer bag • PET • paper

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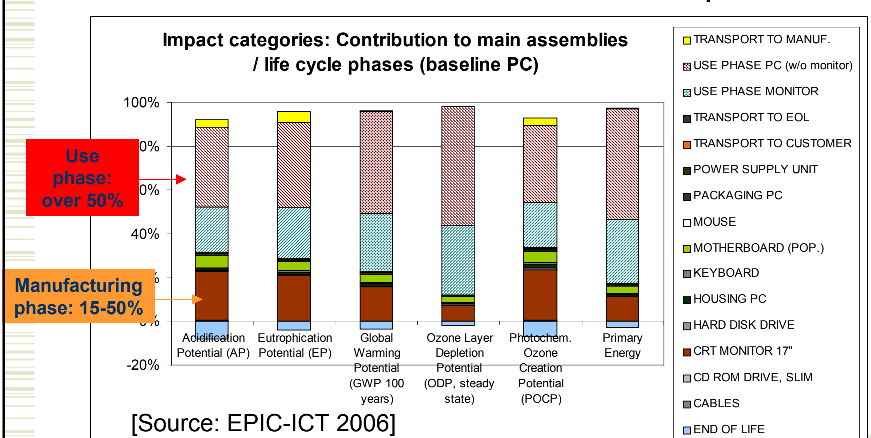
LCA AT FINAL PRODUCT LEVEL

- Added value of LCA: holistic picture
- Eventual impacts of nanoelectronics to be assessed in the context of the final product



[Source: EPIC-ICT 2006]

CONCLUSIONS - NANOELECTRONICS

- As any new technology, Nanotechnologies raise new environmental issues and concerns
- Impacts may occur in any life-cycle stage
  - Methodological framework for LCA (+RA) and Nanotechology being developed
- Nanoelectronic products
  - Good control in manufacturing
  - Low risk in use and maintenance
  - Potential (but not certain) challenges in end-of-life, to be further assessed
- Pro-active role of electronic industry
  - Involvement of stakeholders along the product LC
  - Environmental information disclosure

CONCLUSIONS – LCA

Added value of LCA is twofold:

1. Identification of the life cycle stages, at which major environmental impacts may occur
   → eco-design, impacts minimization

2. Comparison with conventional (final) products
   - Easier acceptance of (potential) risks related to nanotechnology if benefits for stakeholders and consumers are clearly assessed and communicated