# Presentation of Nanotechnology Roadmap (2012-2016)

Erwin P. Enriquez, PhD Chemistry / Materials Science & Engineering Program Ateneo de Manila University



# Outline

- Definition
- Why Nanotechnology
- Nanoscience in a nutshell
- Philippines' Roadmap (2012-2016)
- Local Capabilities



# Definition

# NANOTECHNOLOGY

 $1 \text{ nm} \equiv 10^{-9} \text{ m} = 0.00000001 \text{ m}$ 1 atom ~ 0.1 nm diameter

for



meter dimensions

Deals with the *design, fabrication or synthesis, and manipulation* of matter with **dimensions within 100 nm** including processes that occur within these length scales.



Intel <sup>®</sup> Core <sup>™</sup> 8M Cache, up to 4.50	i7-7700K Processor		Add to Compare
Specifications	Essentials		Export specifications
Performance	Product Collection	7th Generation Intel® Core™	' i7 Processors
Supplemental Information	Code Name	Products formerly Kaby Lak	(e
Graph	e 🥐		Q1'17
Packa Advan	y 🕐		14 nm
Securi Recommen Ordering and Compliance	ded Customer Price ?	\$339.00 - \$350.00	\$339.00 - \$350.0

\*Wennersten et al. Handbook of Performability Engineering (2008)



Discover Magazine Top Nanotechnology in Consumer Products (2010)



By formulating their product with bits of **carnauba (palm-tree wax) that are only nanometers wide**, automotive cosmetics maker Eagle One says it's able to make a coating that always goes on clear.

\*Wennersten *et al.* Handbook of Performability Engineering (2008)



Discover Magazine Top Nanotechnology in Consumer Products (2010)



Clay nanoparticles allow Miller Brewing to bottle its beer in plastic containers. The tiny reinforcements keep oxygen out and hold carbon dioxide in, which prevents the brewed beverage from spoiling.

\*Wennersten et al. Handbook of Performability Engineering (2008)



Discover Magazine Top Nanotechnology in Consumer Products (2010)



### Gold nanoparticles can

make the pink "get ready to
be a parent" mark on home
pregnancy tests much
easier to read. When a
woman gets pregnant, her
body immediately starts
making the hormone
human chorionic
gonadotropin (hCG).

\*Wennersten *et al.* Handbook of Performability Engineering (2008)



Product of the Philippines

Air-cleaning and Self-sanitizing Anti-bacterial Protection Technology Odor-less and low VOC Water-based, lead-free and mercury-free Outstanding color retention Acrylic water-based Flat finish

BOYSEN KNOXOUT Air Cleaning Paint

BOYSEN<sup>®</sup> KNOxOUT<sup>™</sup> contains CristalACTiV<sup>™</sup> photocatalytic technology, which is **ultrafine titanium** dioxide, (TiO<sub>2</sub>) that absorbs energy from light and transforms ordinary water vapor into hydroxyl and peroxyl free-radicals at the surface of the  $TiO_2$ .

\*Wennersten *et al.* Handbook of Performability Engineering (2008)



## Nanoscience: unique properties in the nanoregime 0.923 Number of total atoms

R(n)

0.2

L.

0.03,



•

•

Nanomaterial

Quantum effects: size-tunable properties

under 'tension'

Large surface-to-volume

ratio: surface atoms are





Melting

Shells:

Gold Nanoparticles 2 nm  $\rightarrow$  20 nm

Surface Area-to-

Volume Ratio vs

Number of Atoms



Klabunde (2001). Copyright: Wiley-VCH Verlag GmbH & Co. KGaA.



NANOTECHNOLOGY R&D ROADMAP (2012-2016)

## PCASTRD (2008) PCIEERD

Dr. Reynaldo V. Ebora Dr. Amelia P. Guevara Dr. Rowena Cristina L. Guevara Dr. Carlos Primo C. David



Philippine Council for Industry, Energy and Emerging Technology Research and Development

# 2012-2015 Philippine Nanotechnology Roadmap



Chapter 1: Introduction: Nanotechnology for the Philippines, co-authored by Dr. Fabian M. Dayrit and Dr. Erwin P. Enriquez, with the assistance of Christian A. Malapit

Chapter 2: Applications of Nanotechnology in Food and Agriculture, authored by Dr. Milagros Peralta with contributions from Dr. Veronica Sabularse, Dr. Fortunato Sevilla, and Dr. Antonio Laurena, and with the assistance of Ruby Janet Ortiz

Chapter 3: Natural Nanomaterials for Polymers and Composites, authored by Dr. Blessie A. Basilia, Marissa A. Paglicawan, Josefina Celorico, and Richard Clemente

Chapter 4: Applications of Nanotechnology in Energy, authored by Dr. Erwin P. Enriquez with contributions from Dr. Jim Josephus G. Minglana and Dr. Guillermo M. Nuesca, and with the assistance of Ian Harvey J. Arellano

Chapter 5: Applications of Nanotechnology in Biomedicine, authored by Dr. Cynthia Saloma

Chapter 6: Applications of Nanotechnology in ICT and Semiconductors, authored by Dr. Arnel Salvador with contributions from Dr. Roland Sarmago and Dr. Armando Somintac, and with the assistance of Michael Defensor and Athan Azares

Chapter 7: Applications of Nanotechnology to the Environment, authored by Dr. Fabian M. Dayrit and Dr. Christina A. Binag, and with the assistance of Christian A. Malapit

Chapter 8: Safety and Risk Assessment in Nanotechnology, authored by Dr. Fortunato Sevilla III

Chapter 9: Education and Metrology in Nanotechnology, authored by Dr. Fabian M. Dayrit and Dr. Erwin P. Enriquez

Chapter 10: A Roadmap for the Development of Nanotechnology in the Philippines, authored by Dr. Fabian M. Dayrit

#### **Key Topics**

- Food and Agriculture
- Polymers and Composites
- Energy
- Biomedicine
- ICT & Semiconductors
- Environment
- Nanotechnology Risk
- Education

Health and <u>Envtl</u> Risk	Local need	UN MDG	Existing Local capability	Funding needed
5: Low	5: High	5: High	5: High	5: Small
1: High	1: Low	1: Low	1: Low	1: Large



## A Competitive Philippine Industry and Agriculture Through Nanotechnology





#### **CHEMICALS**

### **OUTPUTS**

 Nano- photocatalytic treatment of organic waste water and gaseous formaldehyde (March 2015)

Nanosilica as fluid in heat exchanger (December 2014)

- Nanosilica/siliceous materials for high-strength concrete/construction composite materials (January 2012)
- Nanoclays for commodity / engineering plastics,ceramics, flame retardants, coatings, packaging products (January 2012)

- Applications of nanosilica in production of nananofluid for heat exchanger
- Synthesis of photocatalysts with various dopants for the treatment of organic waste water and gaseous formaldehyde

2015

### S & T INVESTMENTS and ACTIVITIES

2016

## Highlights

- Nanophotocatalysts
- Nanosilica heat exchanger
- Nanocomposite
- Nanoclay-based materials

INNOVATION Store COUNCIL

#### FOOD AND AGRICULTURE

### **OUTPUTS**

#### Nanotechnology Center at UPLB (December 2016)

✤ Nanosensor for N, P and K soil nutrients (December 2016)

- Standards for food, beverage and nutraceuticals and for fertilizers, pesticides and other agrochemicals that contain nanomaterials (June 2016)
- Pilot-scale production of plant growth regulator for sweet pepper, coffee and other selected crops. (December 2015)
- Bench-scale application nanosilica for remediation and detection of arsenic-contaminated groundwater (December
- Behth-scale production of plant growth regulator for sweet pepper, tomato and coffee (December 2014)
- Bench-scale production of nanocomposite coating for papaya, bell pepper and mango (December 2014)
- Bench-scale production of biodegradable film for covering of mangoes in trees (December 2015)
- Bench-scale production of cellulosic nanocrystals from bamboo (December 2015)
- Purified lagundi and amplaya extracts (December 2015)
- Bench-scale application of nanosensors for ammonia (December 2015)
- Bench-scale production of food-grade nanoprecipitated calcium carbonate from local limestone (December 2014)
- Nanoencapsulated plant growth regulators derived from locally available plant growth promoting bacteria for high value crops production (December 2014)
   Nanobiosensor for detection of diseases in banana and abaca (December
- Nanobiosensor for detection of diseases in banana and abaca (December 2014)
- Nanosilica fertilizer for tomato (December 2014)
- DNA-based single and multiplex biosensors for pathogen detection using electrically active/magnetic nanoparticles (September 2014)
- Portable nanosensors for the rapid detection and measurement of microbial contaminants in food and water, chemical contaminants and EDCs using Molecularly Imprinted Polymers (September 2013)
- Nanoencapsulation of plant growth regulators derived from locally available plant growth promoting bacteria for high value crops production (January 2013)
- Nanoliposomes for controlled release applications for flavors and spices, nutraceuticals and cosmeceuticals (January 2012)

OR INDUSTRY, ENERGY AND EMERGING TECHNOLOGIES (DOST-PCIEER

#### Development and Optimization of nanosensor for the detection of soil nutrients production and efficacy

- Upscale production and efficacy tests of the nanoencapsulated plant growth regulators in selected high value crops.
- Optimization of nanosensor for the detection of soil nutrients and harmful gases
- Optimization of nanoprecipitated calcium
- carbonate for bench-scale food-grade application
   Production and optimization of molecularly imprinted polymers for the purification of natural compounds
- Establishment of a Center for Agrifood Nanotechnology (standards setting and monitoring using nanosensors for food safety and security)
- Optimization of nanosilica for application in arsenic detection and remediation, nanocomposite biodegradable films for coating of fruits and vegetables, cellulosic nanocrystals, and nanocomposite fertilizer
- Applications of nanosilica in arsenic detection and remediation, nanocomposite biodegradable films for coating of fruits and vegetables, cellulosic nanocrystals, and nanocomposite fertilizer
- Dev't of nanobiosensors based on magnetic and electrically active nanoparticles
- Production of nanobiosensors for the detection of ABTV, AMV in abaca and BBTW, BBMV in banana; and for the detection of pathogens in food and water
- Optimization of the nanoencapsulation of plant growth regulators for high value crops.

### S & T INVESTMENTS and ACTIVITIES

## Highlights

- Nanotech Center at UPLB
- Nanobiosensors
- Nanosensors
- Nano-standards for neutraceticals
- Nanosilica
- Nanocellulose
- Nano-precipitated CaCO<sub>3</sub>
- Nano-encapsulated
- Molecularly imprinted polymers
- Nanoliposomes

#### SEMICONDUCTORS

#### Nanostructured energy conversion and storage devices to target and develop innovations for the Philippines Highlights

Bench scale Production of

Nanocarbon-Based Catalysts for Biomass

Production of carbon from straight pyrolysis of

Synthesis and chemical modification of fullerene from local

S & T INVESTMENTS

ACTIVITIES

and

Nanostructured Solar Energy Devices

2016

٠.

**Conversion Processes** 

Nanotechnologies for Energy Conversion and Storage Devices

glycerol for ink applications

Materials Development for Nanostructured Solar Energy Devices (Solar Cells)

Engineering Process Technologies for Nanostructured Solar Energy Devices

(Batteries, Fuel Cell and Supercapacitors)

sources

### OUTPUTS

- Process technology for fabrication of nanostructured solar energy devices: scaling up process
- Direct ethanol fuel cell-powered LED emergency light (December 2016)
- Novel cathode material for direct ethanol fuel cell (December 2016)
- Biofuel from nano-carbon based catalysis of biomass (October 2016)
- Nanomaterials for printed electronic devices using carbon ink (September 2016)
- Platinum- and Palladium-based anode catalyst for direct ethanol fuel cell (June 2016)
- Carbon Nanotubes (CNT)-Silicon Heterojunctions for the Fabrication and Assembly of a Solar Panel (June 2016)
- Flexible Nanohybrid Supercapacitor Based on Conducting Polymers and Metal Oxides (December 2015)
- Fullerene-based nanomaterials for optoelectronic applications (December 2014)
- Carrageenan-based dye-sensitized solar cells (December 2014)
- GaAs Solar cells; photovoltaics, and bulk-heterojunctions solar cells; modification of graphene for nanostructured solar cells (March 2014)
- Nanolab at the Materials Science Division of ITDI (2014)
- ♦ Acquisition of TEM (2014)
- National Solar Cell R&D Testing Facility (January 2012)



 Fuel Cell applications

Nanolab at the

- Printed Electronics
- Fullerene, Carbon Nanotubes, Graphene
- Solar Cell applications
- Supercapacitors
- Optoelectronics applications

Equipment Acquisition

equipment

٠

Training of people for operation of the



# Capabilities

## • Research Expertise

- Nanomaterial synthesis and formulations: CNT, graphene, metallic, semiconductor (TiO<sub>2</sub>, Q-dots), nanoclays
- Nanocomposites: polymer-nanoclay, organic-inorganic hybrid materials, bio-sourced nanomaterials
- Nanosensors and biosensors: design and fabrication, testing
- Advanced characterization techniques

### Human Resources

- Faculty and fulltime researchers
- Graduate student scholarships and special grants (e.g., ADMATEL support)

### Instrumentation

- Composition (Auger, TOF-SIMS, FE-SEM/TEM-EDS, Powder XRD)
- Microscopy-Sizing (TEM, FE-SEM, SEM, AFM, Nano-sizers, DLS-Zetasizers)
- Fabrication (E-beam, MBE, CVD, Self-Assembly, Synthesis, Printing/Additive Manufacturing)

## Products/technologies

- Patent applications, IP reviews
- Commercialization evaluations and strategies
- Technology transfer support
- Industry linkages (e.g., TODAY)



# Thank you for your attention.

