Nanoscience and Nanotechnology from an Indian Perspective

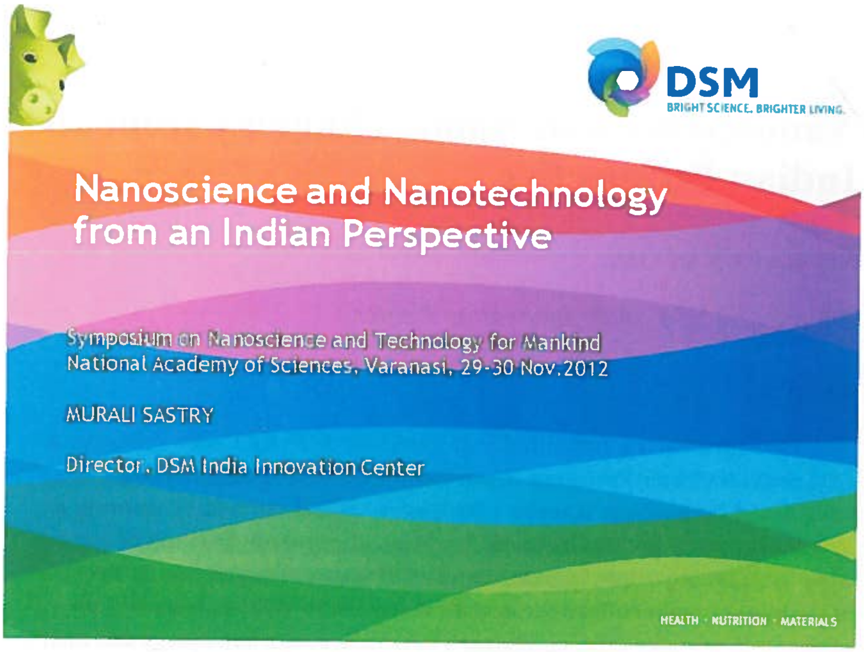
MURALI SASTRY

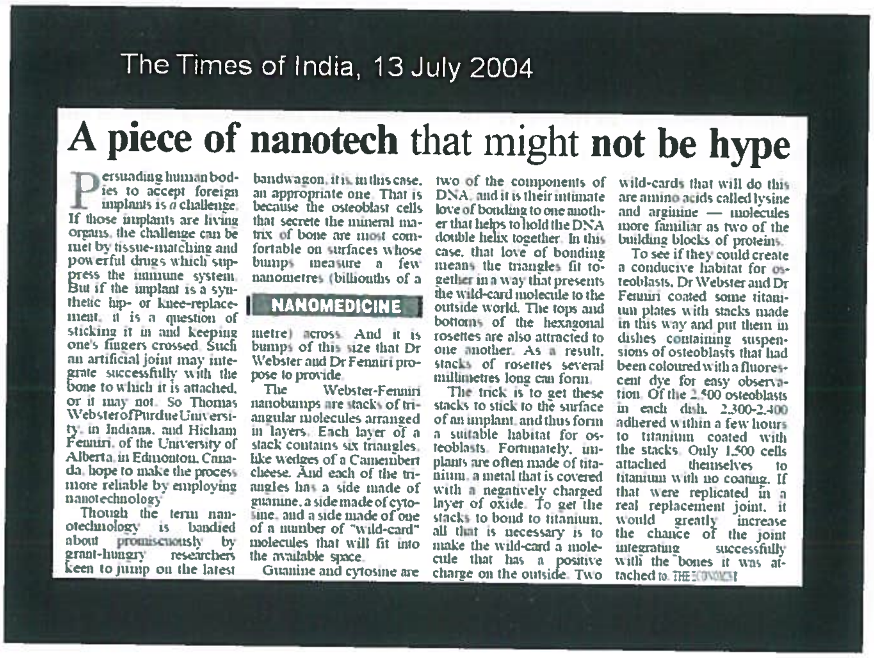
Director, D.S.M. India Innovation Center.

Abstract

Dr. Murli Sastry, Institute Chair Professor & INAE Chair Professor & C.V. Seshadri Chair Professor, Department of Chemical Engineering Indian Institute of Technology, Kanpur - Dr. Sastry started the talk by showing an article way back in 2004 entitled, "A piece of nanotech that might not be hype". According to him India is a country with a huge population and people at the bottom cannot afford the new technologies. He talked about the impact of nanotech or water need, agriculture, nutrition, health and energy and their affordability. The he explained the applications of nano-technology in energy storage; production and conversion, driving delivery systems, food processing and storage, Air pollution and remediation, health monitoring etc. He talked about the "Mitticod" use of clay and water for refrigeration in areas with no electricity. He explained the "Swach" model of Tata which used rice husk ash (RHA) and nano-silver as filters. He talked about the use of Nano-science and nano-technology which may be able to help country's economic growth. Finally the conclusion was an attempt to provide a balanced perspective of what this exciting branch of science and technology has to offer India in particular but mankind in general.

Keywords : nanosilver, rice husk ash, grassroots, innovation, drinking water.





The Times of India, 13 July 2004

A piece of nanotech that might not be hype

Persuading human bodies to accept foreign implants is a challenge. If those implants are living organs, the challenge can be met by tissue-matching and powerful drugs which suppress the immune system. But if the implant is a synthetic hip- or knee-replacement, it is a question of sticking it in and keeping one's fingers crossed. Such an artificial joint may integrate successfully with the bone to which it is attached, or it may not. So Thomas Webster of Purdue University, in Indiana, and Hicham Fenniri, of the University of Alberta in Edmonton, Canada, hope to make the process more reliable by employing nanotechnology.

Though the term nanotechnology is bandied about promiscuously by grant-hungry researchers keen to jump on the latest bandwagon, it is, in this case, an appropriate one. That is because the osteoblast cells that secrete the mineral matrix of bone are most comfortable on surfaces whose bumps measure a few nanometres (billionths of a metre) across. And it is bumps of this size that Dr Webster and Dr Fenniri propose to provide.

NANOMEDICINE

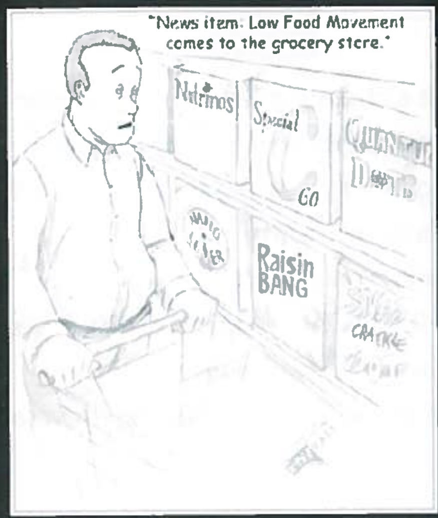
The Webster-Fenniri nanobumps are stacks of triangular molecules arranged in layers. Each layer of a stack contains six triangles, like wedges of a Camembert cheese. And each of the triangles has a side made of guanine, a side made of cytosine, and a side made of one of a number of "wild-card" molecules that will fit into the available space.

Guanine and cytosine are two of the components of DNA, and it is their intimate love of bonding to one another that helps to hold the DNA double helix together. In this case, that love of bonding means the triangles fit together in a way that presents the wild-card molecule to the outside world. The tops and bottoms of the hexagonal rosettes are also attracted to one another. As a result, stacks of rosettes several millimetres long can form.

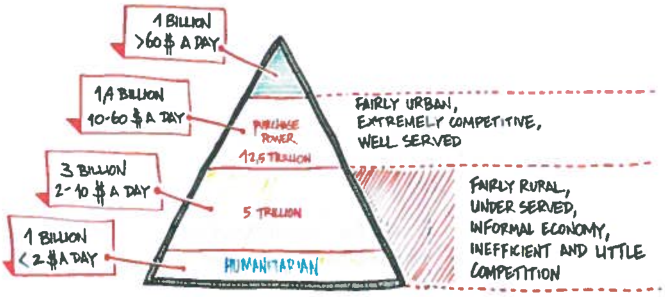
The trick is to get these stacks to stick to the surface of an implant, and thus form a suitable habitat for osteoblasts. Fortunately, implants are often made of titanium, a metal that is covered with a negatively charged layer of oxide. To get the stacks to bond to titanium, all that is necessary is to make the wild-card a molecule that has a positive charge on the outside. Two wild-cards that will do this are amino acids called lysine and arginine — molecules more familiar as two of the building blocks of proteins.

To see if they could create a conducive habitat for osteoblasts, Dr Webster and Dr Fenniri coated some titanium plates with stacks made in this way and put them in dishes containing suspensions of osteoblasts that had been coloured with a fluorescent dye for easy observation. Of the 2,500 osteoblasts in each dish, 2,300-2,400 adhered within a few hours to titanium coated with the stacks. Only 1,500 cells attached themselves to titanium with no coating. If that were replicated in a real replacement joint, it would greatly increase the chance of the joint integrating successfully with the bones it was attached to. THE ECONOMIST

On a lighter note, nano will be everywhere……



Where Innovation could have the most impact



Report to the secretary general of United Nations: by Commission on The Private Sector & Development

4 billion people at the bottom of the pyramid, mainly in the developing world.

Technology focused on the needs of the 'bottom-of-the-pyramid' makes business sense and addresses the UN-MDGs.

UN-Millennium Development Goals (UN-MDGs)

1. Eradicate extreme poverty and hunger
2. Achieve universal primary education
3. Promote gender equality and empower women
4. Reduce child mortality
5. Improve maternal health
6. Combat HIV/AIDS, malaria & other diseases
7. Ensure environmental sustainability
8. Develop a global partnership for development

The Millennium Development Goals Report 2007

UN - MDGs & Nanotechnology

Impact. How much difference will the technology make in improving water, agriculture, nutrition, health, energy and the environment in developing countries?

Burden. Will it address the most pressing needs?

Appropriateness. Will it be affordable, robust and adjustable to settings in developing countries and will it be socially and culturally and politically acceptable?

Feasibility. Can it realistically be developed and deployed in a time frame of ten years?

Knowledge gap. Does the technology advance quality of life by creating new knowledge?

Indirect Benefits. Does it address issues such as capacity, building and income generation that have indirect, positive effects on developing countries?

Singer et al, PLOS Medicine, Vol 2, e97, May 2005

Nanotechnology & the developing world

Ranking	Applications of Nanotechnology	Examples
1	Energy Storage, Production and Conversion	Novel Hydrogen Storage Systems based on carbon nanotubes and other light weight nanomaterials Photovoltaic cells and organic light emitting diodes based on quantum dots, Carbon nanotubes in composite film coatings for solar cells, Nano catalysts for hydrogen generation
2	Agricultural Productivity Enhancement	Nanoporous Zeolites for slow release and efficient dosage of water and fertilizers for plants, and of nutrients and drugs for livestock, Nanocapsules for herbicide delivery, Nanosensors for soil quality and for plant health monitoring, Nanomagnets for removal of soil contaminants

PLOS Medicine, Vol 2, e97, May 2005

Ranking	Applications of Nanotechnology	Examples
3	Water Treatment and Remediation	Nanomembranes for water-purification, desalination and detoxification, Nanosensors for the detection of contaminants and pathogens, Nanoporous zeolites, Nanoporous polymers and attapulgite calys for water purification, Magnetic Nanoparticles for water treatment and remediation, TiO_2 nanoparticles for the catalytic degradationwater treatment
4	Disease diagnosis and Screening	Nanoliter systems (Lab-on-a-chip) Nanosensor arrays based on carbon nanotubes, Quantum dots for disease diagnosis, Magnetic nanoparticles as nanosensors, Antibody-dendrimer conjugates for diagnosis of HIV-1 and cancer, Nanowire and nanobelt nanosensors for disease diagnosis, Nanoparticles as medical image enhancers

PLOS Medicine, Vol 2, e97, May 2005

Ranking	Applications of Nanotechnology	Examples
5	Drug Delivery Systems	Nanocapsules, liposomes, dendrimers buckyballs, nanobiomagnets and attapulgite clays for slow and sustained drug release systems.
6	Food Processing and Storage	Nanocomposites for plastic film coatings used in food packaging Antimicrobial nanoemulsions for applications in decontamination of food equipment, packaging or food nanotechnology based antigen detecting biosensors for identification of pathogen contamination.
7	Air Pollution and Remediation	TiO_2 nanoparticles-based photocatalytic degradation air pollutants in self cleaning systems, Nanocatalysts for more efficient, cheaper and better-controlled catalytic converters, Nanosensors for detection of toxic materials and leaks gas separation nanodevices.

PLOS Medicine, Vol 2, e97, May 2005

Ranking	Applications of Nanotechnology	Examples
8	Construction	Nanomolecular structures to make asphalt and concrete more robust to water seepage, Heat resistant nanomaterials to block ultraviolet and infrared radiation, Nanomaterials for cheaper and durable housing, surfaces, coatings, glues, concrete and heat and light exclusion, self cleaning surfaces with bio-active coatings.
9	Health Monitoring	Nanotubes and nanoparticles for glucose, CO_2 and cholesterol sensors and for in-situ monitoring of homeostasis.
10	Vector and pest detection and control	Nanosensors for pest detection, Nanoparticles for new pesticides, insecticides and insect repellents.

PLOS Medicine, Vol 2, e97, May 2005

Nanotechnology – can it bridge the north – south divide or the south – south divide ?

Earlier technology revolutions such as those involving Biotechnology & Information Technology lead to a North-South Divide between the Haves and Have-nots of the world

However, Nanotechnology may offer a more level playing field in terms of trained manpower & resources

With increasing number of highly trained scientists choosing to stay home and their governments chipping-in with funds, many developing nations such as China, South Korea, India, South-Africa, Brazil & Mexico are closing the gap with developed nations in Nanotechnology research

- China ranks third in Nanotech publications, just behind the US & Japan
- China & India amongst top 10 nanotech publishing nations * and spend 1.1 % & 1.2 % of their GDPs respectively, on Science & Technology #
- These developing economies constitute the largest world markets

* R. Kostoff, Scientist 18 (18), 10 (27 September 2004) # Economist (5 to 11 March 2005), p. 9.

What might these new paradigms be ?

- A clear understanding of the NEEDS of the BoP a must; definition of constraints/assumptions much more complex than other market segments
- Using traditional knowledge a good starting point (MittiCool); traditional knowledge + modern S&T can be greater combination (Tata Swach, psoriasis treatment discovery)
- What will work in India - Frugal Innovation driven products/Gandhian Engineering - move from M4M to M4L4M (Dr R A Mashelkar & Prof C K Prahalad, HBR)
- Develop methodologies for products/services at GGL (Krishna Palepu, HBS - Winning in Emerging Markets : A Road Map for Strategy and Execution)
- Examples of M4L4M

1) MittiCool 2) Tata Swach 3) Jaipur Foot
4) GE's MACi 5) Sachets 6) ITC's e-Choupal
7) Tata Nano......

DSM BRIGHT SCIENCE. BRIGHTER LIVING.

Sustainable grassroots Innovation - MittiCool

- Boundaries of the sandbox -

  1) Must be able to able to enhance shelf-life and perishables by at least one week
  2) Cannot use electricity !
  3) Must be cost effective, in the ultra low cost segment
  4) Difficult to classify - LLL ?

- Solution

  1) Use traditional knowledge and find new application (Matka technology)
  2) Functional design resembling a fridge - can sustain ~ 7 °C temperature drop by pure water evaporation
  3) Use locally available material (clay) to keep costs low
  4) Clearly understand the needs of the BoP - increasing shelf-life by 5-7 days a big win for BoP. 15 °C/4°C not required !
  5) Where science can meet tradition - anti-microbial coatings for the clay to enhance shelf-life further ?

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Nanotechnology to address a national need

Bringing safe, affordable drinking water to India – the Swach story

When is the "world water day"?

Drinking water problem in India

- 75% of the rural population in India does not have access to safe drinking water
- 80% of diseases and 33% of deaths are caused by unsafe drinking water
- An estimated 400,000 children in India under five years of age die each year due to diarrhoea
- There are about 6,00,000 primary schools in rural India
  - Safe water is not available in 50% of the schools

- *No standard water treatment system is available in rural India*

The challenge

To make safe drinking water accessible to millions of people

Tata Swach was unveiled on 7th Dec 2009

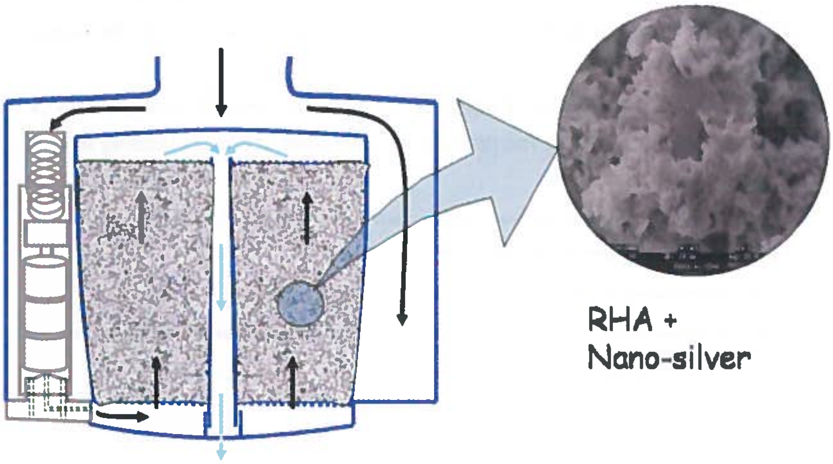
Features of Swach

- Purifies 3000 lit of water – removes bacteria & viruses
- Tested across national and international labs against challenge levels prescribed by the USEPA
- Attractive models at entry points of Rs.999 & Rs.749
- Replacement cost of Rs.299/- for 6 months

An ambitious goal of eventually providing access to safe drinking water to the entire nation

Tata Swach (Crystal)

Cartridge internals



Rice-husk-ash (RHA)

- Naturally occuring mesoporous substance
- An abundantly available agri-waste
- 80-90% active silica
- Large surface area for interaction ~ 25-50 m^2/gm

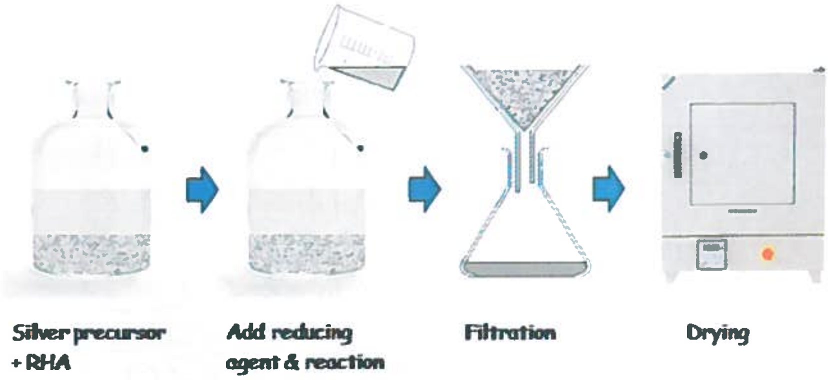
Nano-silver

- Silver is a potent biocide while being completely safe to humans
- Silver ions have the highest level of antimicrobial activity of all the heavy metals
- The bactericidal efficacy of silver is through the strong binding with S-S and -SH groups found in the proteins of microbial cell walls leading to cell death
- Nano-silver has a positive ion cluster and can be kept stable with no change of properties from any chemical reaction
- Nano-silver very slowly dissolves in water releasing Ag^+ ions
- The enormous area / volume ratio of nanoparticles provides for numerous local sites for interaction with microbes

The challenge

How to combine nano-silver with RHA for maximum availability and minimum leaching ?

Coating methods by TCL-IC – In-situ synthesis

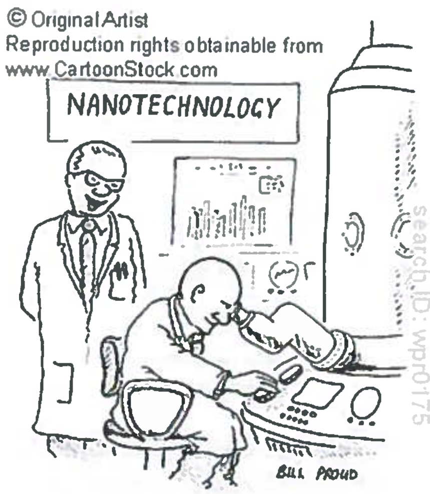


About at dozen different coatings made at TCL-IC and sent to TCS-TRDDC

Summary

- Tata Swach is a good example of R&D collaboration between three Tata companies (TCL-TCS-Titan)
- One company may not have the capabilities to attack all dimensions of a real-world problem
- TCL, TCS and Titan brought complementary competencies (nanotechnology/productization & testing) to the table
- Can be a good example for future R&D collaboration between companies on innovation

Just for laughs ....



"If you increase the magnification another million times you can see the safety regulations."


Our purpose is to create brighter lives for people today and generations to come.
Thank you
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