Role of Green Nanotechnology in Sustainable Nanotechnology

Panel Discussion

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Yorkshire Forward Professor of Nanomanufacturing Innovation

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Prince of Wales Award
For Innovation & Production

SUN - SNO – GUIDENANO Sustainable Nanotechnology, March 2015, Venice
Your Panel

- Dr Mark Wiesner, Duke U, US*
- Dr Barb Karn, SNO, US*
- Dr Anna Costa, Istec CNR, IT
- Dr Socorro Vázquez-Campos, LEITAT, ES
- Dr John Warner, Warner-Babcock Institute for Green Chemistry, LLC, US
- Prof Terry Wilkins, Leeds U, UK*

* Short presentations
Designing Green(er) Nanotechnology

Exploitation of the validated knowledge and tools from global nanosafety research to design both products and processes that quantitatively minimise negative impacts &/or maximise benefits for the environment

NB: Nanomaterials have one or more dimensions between 1-100 nm
Analysis of 50 FP7 Nano EHS Projects in Relation to EC Strategy for REACH

REACH & CLP
Regulation, Classification, Labelling, & Packaging of Nanomaterials

New ENPs Submitted For regulatory testing
REACH & CLP Approval

European Industry
Development & Scale up of novel nanomaterials

“Safe-by-design” Products & processes
“Safe-by-design” Modelling
“Safe-by-design” Modelling

Key:
- Nanomaterials hazard and risk research and Innovation projects
- Nanomaterials hazard and risk infrastructure development projects
- Quantitative Structure Activity Analysis (QSAR)
- NanoFutures European Technology Platform (11 Industry Sectors Input into nanosafety research needs)

Marina
Qnano
Hazard & Exposure
NanoReg
ITS_Nano
Research Infrastructure
Regulatory Testing Infrastructure

SUN
Modena
NanoReg-2

UNIVERSITY OF LEEDS
What TRLs are:
a) nanotechnology and b) nanosafety translational research currently at?

<table>
<thead>
<tr>
<th>CATALYST Phase</th>
<th>CATAPULT Phase</th>
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<tbody>
<tr>
<td>TRL 1</td>
<td>TRL 7</td>
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<tr>
<td>Basic principles...</td>
<td>System prototype...</td>
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<tr>
<td>observed and reported</td>
<td>demonstrated in an...</td>
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<tr>
<td>Technology concept...</td>
<td>operational environment</td>
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<tr>
<td>and/or application</td>
<td>Actual system completed...</td>
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<tr>
<td>formulated</td>
<td>and qualified through...</td>
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<tr>
<td>Analytical and...</td>
<td>Actual system proven...</td>
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<td>experimental...</td>
<td>through successful...</td>
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<tr>
<td>critical function...</td>
<td>operations</td>
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<tr>
<td>and/or</td>
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<tr>
<td>Characteristic</td>
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<tr>
<td>proof of concept</td>
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<td>Component...</td>
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<td>and/or validation...</td>
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<td>in laboratory...</td>
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<td>Component...</td>
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<td>and/or validation...</td>
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<td>in relevant...</td>
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<tr>
<td>System model...</td>
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<tr>
<td>or prototype...</td>
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<tr>
<td>demonstration in a...</td>
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<td>relevant environment</td>
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<td>demonstration in an...</td>
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<td>operational environment</td>
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<tr>
<td>TRL 3</td>
<td>TRL 8</td>
</tr>
<tr>
<td>TRL 4</td>
<td>TRL 9</td>
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</table>

Many innovations fail here

Product & process R&I

Nanosafety R&I

Greener by Design

Diverse research, innovators, entrepreneurs, industry & investors collaborators
CIRCULAR ECONOMY

H2020 NMBP Industrial Technologies R&I Programme Objective

- no longer linear
- extended life time
- collaborative approach
- cross-sectors
- multi-stakeholders
- innovation in all forms
- design strategies
- new business models
- demand-side measures
- etc...
Designing Green(er) Nanotechnology

- QSAR Products
- Processes
- Treatment
- Remediation

Physicochemical data
Hazard data

Multi-vartiate statistical process control

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Plasma Enhanced Chemical Vapor Deposition

Diamond-like Carbon Coating

Nano-Dynamic Lubricant Systems
FP7 2020 Interface Project (TRANSPORT)

Car Engine components

Note:

Migrating Innovation from one sector to another!

FP7 2020 Interface
- €2.8M
- 3 years
- Market in 2 years

FP7 LifeLongJoints (NMP)
- €15.4M
- 5 years
- Ready for first in man

20% increase in fuel efficiency

Triggers nano-layering of lubricant
HFC Refrigerant Gas Manufacturing

In 1995

Closed loop control system

Chemical engineering Design models

KLEA 134a
Hydrofluoroethane

NB: Measures all reactants & products at T=200°C & P= 200 psi in an atmosphere of HF (75%) and HCl (25%)

Ozone layer hole repairing (due to HFCs replacement of CFCs)
UN Environment Panel Sept 2014

NB: HFC Sales €15Bn/year
Life Cycle Assessment of Nanomaterials and Nanoproducts

1st Sustainable Nanotechnology School

Dipl. Ing. Michael Steinfeldt
Venice, 12th January 2015
Nanotechnology-based products / applications on the market (II)

- Conductive polymers (organic metals)
- Abrasion resistance
- Easy-to-clean coating
- Corrosion protection coating
- Anti-reflex coating
- UV-protection coating
- Non-stick coating
- Wear protection coating
- Scratch-resistant coating
- Catalytic-clean coating
- Anti-microbial technical facilities
- Polymers with better rheology
- Flame retardants
- Wear protection lubricants
- Ferrite adhesives
- Process catalysts
- Special cements, nanoelektronics
- Abrasion-resistant car tires
- Water storing granulates
- Conductive foils
- Fuel additives
- OLEDs
- Lighting - LEDs
- Insulation, aerogels
- Ceramic separators, Li-ion batteries
- Photovoltaics, thin film

Integrated Nano-Innovations, process- / product-integrated

Nano-Innovations, energy related solutions

Efficiency

Storage

Conversion

University of Bremen
Overview of studies of published LCAs of the manufacture of nanoparticles and nanocomponents

- only 35 publications: “LCA” of Nano-Applications

- only 15 publications: “LCA” of the manufacture of nanoparticles and nanocomponents
Nanotechnology for contaminated land Remediation

University of Stuttgart, USTUTT – VEGAS
Hans-Peter Koschitzky
Nano particles for *in situ* remediation

- Small size
  - higher surface area
  - more reactive
- NPs (in a carrier fluid) injected into saturated zone via wells
- Focus on source treatment
- Applicable below buildings
- “independent” of application depth
- „semi-passive“ technology
- particles e.g. nZVI
- innovative technology
NanoRem Structure

Taking Nanotechnological Remediation Processes from Lab Scale to End User Applications for the Restoration of a Clean Environment

**Project Structure**

Sustainable Nanotechnology Conference Venice, 9-11 March 2015

NanoRem short overview
# NanoRem Pilot Sites

<table>
<thead>
<tr>
<th>Site</th>
<th>Country</th>
<th>Site Primary Investigator</th>
<th>Target Cont.</th>
<th>NP-Type</th>
<th>Reaction Principle</th>
<th>Aquifer</th>
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<tr>
<td>Zurzach</td>
<td>CH</td>
<td>Solvay</td>
<td>CHC</td>
<td>milled nZVI</td>
<td>Reduction/Sorption</td>
<td>porous / unconfined</td>
</tr>
<tr>
<td>Spolchemie 1</td>
<td>CZ</td>
<td>Aquatest</td>
<td>CHC</td>
<td>NANOFER 25s</td>
<td>Reduction</td>
<td>porous / unconfined</td>
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<tr>
<td>Spolchemie 2</td>
<td>CZ</td>
<td>Aquatest</td>
<td>BTEX</td>
<td>Iron-Oxide</td>
<td>Oxidation/microbial Enhancement</td>
<td>porous / unconfined</td>
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<tr>
<td>Barreiro</td>
<td>PO</td>
<td>GeoPlano</td>
<td>HM</td>
<td>Iron-Oxide</td>
<td>Immobilisation</td>
<td>porous / unconfined</td>
</tr>
<tr>
<td>Besor-Secher Neot Hovar</td>
<td>IS</td>
<td>Negev, BGU</td>
<td>CHC</td>
<td>air-stable nZVI NANOFER STAR*</td>
<td>Reduction</td>
<td>fractured</td>
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<tr>
<td>Balassagyarmat</td>
<td>H</td>
<td>Golder</td>
<td>CHC</td>
<td>Carbo-Iron</td>
<td>Reduction / Soption</td>
<td>porous / unconfined</td>
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<tr>
<td>Bizkaia</td>
<td>ES</td>
<td>Tecnalia</td>
<td>HM</td>
<td>Iron-Oxide</td>
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Panel discussion topics:

- Definition of “Green nanotechnology in Sustainable nanotechnology”?
  - Greener by design principle for products and processes
  - Nanotechnology to address big environmental issues (Ozone layer, energy global warming etc.)
  - Nanotechnology for environmental remediation
- Where are the gaps in science and translational research?
- What new challenges are there for regulators and industry?
- Addressing ethical and public dialogue issues?
- What should our priorities be for future collaborative projects?
Cataract Eye Surgery…

.........a Personal View of “Green by Design”

Jan 2009

Aug 2009

Diffraction Lens Cross-section (~100 nm steps)