Nanotechnology and Sustainable Development in The Arab world

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Outline

➤ Introduction to Nanotechnology
➤ Nanotechnology and Sustainable Development in The Arab World
➤ Potential Applications of Nanotechnology
  ➤ Photo catalyst for Water Treatment
  ➤ Nanotechnology for Thermal insulation- Aerogel
  ➤ Nanotechnology for cultural Heritage
➤ Conclusions
Top Problems for The Next 50 Years

2003 6.3 Billion People

2050 10 Billion People

Arab world is no exception
What is Sustainability??

• Sustainable development is generally defined as “development, which meets the needs of the present without compromising the ability of future generations to meet their own needs”

• “enable all people to meet their basic needs and improve their quality of life, while ensuring that the natural systems, resources and diversity upon which they depend are maintained and enhanced both for their benefit and for that of future”
Major Industrial Revolutions

- Micro-electronics
- Biotechnology
- Nanotechnology

R&D / Market vs. Year (1950-2010)
Nanotechnology Everywhere

Any given search engine will produce 1.6 million hits

An animated film in China

Nanotechnology Scientist: Willem Dafoe in Spiderman
Rapid Growth of Nanotechnology

International Government Funding

➤ Rapid growth of funding and public awareness since the year 2000.
➤ >3 billion $ by 2004.
➤ excellent opportunities for research & development

Scientific Publications

➤ Rapid growth; by 2004: already ~5% of articles in high impact factor journals are “nano”

exponential?
What is So Special About Nanotechnology?
Nanotechnology is on the way to becoming the FIRST trillion dollar market.

Nanotechnology influences almost every facet of everyday life such as energy, clothes, environment, buildings and medicine.
Projected Nanotechnology Market

WORLD MARKET INCORPORATING NANOTECHNOLOGY (billion USD)

- USD 40 bn (2000)
- USD 120 bn (2005)
- USD 250 bn (2010)
- USD 1 trillion by 2015
- USD 3 trillion by 2020

World annual rate of increase ~ 25%; Double each ~ 3 years

Source: Journal of Nanoparticle Research 2011, Mihail C. Roco
Combination of Nanotechnology, Information technology and biotechnology leads to new development in genomics, drug discovery, gene sequencing.
...and the Promising Role of Nanotechnology

Nanotechnology promises:

• Meet Energy demand
• Water treatment,
• Improve food supply
• Improve environmental technologies (treatment, remediation, sensing)
• Improve manufacturing processes (efficiency, waste reduction)
• Reduce gas Emission
• Improve drug development and delivery, medical diagnosis
• Treat Cancer.
What is Nanotechnology? And How Nanotechnology can help?

- **Nanotechnology**: is the art, design, fabrication, characterization, and utilization of materials, structures, and devices, which are less than one hundred nanometers.

- **Nanoscience**: The study of the fundamental principles of molecules and structures with at least one dimension roughly between 1 and 100 nanometers.

  “NSF”
What is Nano? How small is A Nanometer?

10^{-9} m

Or a Nanometer (nm) is one billionth of a meter

1 nm = \frac{1}{1\text{,}000\text{,}000\text{,}000} \text{ m}

“Nano” – Greek word
Means “dwarf”

iPod Nano

80,000 nm

1.27 \times 10^7 \text{ m}

12,756 \text{ Km}

10 millions times smaller

22 cm

0.22 m

1 billion times smaller

0.7 \times 10^{-9} \text{ m}

0.7 nm
The decrease of the size and the increase in surface area to volume ratio alters the mechanical, thermal, and catalytic properties of materials.

What Happened at the Nanoscale?

High Surface area & High Chemical Reactivity

The decrease of the size and the increase in surface area to volume ratio alters the mechanical, thermal, and catalytic properties of materials.
Thanks to Advanced microscopes, Now we Can Now See and Control Things at the Nano-Scale

**Scanning Probe Microscopy**


**Atomic Force Microscopy**
Nanotechnology enable sustainable communities by conserving resources, providing new ways to generate energy & potable water, and recycling waste.
Nanotechnology Applications

How might nanoscale science and engineering improve our lives?

**Information Technology**
- Smaller, faster, more energy efficient and powerful computing and other IT-based systems

**Energy**
- More efficient and cost effective technologies for energy production
  - Solar cells
  - Fuel cells
  - Batteries
  - Bio fuels

**Medicine**
- Cancer treatment
- Bone treatment
- Drug delivery
- Appetite control
- Drug development
- Medical tools
- Diagnostic tests
- Imaging

**Consumer Goods**
- Foods and beverages
  - Advanced packaging materials, sensors, and lab-on-chips for food quality testing
- Appliances and textiles
  - Stain proof, water proof and wrinkle free textiles
- Household and cosmetics
  - Self-cleaning and scratch free products, paints, and better cosmetics
Nanotechnology Consumer Products In the Market

Examples of current consumer products allegedly using nanotechnology

Source: Woodrow Wilson international Center for Scholars (www.nanotechproject.org/consumerproducts)
Top 10 Nanotechnologies for the developing world

1. Energy storage, production and conversion
2. Agricultural productivity enhancement
3. Water treatment and remediation
4. Disease diagnosis and screening
5. Drug delivery systems
6. Food processing and storage
7. Air pollution remediation
8. Construction
9. Health monitoring
10. Vector and pest detection and control

Arab countries spend just 0.3% of their gross domestic product (GDP) on science and technology, compared to 1-3% in other developing countries.

Average publication rate of Arab scientist is less than 1% of the world's peer-reviewed scientific articles.
Major investment in The Arab world in Education and Research

- Mega project such as Qatar Foundation (QF) and Science and Technology park (QSTP) in Qatar
- King Abdullah University of Science and Technology (KAUST) in Saudi Arabia
- Masdar Institute in UAE and other projects in other Arab counties.
Nanotechnology In The Arab World

Arab Industrial Organization Development and Mining (Arab initiative to adapt the Science and Nanotechnology and converging technologies)
## Summary of nanotechnology status in the Arab countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Population in millions [34]</th>
<th>Number of institutions conducting nanotechnology research</th>
<th>Number of nanotechnology-related publications¹</th>
<th>Total publications</th>
<th>Number of nanotechnology-related publications per million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saudi</td>
<td>26.5</td>
<td>11</td>
<td>44, 1398</td>
<td>1442</td>
<td>56</td>
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<tr>
<td>Tunisia</td>
<td>10.7</td>
<td>8</td>
<td>139, 418</td>
<td>557</td>
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<tr>
<td>Emirates</td>
<td>5.3</td>
<td>5</td>
<td>37, 190</td>
<td>227</td>
<td>43</td>
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<tr>
<td>Kuwait</td>
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<td>2</td>
<td>27, 58</td>
<td>85</td>
<td>33</td>
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<tr>
<td>Jordan</td>
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<td>2</td>
<td>44, 143</td>
<td>187</td>
<td>29</td>
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<tr>
<td>Egypt</td>
<td>83.6</td>
<td>4</td>
<td>385, 1634</td>
<td>2019</td>
<td>24</td>
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<tr>
<td>Oman</td>
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<td>62</td>
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<tr>
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<tr>
<td>Morocco</td>
<td>32.3</td>
<td>1</td>
<td>45, 142</td>
<td>187</td>
<td>6</td>
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</tbody>
</table>

¹The number of publications in peer-reviewed journals in the topics related to nanoscience and nanotechnology during the period January 2002 to March 2013. The data obtained searching for the phrase ‘nano’ in the title using the Scifinder database.

> **New Era in Arab Nanotechnology**
Arab World Market

- Fastest developing economies in the world
- Total Arab League GDP is estimated to be more than $2.3 trillion in 2011. Which make it world’s eighth largest economy in the world
- Middle class is growing to almost 44% of the region’s economy
- More than 150 million people with household consumption. 60% of the Arab countries
Energy

• Nanotechnology based solar cells can provide better conversion of sunlight to electricity, cheaper manufacturing cost, simple installation, easy manufacturing (paintable manufacturing processes) using flexible rolls.
• Nanotechnology can improve the efficiency of fuel production using nanocatalyst and increase fuel consumption efficiency in vehicles and power by reducing friction.
• Enables the production of new batteries such as lithium-ion battery which are less flammable, fast charging, high efficiency, with lighter weight, and a higher power density.
• Recycling of waste heat in many devices and processes such as computers, automobiles, and power plants to electrical power.
• Developing carbon nanotubes containing wires that reduces the resistance in the electric grid and thus reduce transmission power loss.
Nanotechnology in Medicine

- Enhancing medical imaging and diagnostics using semiconducting Nanocrystals called Quantum Dots in imaging techniques such as MRI and the conventional dyes and provide more information.
- Gold nanoparticles can be used to detect early-stage Alzheimer’s disease and cancer cells.
- Targeting to cancer cells and deliver the treatment without affecting normal tissues.
- Spur the growth of nerve cells such as damaged spinal cord or brain cells by injecting nanostructured gel to fills the space between cells and encourages new cells to grow or using nanofibers to regenerate damaged spinal nerves.
- Using microfluidic lab on a chip to monitor and manipulate individual cells and track the movements of cells and individual molecules.

Detecting Diseases Earlier
Using Quantum which dots glow in UV light “Could locate as few as 10 to 100 cancer cells”
http://www.whitaker.org/news/nie2.html

Thermal ablation of cancer cells using Nanoshells have metallic outer layer and silica core
National Cancer Institute
Nanotechnology in Water

• Achieving affordable and clean drinking water by rapid, cheaper detection of impurities in and filtration and purification of water. For example, using magnetic interactions between rust nanoparticles can remove arsenic or carbon tetrachloride from water.

• Development of photocatalytic materials for cleaning water using sun light energy

• Development of nanostructured filters capable of removing virus from water

• Development of nanotechnology sensitive sensors to detect and monitor contaminants in water.

• Development of Nanofibers membranes to remove salt from water.

• Development of highly porous electrodes made from nanomaterial that can be used in capacitive water desalination.
Nanotechnology in Chemical Industry

- Reducing the amount of platinum in the cars catalytic convertor.
- Using Nano photocatalysts such as Titanium and zinc dioxide in water treatment and air purification.
- Using Low temperature Nanocatalysts for petrochemicals to reduce energy consumption.
- Using Nanocatalysts to produce new chemicals and plastics.
- Produce fuel from air
- Using photocatalysts split water to produce hydrogen fuel.
- Using photocatalyst to break CO2 to carbon and oxygen using the sun light.
- Engineering of biodegradable plastic materials with super thermal, mechanical and electrical characteristics. For example, it can be make easy-to biodegrade plastic bags.
Nanotechnology in Environmental applications

- Using Nanomaterials to minimize the amount of noble metal but with the same catalytic performance.
- Using nanofibers filter media in automobile and airplanes industry And dust removal in many at industrial plants and gas turbines.
- Using Nano membranes for CO2 capture from power plant flue gases.
- Using Metal Organic Frameworks (MOFS) for CO2 absorption (these materials can absorb 9 times its weight)
- Using nanoscale titanium dioxide in cement photocatalytic active concrete surfaces can be produced for air purification in towns.
- Development of nanofabric "paper towel," woven from potassium manganese oxide wires, that can absorb 20 times its weight in oil for cleanup applications.
Nanotechnology in Oil & Gas

- Enhancing the performance and reliability of the drilling equipment by increasing the strength and durability under extreme conditions such as high-temperature and high-pressure.
- Using hydrophobic or hydrophilic Nanomaterials for water flood applications in drilling operation.
- Using Lightweight rugged Nanomaterials that reduce for offshore platforms, and more- energy efficient transportation vessels.
- Using Nano sensors and imaging techniques for extreme environment operations such as deep wells and provide data on reservoir environment and hence improve drilling cost.
Nanotechnology in Agriculture

- Develop Nanomaterials such as hydrogels that can be mixed with the soil and store water and prevent evaporation.
- Developed nanoscale powders of nutrition product that have a high surface area which make it easy to be absorbed.
- Develop new fertilizer particles to minimize the excess use of dangerous fertilizers.
- Developed new materials based on polymer-nanoparticles nanocomposites to be used in the water delivery systems
Nanotechnology in Food

- Development of biosensors for bacteria identification and food quality monitoring.
- Development of Nanomaterials and coating for intelligent, active, and smart food packaging.
- Development of anti-microbial agents such as silver nanoparticles for the surface of the coated film on the packaging.
- Development of Nanomaterials for Nano encapsulation of bioactive food compounds
Nanotechnology in Aerospace and Cars

- Develop lighter and stronger materials for aircraft to increase their performance and reduce energy consumption.
- Develop lighter and stronger materials for vehicles to make it faster and safer.
- Develop lubricant for combustion engines to reduce wearing and increase the heat resistant.
- Develop Nano coating for the outer parts of the airplanes and cars to reduce the drag force and hence reduce the fuel consumption.
- Develop Nano scratch resistance coating for cars.
Nanotechnology in Construction and Building

- Develop Nano sensors to monitor everything in the building.
- Utilized waste materials to create new sustainable Nanomaterials to be used in new buildings.
- Develop nanoparticle for anti-corrosion coating to prevent structural damage.
- Develop none flammable and thermal insulation materials and coating based on Nano clays and silica aerogels to reduce energy consumption and enhance the safety in buildings.
- Develop self-cleaning and photocatalytic coating to be used on the outer envelope of the building.
Nanotechnology in Textile

- Develop nanofibers to make functional textile such as water and stain-repellent or wrinkle-free.
- Develop heat resistance coating.
- Develop electrostatic resistance textile by integrate carbon nanoparticle membranes.
- Develop smart textile for monitoring of human body temperature and heart rate and solar chargers.
- Develop wound dressing textile which has silver nanoparticles as anti-bacteria agent.
Case study 1: Aerogel material for Thermal Insulation
Nanotechnology for Thermal Insulation and Green Building

Aerogel Translucent Insulation Panels
2022 FIFA World Cup

Anti-flammable Coating for Expanded Polystyrene (EPS)

Dr. Khaled Saoud – a physics professor from Virginia Commonwealth University in Qatar – remembers Challenge 22 experience.

Local scientist on how Challenge 22 turned dream to reality: Supreme Committee for Delivery &...
3D Printing of Ultra-Light and mechanically Strong Aerogel on Different Substrates using Low Power Visible Lasers with resolution of 10μm

Physical properties: Shrinkage: 10.4% Density: 0.56 g/cm³, Modulus: 81.3 Mpa, BET surface area: 155.3 m²/g

Laser Induced Instantaneous Gelation: Aerogels for 3D Printing

Shaukat Saeed, Rola Al Soubaihi, Massimo Bertino, Lauren White and Khaled Saoud,
Journal of Materials Chemistry A, 2015, DOI: 10.1039/c5ta04215a
Case Study 2: Silver/Zinc Oxide Photo catalyst (Ag/ZnO) for Waste Water Treatment
Antibacterial activity of Ag-ZnO Nanoparticles Under Light

Nanoparticles Under Light

ZnO under light

Ag/ZnO under light

Control (Dark spots are bacteria colonies)

ZNO Light (No bacteria colonies)

Control (Dark spots are bacteria colonies)

ZNO-Ag Light (No bacteria colonies)
Case Study 3: Mg(OH)$_2$ Nano Sheets
Reference paper and old paper treated with Mg(OH)$_2$ and Ca(OH)$_2$ Nano-particles

Ca(OH)$_2$  Mg(OH)$_2$

The pH value for old paper sample is 2.5 which rises to 8.5 in case of calcium hydroxide and to 10.5, in case of magnesium hydroxide sample.
Challenges for Technology Transfer

• Expensive analytical/quality control/facilities are required to set up a manufacturing plant for nanotechnology-based products.
• Lack of early involvement of industry partner in the technology development and transfer project and mutual trust.
• Industry lacks technology adoption capabilities and risk taking attitude.
• Lack of finance/capital and incentives to take up innovative and risky technology projects for commercialization.
• Industry is not aware of technologies available with laboratories and also not having enough funds to promote lab/industry interactions.
• Nanotechnology is highly interdisciplinary in nature, availability of skilled manpower in this area is also a major challenge to face the severe competition from multinationals.
The Future of The Arab world is in Your Hands

Investing in Nanoscience, and Nanotechnology holds a great potential for major improvement in the Arab world in many sectors such as products, technologies, and services. The Projected Nanotechnology Market will reach $2.6 trillion in 2015 and provides more than 7 million jobs.
Acknowledgment

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Lauren White (PhD student)
Thank you
Questions???