Current Status of Nanotechnology Research and Trends in Korea

Prof. Haiwon LEE
Korea Nanotechnology Research Society
Asian Research Network Korea
Hanyang University

KoNTRS

ARN ASIAN RESEARCH NETWORK

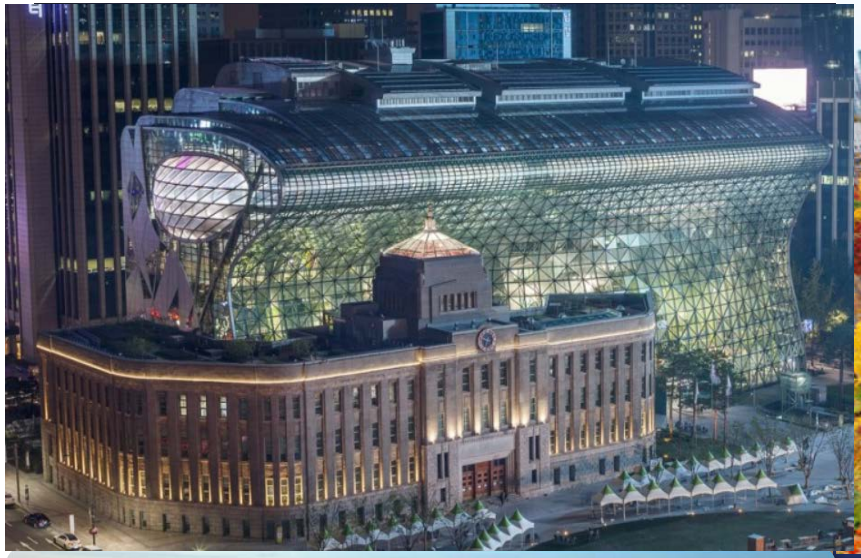
29/09/2014 11th US-Korea Nano Forum

Content

I. Introduction
   - Power of Korea, General Statistics
II. Government NT Policy and NT Statistics
III. Government Associated NT Institutions and Programs
   - Research Society, Infrastructure Network, Policy Center, R&D Programs, Nano Korea
IV. Government Associated Association and Programs for NT Commercialization
V. Network Globalization and Brain Mobility
VI. Research Activities

I Miracle on Han River

- **Overnight transformation** from the ashes of the Korean War to a wealthy developed country



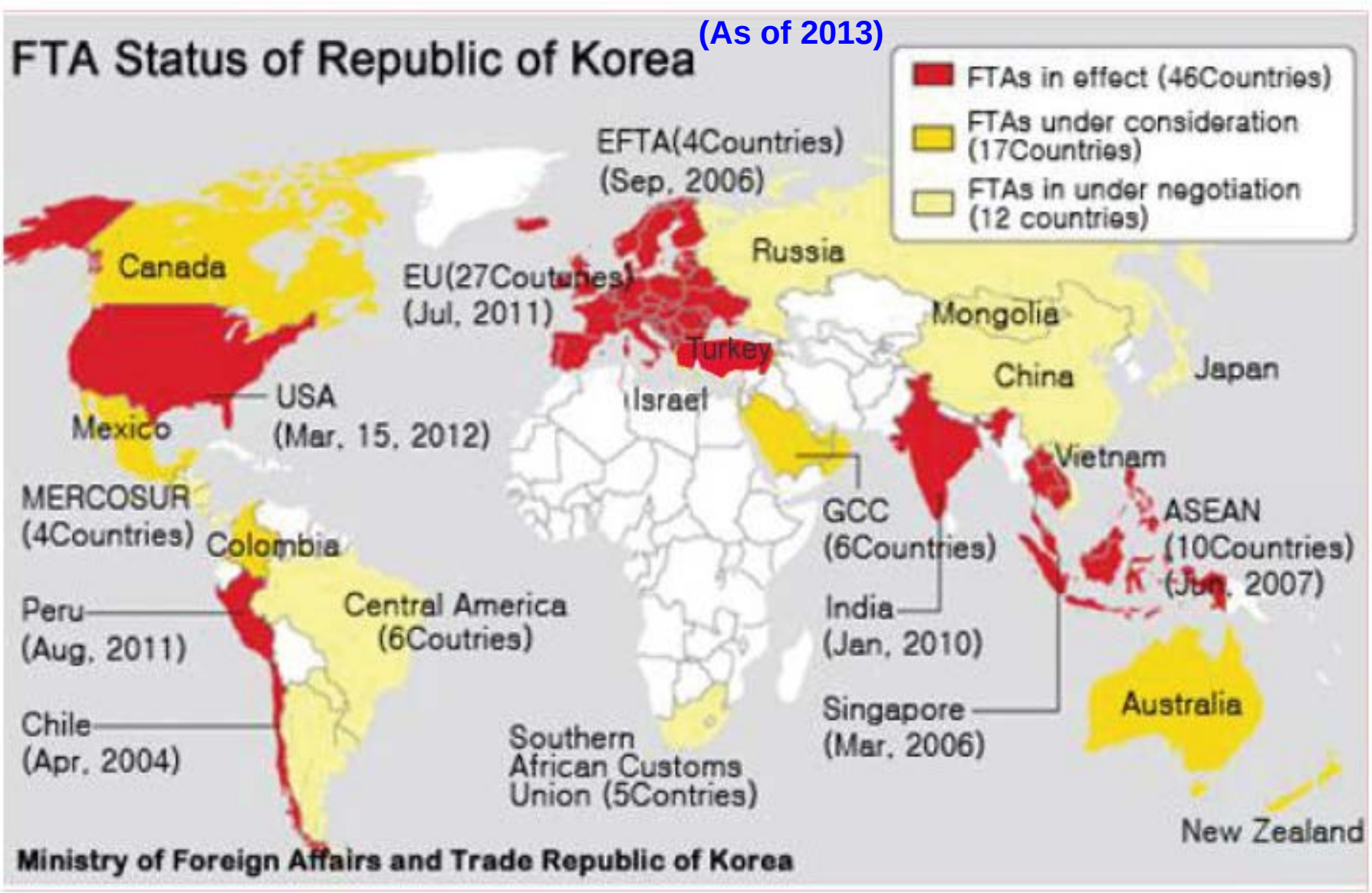
The Power of South Korea

PyeongChang will become the first Asian city outside of Japan to host the Winter Olympics in 2018.

I Engineering Manpower

I The Power of South Korea

Territory of Global Economy



The Most Innovative in the World

BLOOMBERG RANGKINGS in 2014

Rank	Country	Total Score
1	South Korea	92.10
2	Sweden	90.80
3	United States	90.69
4	Japan	90.41
5	Germany	88.23
6	Denmark	86.97
7	Singapore	86.07
8	Switzerland	86.02
9	Finland	85.86
10	Taiwan	83.52

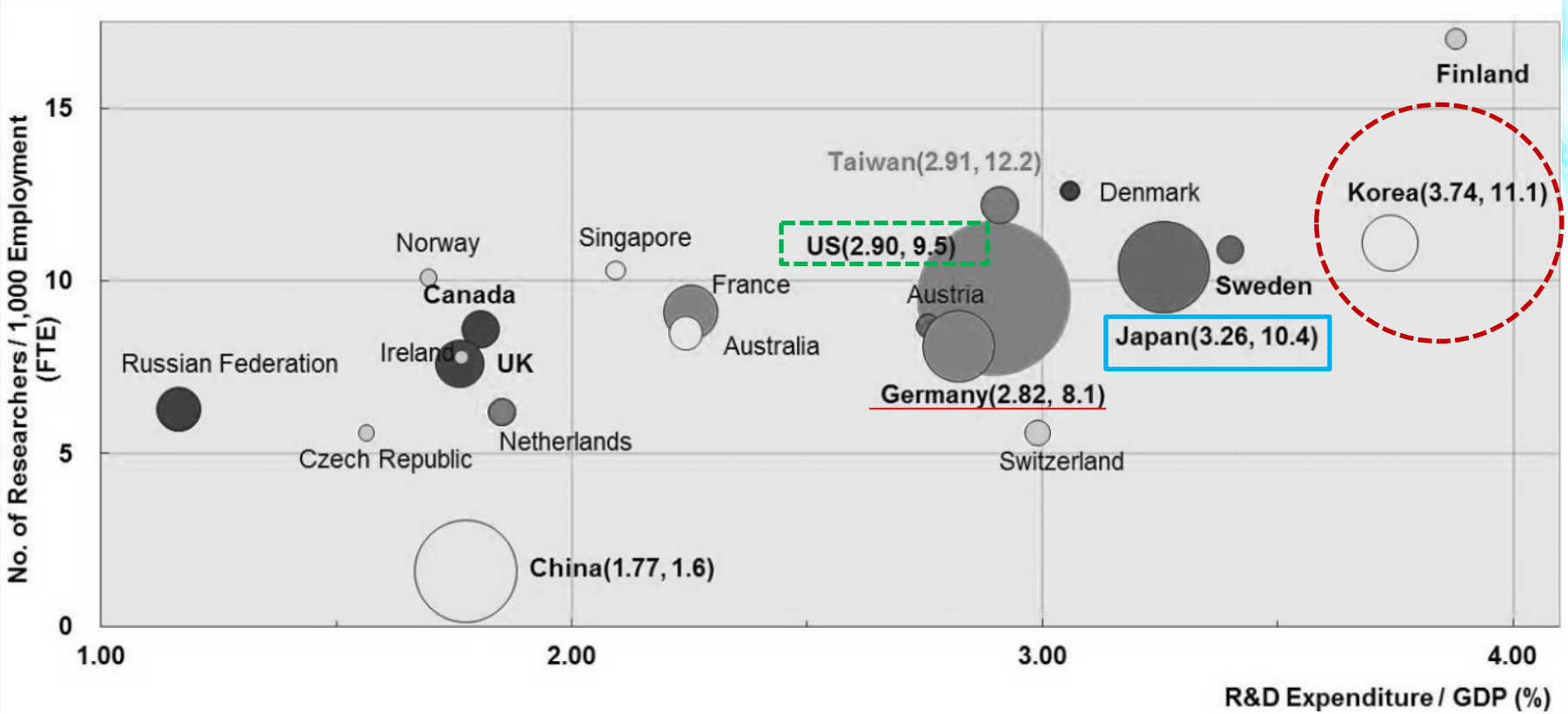
I Engineering Manpower and R&D Spending

Rank	Country	No. of Graduates in Engineering (Per Year)
1	Russia	417,343
2	Japan	195,670
3	United States	189,532
4	S. Korea	179,143
5	France	94,737
6	Mexico	59,117
7	Italy	56,428
8	Germany	55,998
9	Turkey	53,311
10	UK	52,798

Rank	Country	Exports (Unit : B$)
1	United States	$ 405.3
2	China	$ 296.8
3	Japan	$ 160.3
4	Germany	$ 69.5
5	S. Korea	$ 55.8
6	France	$ 42.2
7	UK	$ 38.4
8	India	$ 36.1
9	Canada	$ 24.3
10	Russia	$ 23.8

Source: *UNESCO Report-Engineering*, 2010

Comparison of the World's R&D Expenditure and Personnel



Source: ***Main Science and Technology Indicators*****. OECD, 2012/1.**

Note: 1. The circular areas stand for the amount of R&D expenditure which is divided by purchasing power parity (PPP).

2. The numbers beside each country name = (R&D expenditure/GDP (%), number of researchers per 1000 employment (FTE))

3. The data is of the year 2010 except the US one, which is of (2009, 2007).

National Nanotechnology Initiative Funding in U.S.

NSF FY 2015 Budget Request: $412

Agency	FY 2001 Actual	FY 2002 Actual	FY 2003 Actual	FY 2004 Actual	FY 2005 Actual	FY 2006 Actual	FY 2007 Actual	FY 2008 Actual	FY 2009 Actual	FY 2009 ARRA	FY 2010 Actual	FY 2011 Actual	FY 2012 Actual	FY 2014 Request
National Institutes of Health (DHHS)[a]	40	59	78	106	165	192	215	305	343	73	457	409	456	461
National Science Foundation	150	204	221	256	335	360	389	409	409	101	429	485	466	431
Department of Energy[b]	88	89	134	202	208	231	236	245	333	293	374	346	314	370
Department of Defense[c]	125	224	220	291	352	424	450	460	459		440	425	426	217
National Institute of Standards and Technology (DOC)	33	77	64	77	79	78	88	86	93	43	115	96	95	102
National Aeronautics and Space Administration	22	35	36	47	45	50	20	17	14		20	17	19	18
Environmental Protection Agency	5	6	5	5	7	5	8	12	12		18	17	18	17
Other Agencies	1	3	2	5	9	13	19	22	40		62	32	64	87
TOTAL[d]	464	697	760	989	1,200	1,351	1,425	1,554	1,702	511	1913	1,845	1,857	1,767

Source: NNI website. http://www.nano.gov/. Figures for FY2012 and FY2014 from *The National Nanotechnology Initiative: Supplement to the President's FY2014 Budget*, National Science and Technology Council, Executive Office of the President, May 2013.

- **In 2000, President Clinton launched the NNI** to coordinate federal R&D efforts and promote U.S. competitiveness in NT.
- U.S. Congress has approved ~ **$18.5B** (**FY 2001 ~ FY 2012**) for **NT R&D.**
- U.S. private sector NT R&D is now estimated to be twice that of public funding. The private sector's efforts are focused on translating fundamental knowledge and prototypes into commercial products; developing new applications incorporating nanoscale materials; and developing technologies, methods, and systems for commercial-scale manufacturing.

Source: *Congressional Research Service, Nanotechnology: A Policy Primer*, December 2013

Number of U.S. Granted Utility Patents* & Rank

Country	2007		2008		2009		2010		2011	
	grants	rank	grants	rank	grants	rank	grants	rank	grants	rank
US	79,526	1	77,502	1	82,382	1	107,792	1	108,626	1
Japan	33,354	2	33,682	2	35,501	2	44,813	2	46,139	2
South Korea	6,295	4	7,548	4	8,762	4	11,671	4	12,262	3
Germany	9,051	3	8,914	3	9,000	3	12,363	3	11,920	4

***Design Patents Excluded**

Source: *Indicators of Science and Technology*. *National Science Council*, 2012.

II Nanotechnology Policy in Korea

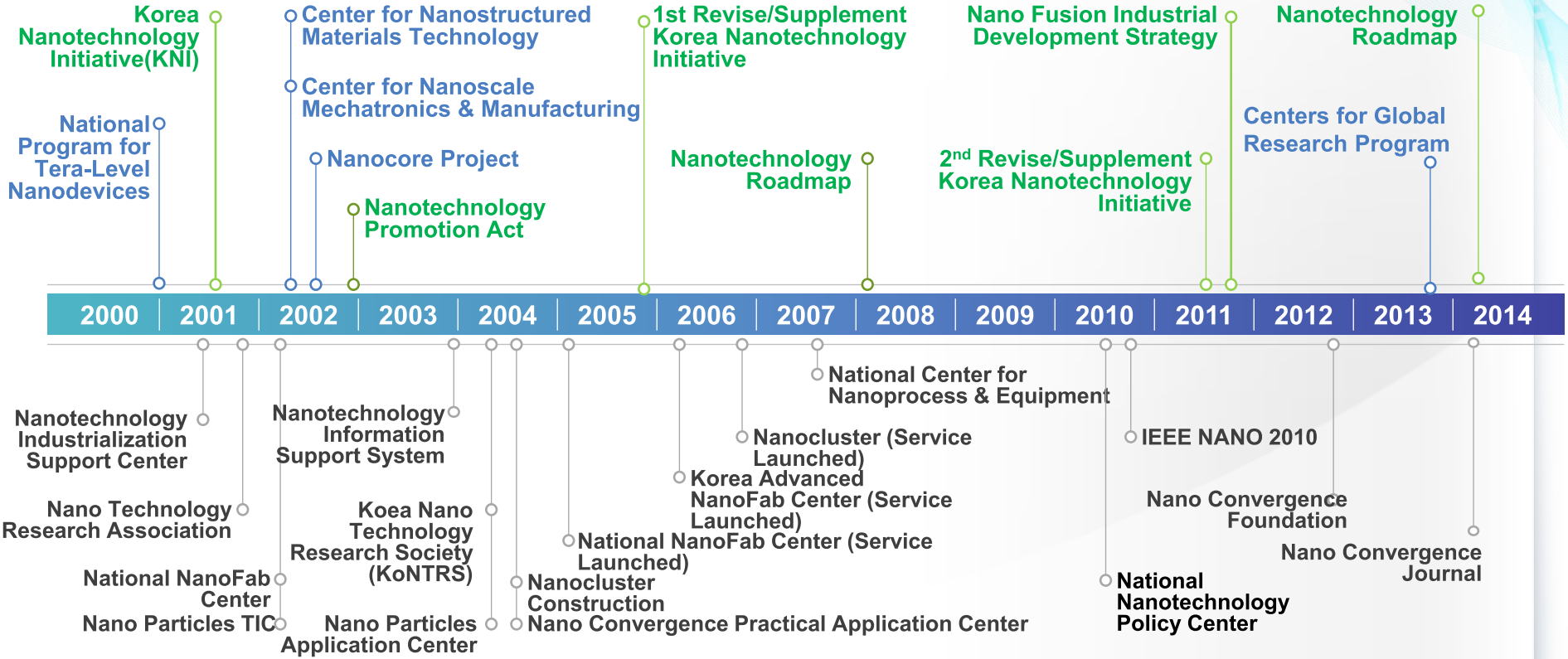
- **Established in accordance with the Nanotechnology Development Promotion Law (enacted in Dec. 2002)**

- **Developed and implemented by the National Comprehensive Development Plan for the Nanotechnology (NCDPN)**
  Need for systematic & comprehensive plan in national level in response to the preoccupation of advanced countries including the US and EU in the field of nanotechnology

- **The 3rd phase NCDPN was established in 2011**
  Select 30 future core technologies in 5 fields for development of nanotechnology to meet the demands of future society

II Milestones of Nanotechnology Initiatives and Policy

KNI : National Comprehensive Development Plan on Nanotechnology (NCDPN)

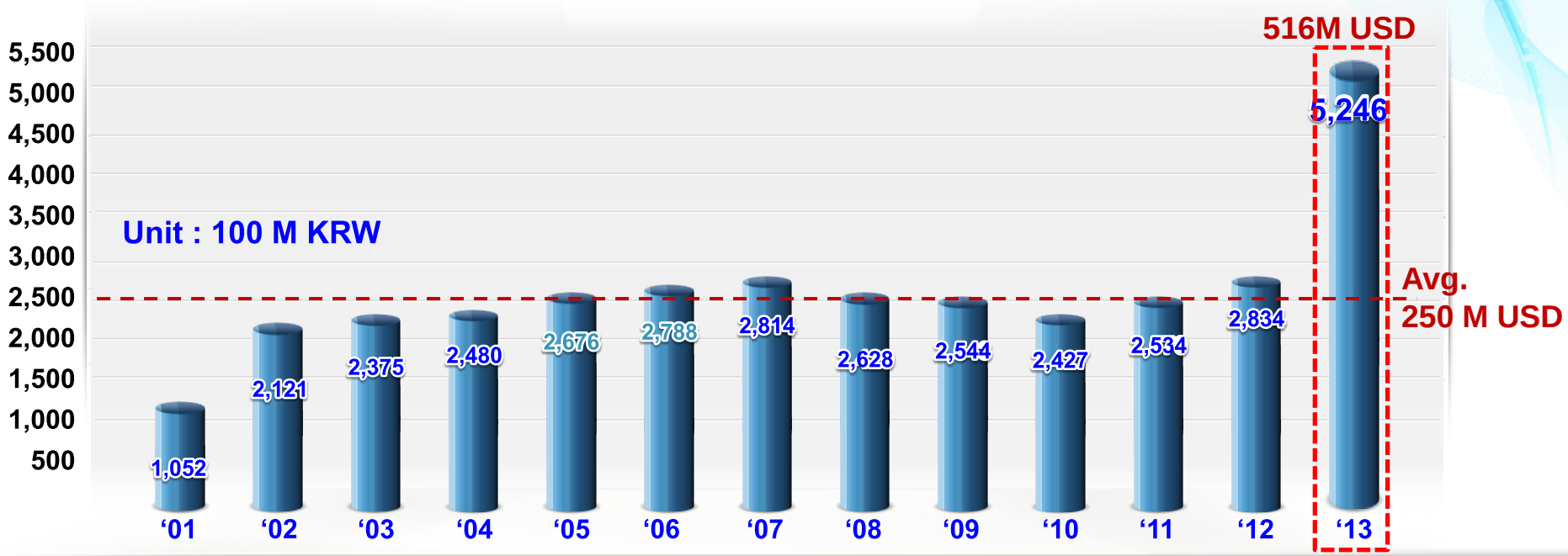


II

Korean Government Funding on NT

For 14 years (Korea) : Total 3,452 Billion KRW(≃ 3.4B USD)

[For 12 years (US) : Total ≃18.5B USD (FY 2001 ~ FY 2012)]

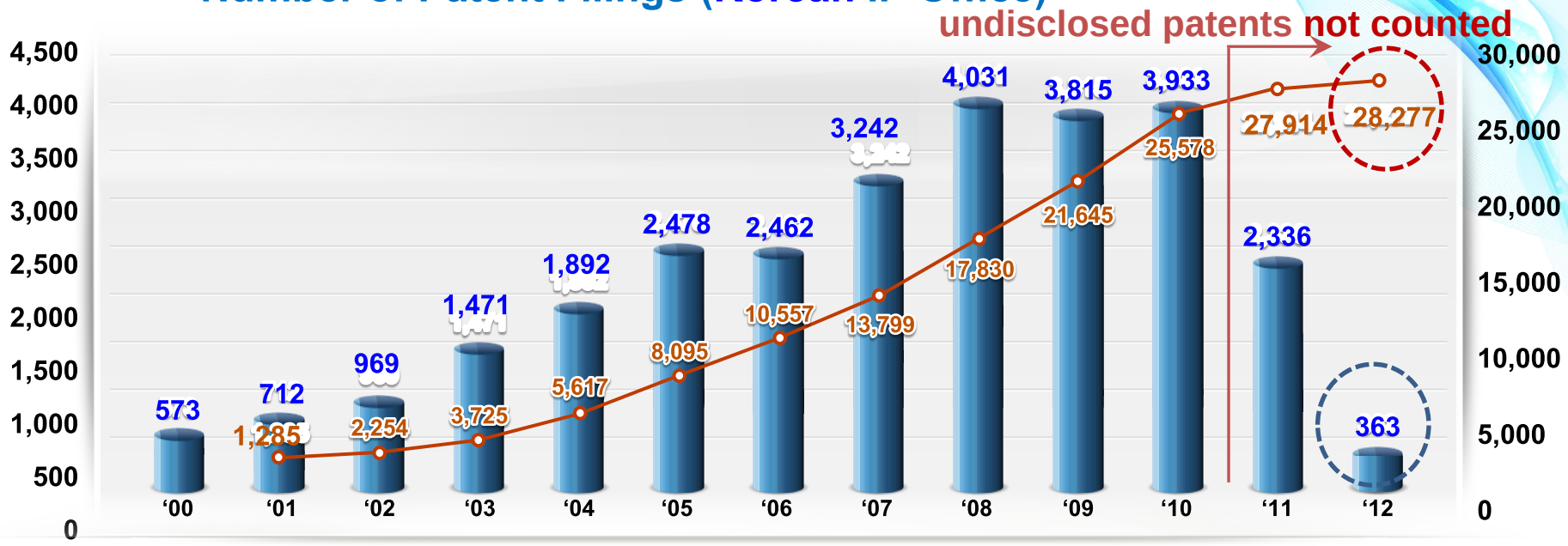


Year	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10	'11	'12	'13
R&D	955	1,589	1,644	1,631	1,700	1,938	2,045	1,963	2,304	2,075	2,178	2,623	4,692
Infra	30	456	626	702	840	688	610	526	110	224	225	181	210
HR	67	76	105	147	136	162	159	139	130	128	131	30	344
Total	1,052	2,121	2,375	2,480	2,676	2,788	2,814	2,628	2,544	2,427	2,534	2,834	5,246

II

Nanotechnology Related Patents

Number of Patent Filings (Korean IP Office)



Year	`00	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10	'11	`12
Number of Patent Filings	573	712	969	1,471	1,892	2,478	2,462	3,242	4,031	3,815	3,933	2,336	363
Accumulated Total	-	1,285	2,254	3,725	5,617	8,095	10,557	13,799	17,830	21,645	25,578	27,914	28,277

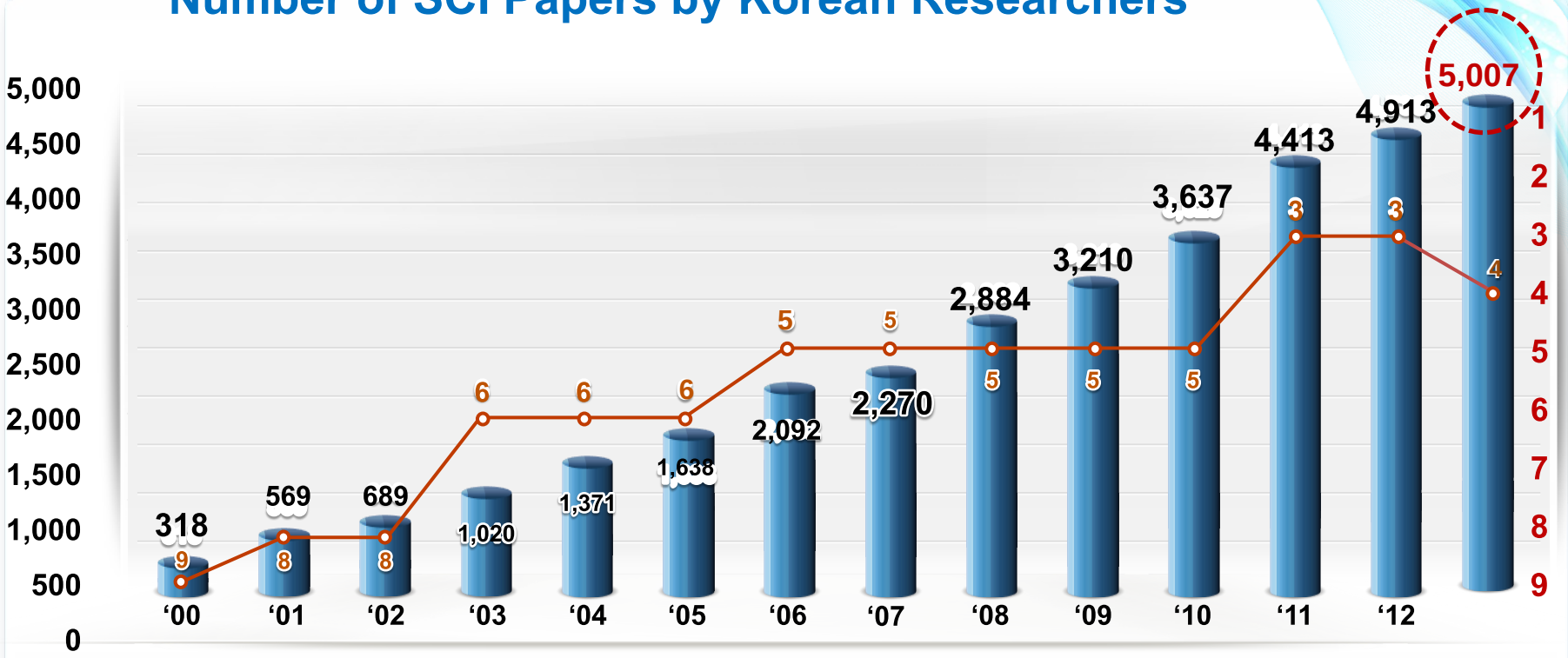
Number of Patent Filings (US IP Office)

Year	`00	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10	'11	`12	`13
Number of Registered Patents	10	26	29	54	73	58	81	100	158	181	333	428	475	494
Ranking	9	6	5	4	4	5	5	4	3	4	3	3	3	3

Source: *USPTO Data Base of Wips*, January 2014

II Nanotechnology Related Publication

Number of SCI Papers by Korean Researchers



Year	'00	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10	'11	'12	'13
Number of Papers	318	569	689	1,020	1,371	1,638	2,092	2,270	2,884	3,210	3,637	4,413	4,913	5,007
Ranking	9	8	8	6	6	6	5	5	5	5	5	3	3	4

In 2013 : China (20,743), US (14,850), India (5,453), Korea (5,007), Germany (4,201), Japan (4,090)

Source: *SCIE Data Base of Thomson*, February 2014

III

Selected Nanotechnology Programs

MSIP (Ministry of Science, ICT, and Future Planning)

Nano Material & Technology Development Program

- Fundamental research on Nano-materials, Nano-devices, Nano-process, Nano-tools, etc.
- Program Duration: 5 - 7 years
- Budget: $0.5 - 1.0M/year

Pioneer Research Center

- High-risk and high-profit convergence technology including Nano
- Program Duration: 6 years
- Budget: $1.0M/year

MSIP (Ministry of Science, ICT and Future Planning)

Global Frontier Program

- Innovative technology which can overcome the limits of existing technologies
- Program Duration: 9 years
- Budget: ~ $15M/year

Nano Convergence 2020

- Commercialization of NT-based convergence technologies and creation of new industrial fields
- Program Duration: 2-9 years
- Budget: up to several M$/year (need-base)

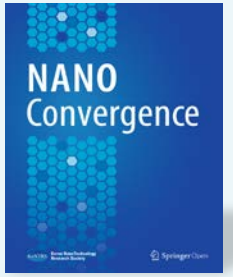
III Korea Nanotechnology Research Society (KoNTRS)

☐ Purpose of Establishment

- Promote joint projects, networking, and information exchanges between corporations and scholarly researchers in Nanotechnology
- Improve mutual collaboration among members and contribute NT policy, research, scholarly activities, and early industrialization

☐ Major Activities

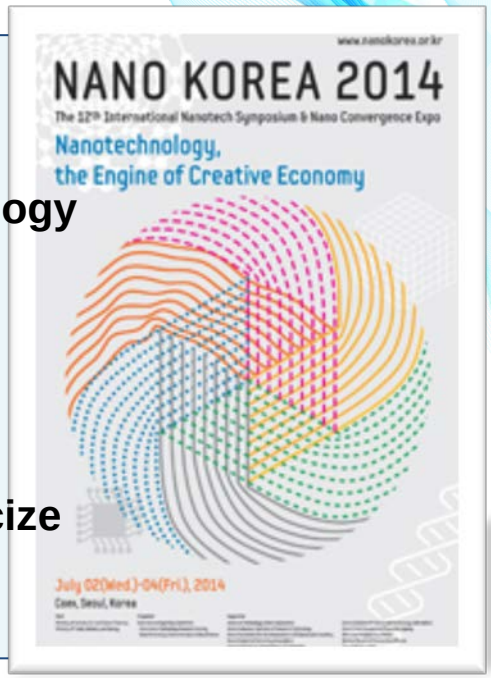
- Korea Nanotechnology Initiative and NT Road Map
- Nano Korea Symposium (Since 2002)
- Domestic & Global Networking and Collaboration
- Nano Convergence (New journal started in 2014 with Springer
- NT Education Programs including e-Nano School
- Knowledge Sharing with Public



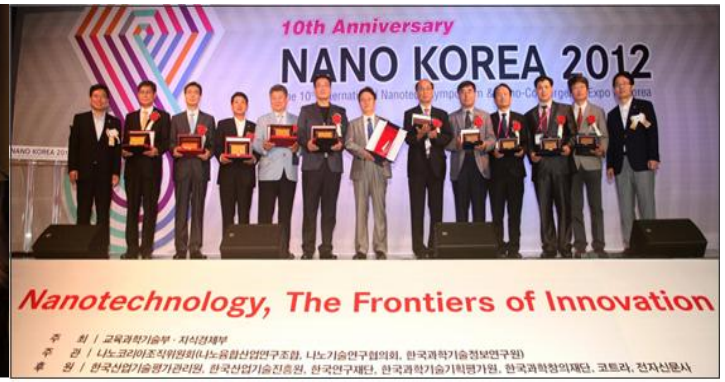
III Korea Nanotechnology Research Society

☐ Nano Korea Symposium

- **Description**
  - · The largest symposium on the nanoscale science and technology in Korea
  - · Meaningful occasion to confirm major research results and up-to-date research trends in world
  - · Opportunities for enterprises and research institutes to publicize commercialization of their technologies



Keynote speaker
Prof. Charles M. Lieber



Nano Korea 2012

Public Program

III Korea Nanotechnology Research Society

The 12th International Nanotech Symposium & Nano-Convergence Expo in Korea

NANO KOREA 2014

July 2-4, 2014, Coex, Seoul, Korea

You are cordially invited to participate in the 12th International Nanotech Symposium & Exhibition, NANO KOREA 2014, to be held in Coex, Seoul, Korea, July 2-4, 2014. NANO KOREA is the biggest nanotech festival in Korea providing a perfect opportunity to get the most up-to-date information and recent trends in the field of, or related to, the nanoscale science and technology. This year, the Symposium will be more exciting and forward-looking with its technical sessions covering the key pending issues and cutting edge technologies as well as the core topical areas in nano science and technology. We hope to see you in Seoul in 2014.

Important Dates

Abstract Submission Due: March 10, 2014

Notification of Acceptance: March 31, 2014

Pre-registration Due: May 30, 2014

Full Paper Submission: July 21, 2014

Organizing Committee

Organizing Co-chairs:

Dr. Sang-Hee Suh
(President of Korea Nano Technology Research Society)

Dr. Hee-Gook Lee
(Chairman of Nano Technology Research Association)

Symposium Chair:

Prof. Haiwon Lee
(Executive Vice-president of Korea Nano Technology Research Society, Hanyang University)

Program Chair:

Dr. Chul-Jin Choi
(Korea Institute of Materials Science)

Program Vice-chairs:

Prof. Kyoungwan Park
(University of Seoul)

Prof. Wan Soo Yun
(SungKyunKwan University)

Topics and Scope

- Nano Electronics & Circuits
- Nanophotonics & Plasmonics
- Nanomaterials & Processings
- Nano Fabrication & Measurement
- Nanobiotechnology & Nanomedicine
- Nano Safety & ELS
- Nano Carbon Technology
- Industrialization of Nano Convergence Technology

Call For Abstracts

NANO KOREA 2014
Symposium Secretariat

#301 Seshin Bldg., 66-2 Umyeon-dong, Seocho-gu, Seoul 137-140, Korea
E-mail: symposium@nanokorea.or.kr
Tel: 82-2-573-6207
Fax: 82-2-573-6208

III National Nanotechnology Policy Center (NNPC)

☐ Purpose of Establishment and Vision

- Help Korea to become a world-class NT country through NT information collection and analysis as well as national NT policy NT policy and strategy development
- Advance into a world-class research institute exclusively for nano policies

☐ Major Functions

- Support for the national NT policy and strategy development
  - R&D and planning for nano policies and strategies
  - research and analysis on NT policies and strategies of major countries
- Collection and analysis of NT information and service
  - collection and analysis of NT policy information
  - establishment and operation of a nano portal, along with precision of high quality NT information
- Support for international cooperation and network establishment

National Nanotechnology Policy Center

Expansion of Workshop

NBIC2 Korea Workshop on Oct 15~16, 2012

Discussions on future direction of convergence technology & policy

NBIC study 2001-2002

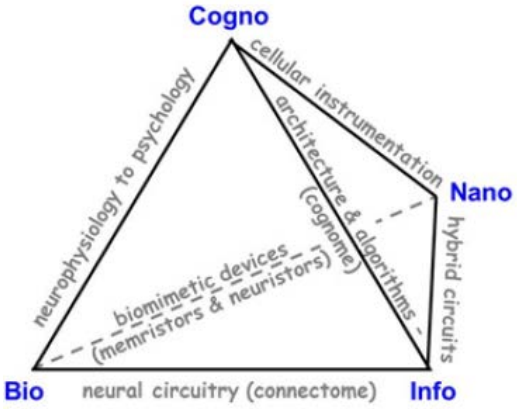
2001-2010: Reactive convergence
Coincidental, based on ad hoc collaborations of partners or individual fields for predetermined goals

NBIC/CKTS study 2011-2012

2011-2020: Proactive convergence
Includes decision analysis in the convergence approach

Organizations for convergence

After ~2020: Systemic convergence
Holistic; driven by higher-level purposes; this includes convergence organizations



WTEC Study on CKTS: Beyond Convergence of NBIC Technologies, 2013.07

III

National Nanotechnology Policy Center

Evolution of Themes of Korea-US Nanoforum

- Find Directions for Collaboration
  - Nano-Bio, Chemical, Energy, Environment
  - Device, Simulation, Fabrication
  - Education

- Nanomanufacturing
- Education

- Nanoelectronics
- Integration/Application
  - Beyond Moore's Law/CMOS

- Nanotechnology for Sustainability
  - Water Reusage/Desalination
  - Greenhouse Gas Capturing/Conversion

The 10th Nanoforum

- Next Generation of Nanotech
  - Products and Processes

- Nano-Bio Technology
  - Materials, Sensor, Device
  - EHS

- Nano Devices/Systems
  - Manufacturing, Photonics
  - Nano-Bio
- Nano Implication(EHS)

- Sustainable Energy
  - Solar Cell
  - Fuel Cell, Hydrogen Storage

- Nano Materials/Systems
- Energy
  - Solar Cell
  - Artificial Photosynthesis

- Convergence
- Nano Materials/Systems
  - Sustainability for Nanomanufacturing
  - Nanoelectronics

From 1st~10th Korea-US Nano Forums

III

Korea Infrastructure Organization for Nanotechnology (KION)

KION 국가나노인프라협의체
Korea Infrastructure Organization for Nanotechnology

□ Purpose and Roles of KION

Major Activities

·Providing effective support for domestic nanotechnology research and development via close collaboration amongst domestic Nano-infrastructure.

Role

·Constructing a mutual cooperation system for preemptive response to the nanotechnology paradigm shifts and consumer demands

·Policy development for increased nano-infrastructure efficacy, research support, manpower training, collaboration projects

·Providing and sharing integrated information on attained technology, equipment, service, and usage, etc.

·Mutual PR for nano-infrastructure

III Korea Infrastructure Organization for Nanotechnology (KION)

□ Purpose and Roles of KION

Major Activities

·Providing effective support for domestic nanotechnology research and development via close collaboration amongst domestic Nano-infrastructure.

Role

·Constructing a mutual cooperation system for preemptive response to the nanotechnology paradigm shifts and consumer demands

·Policy development for increased nano-infrastructure efficacy, research support, manpower training, collaboration projects

·Providing and sharing integrated information on attained technology, equipment, service, and usage, etc.

·Mutual PR for nano-infrastructure

III Members of KION, National NanoFab Facilities

u-ITC

Ubiquitous IT Cluster

KPEC

Korea Printed Electronics Center

NCNE

National Center for Nanoprocess & Equipments

KANC

Korea Advanced Nano Fab Center

NNFC

National Nanofab Center

NCNT

National Center for Nanomaterials Technology

IV Nano Technology Research Association

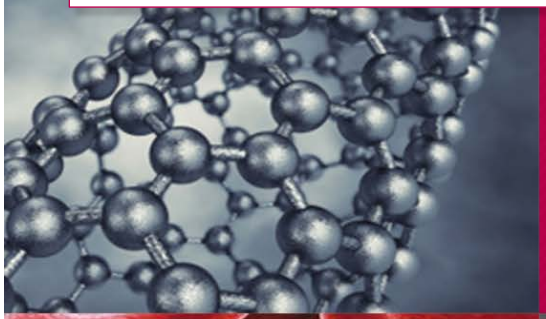
☐ Purpose of Establishment and Mission

- Help private sector for commercialization of research outcomes in nanotechnology
- Networking of government, academia, research institutes and private sector

How to boost up fast commercialization of research outcomes in nanotechnology successfully?

"Strengthening industrial competitiveness of existing major industries"

Convergence Commercialization of NT and other industry fields




IV Nano Technology Research Association

Strategy for Each Issue (Connection)

Connection | Convergence | Commercialization

Nano T2B Program

Seeds → T2B ← Needs

Intermediary Products (Materials / Parts)

Nano-convergence Products

- Nano-tech products permanent showcase
- Nano products transaction support between companies
- Market development & industrialization support

Other industry fields — Nano company — Overseas

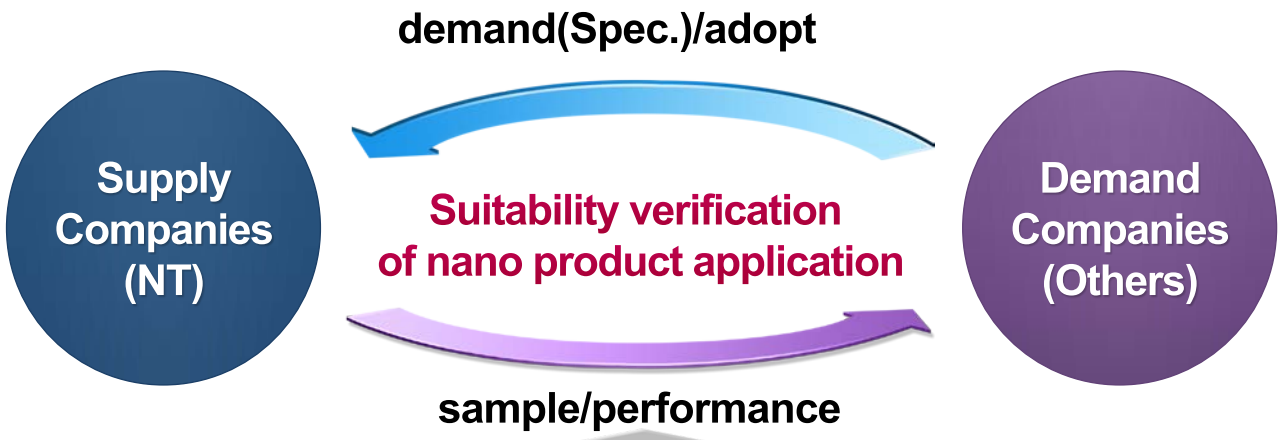
IV

Nano Technology Research Association

Strategy for Each Issue (Convergence)

Connection | **Convergence** | Commercialization

Test & Evaluation Program for NT Application



Prototyping support for commercialization verification of NT products	Testing & evaluation support of NT products (specific performance requirements)

IV Nano-Convergence Foundation (NCF)

□ Background and Vision

- Delayed/Slow Commercialization of Research Outcomes
  - Missing links between research steps
  - Poor linkage between research programs
  - No systematic flow of R&D information between related sectors
  - Absence of systems promoting commercialization of research outcomes
- Creation of new markets & industry through commercialization of nanotechnology

Commercialization

- ❑ Finding breakthrough technologies
- ❑ Developing core nanotechnology
- ❑ Commercialization of research outcomes
- ❑ Bringing-up nanotechnology corporations including start-ups

Integrated platform

- ❑ Mgt. of overall process of R&D
- ❑ Focusing on big convergence tech.
- ❑ Sharing outcomes/information among sectors of private and public
- ❑ Inducing participation of private sector (VC)

IV Nano-Convergence Foundation

Target Areas of Nano-Convergence 2020 Program

Two major convergence technology areas, close to markets or having urgent industrial needs, will be primarily promoted together with cross-cutting technologies.

Tech. Area	Technology-area to be Strategically Promoted
NT-IT	• Next generation devices (Post-CMOS) • Nanotechnology-based flexible devices
NT-ET	• High-efficiency energy conversion technology • High-performance treatment of water/waste
Cross-cutting technologies	Nanomaterials and nanoscale process/ measurement/ instruments required for nanomanufacturing leading to high-rate and massive production with low cost

IV Nano-Convergence Foundation

Routes for Commercialization of Nanotechnology

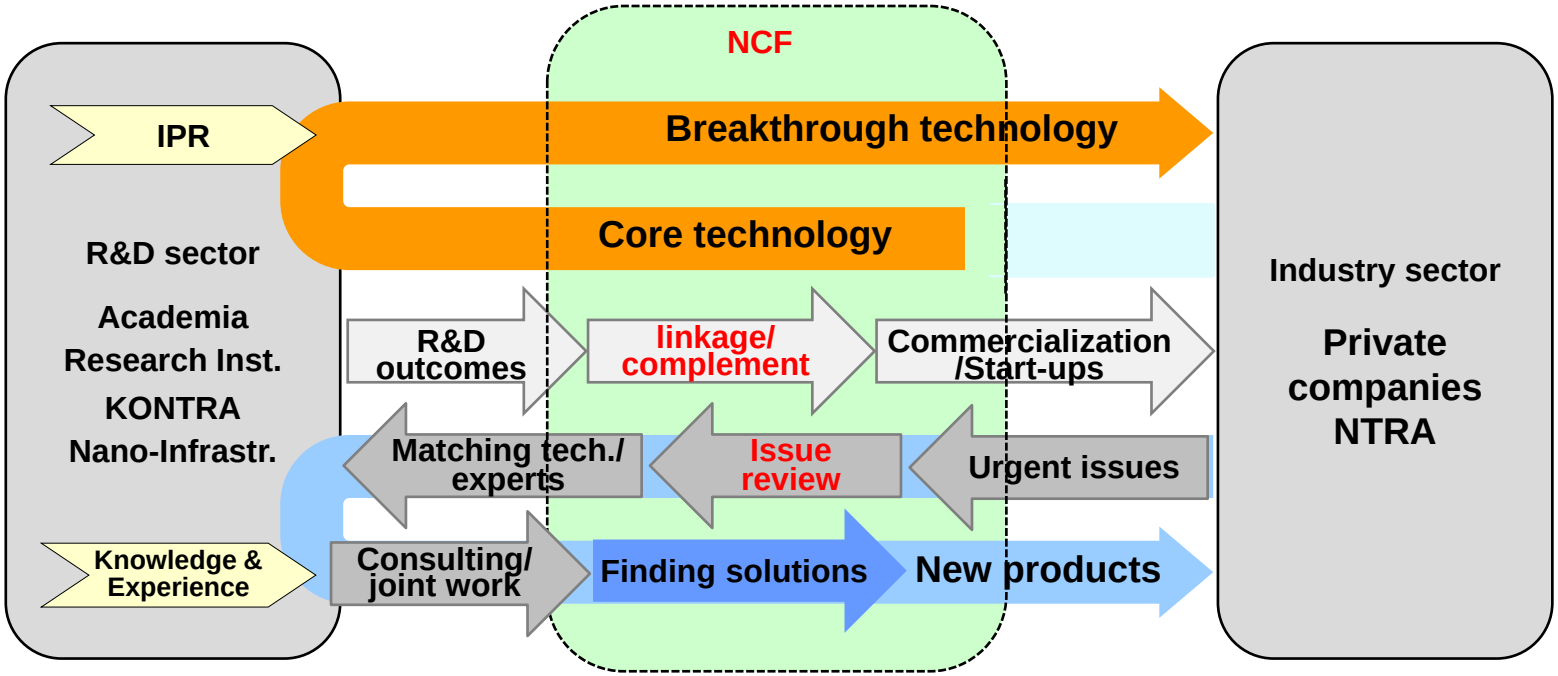
(1) Finding promising breakthrough technologies leading to big industries and financial support for their development (ex. post-CMOS)

(2) Commercialization of research outcomes (linkage and complement)

"Needs-matching Commercialization Program"

(3) Provision of solutions for industrial needs (technology-matching & consulting)

"Technology-matching Issue-Solving Program"



IV Nano-Convergence Foundation

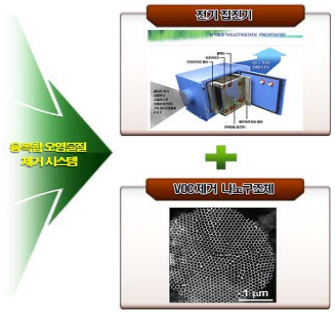
Launched Projects of Nano-Convergence 2020 Program (Examples)

Organic solar cells for outdoor applications

High-yield light extraction (OLED)

Air purification for indoor applications

작업장 내 유해분진, 오일미슴, VOCs 등



Thermal insulation & smart windows (Films)

Heat spreaders (high power LED lamps)

Ceramic inks for printed porcelains

V Science Diplomacy and Global Partnership

- **Informing foreign policy objectives with scientific advice (*science in diplomacy*)**
- **Facilitating international science cooperation (*diplomacy for science*)**
- **Using science cooperation to improve international relations between countries (*science for diplomacy*)**

'Science diplomacy and science and technology cooperation . . . is one of our most effective ways of influencing and assisting other nations and creating real bridges between the United States and counterparts.'

- Hillary Clinton, US Secretary of State -

Academic Mobility

The Lausanne campus of EPFL. Switzerland is the country with the world highest proportion of foreign researchers

Academic mobility refers to students and teachers in higher education moving to another institution inside or outside their own country to study or teach for a limited time.

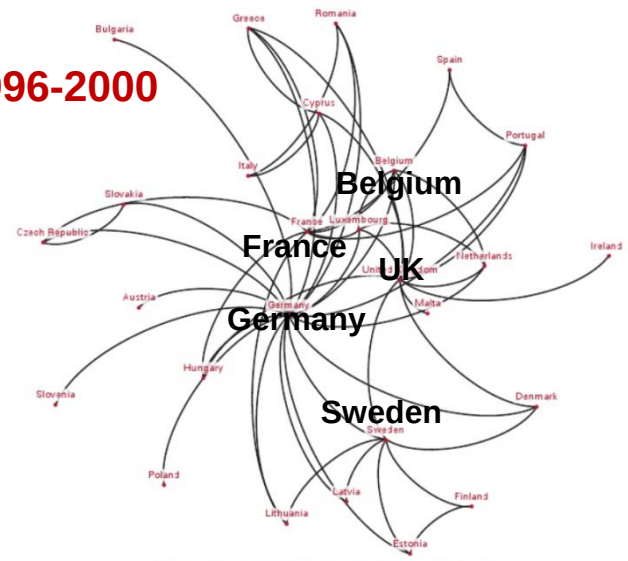
Academic mobility suffers from cultural, socio-economical and academic barriers. Mobile students are usually divided into two groups: *free-movers* are students that travel entirely on their own initiative, while *program students* use exchange programs at department, faculty, institution or national level (such as Erasmus and Fulbright).

The Erasmus Programme (*European Community Action Scheme for the Mobility of University Students***)** is a **European Union (EU) student exchange programme** established in 1987. About **3 million** students have benefited from Erasmus grants.

Network of Global Collaboration

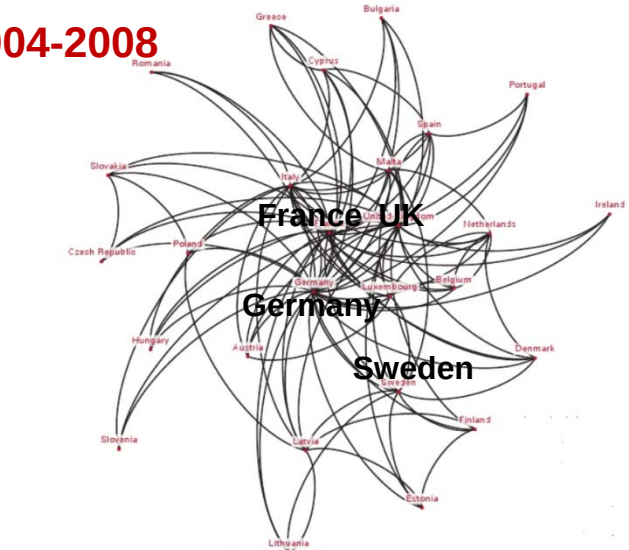
Collaboration between EU

1996-2000

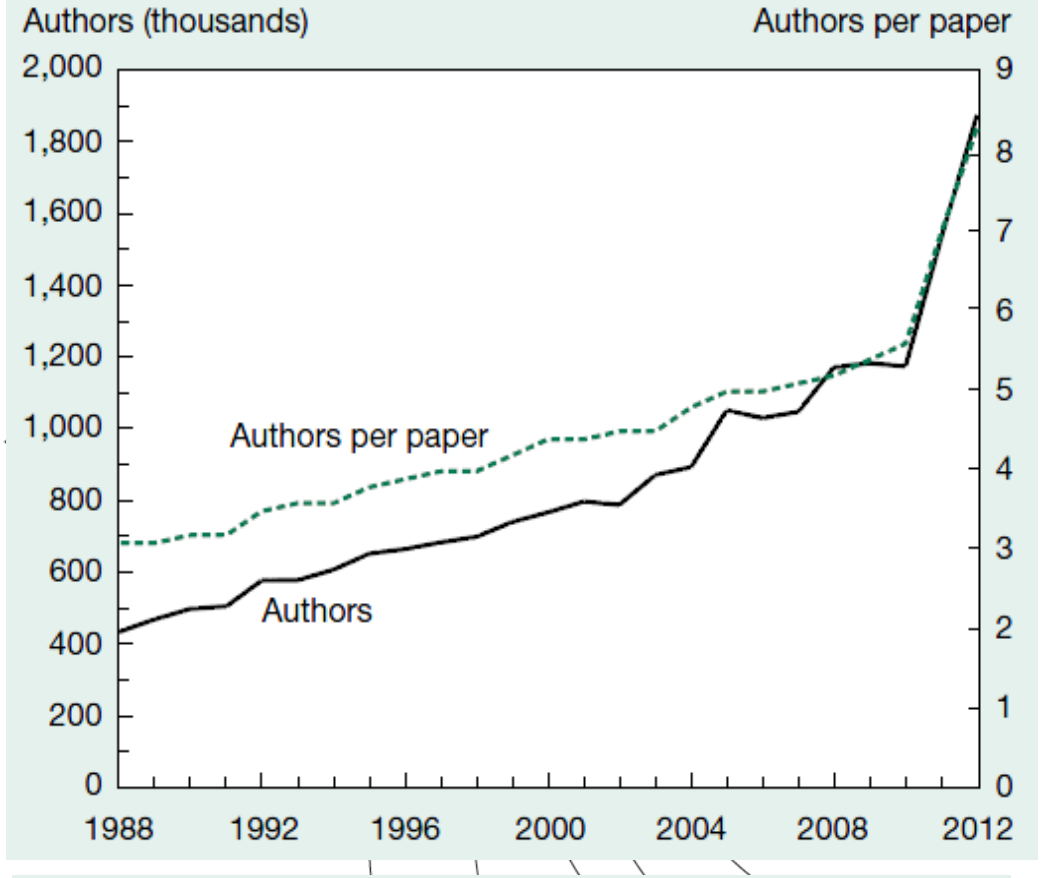


Collaboration between EU27 countries 2004–2008.

2004-2008



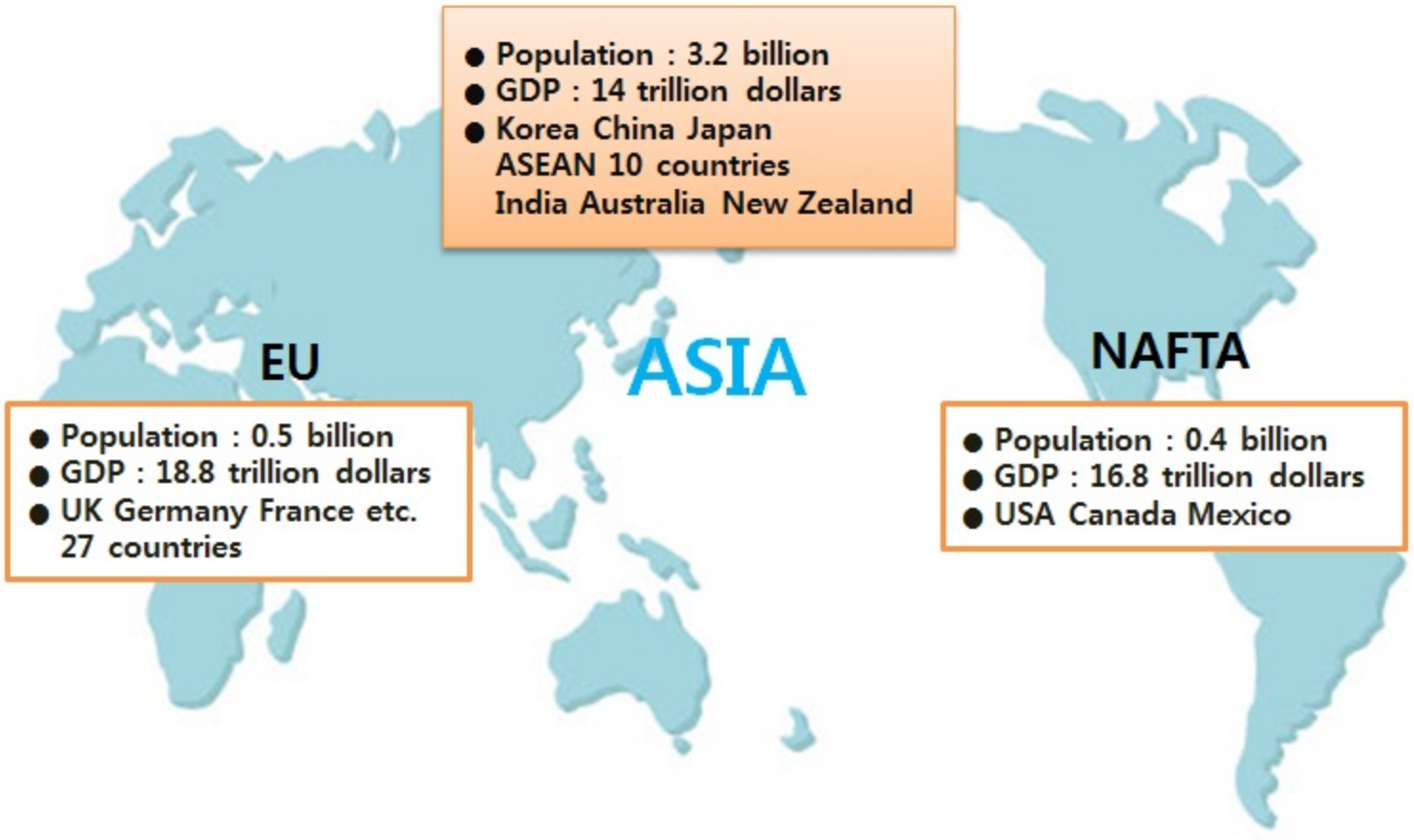
Number of authors and authors per paper for U.S. academic institutions: 1988–2012



NOTES: Article counts are from the set of journals covered by the Science Citation Index (SCI) and Social Sciences Citation Index (SSCI).

Source: (1)*Royal Society: Knowledge, Networks and Nations: Global Scientific Collaboration in the 21st Century*, 2011
(2)*National Science Board: Science and Engineering Indicators* 2014

Asia in the World



CAMPUS Asia Programs

CAMPUS Asia (Collective Action for Mobility Program of University Students in Asia) is a student exchange program funded by the governments of Korea, China and Japan to support universities in extending their global reach.

The objective of this CAMPUS Asia Program is to establish a higher educational network among universities in Japan, China, and Korea to improve the competitiveness in the international academic market and to nurture the development of future leaders who can succeed in the global community

Example: (2) TKT Campus Asia Consortium

PIRE Program

PIRE (Partnership for International Research and Education) is Partnerships for International Research and Education (PIRE) is an NSF-wide program that supports international activities across all NSF supported disciplines. The primary goal of PIRE is to support high quality projects in which advances in research and education could not occur without international collaboration. PIRE seeks to catalyze a higher level of international engagement in the U.S. science and engineering community.

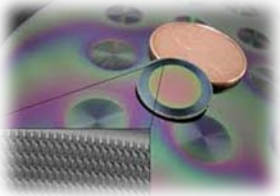
International partnerships are essential to addressing critical science and engineering problems. In the global context, U.S. researchers and educators must be able to operate effectively in teams with partners from different nations and cultural backgrounds. PIRE promotes excellence in science and engineering through international collaboration and facilitates development of a diverse, globally-engaged, U.S. science and engineering workforce.

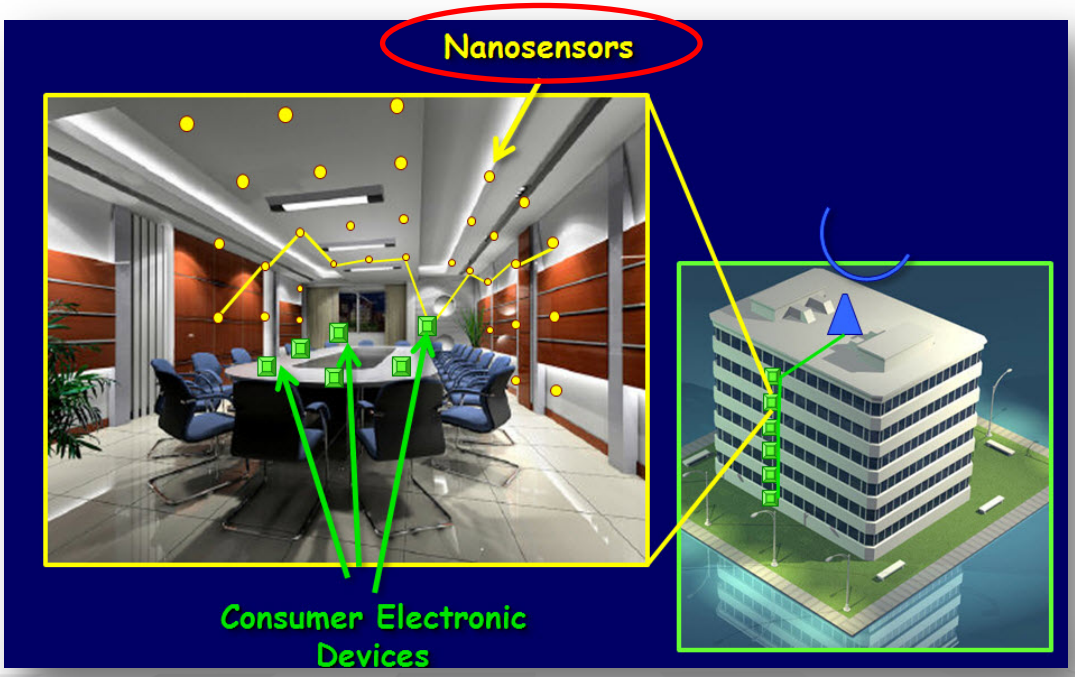
VI Selected Research Areas

Nanorealization Flagship Project (Signature Initiatives)

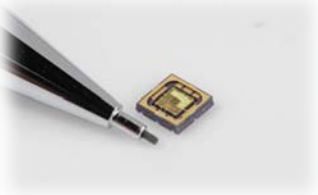
Nanosensor fior IoT(Internet of Things)

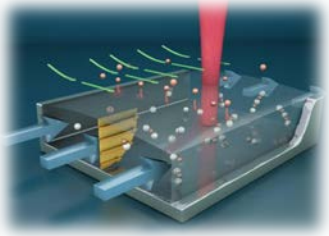
Nanosensor

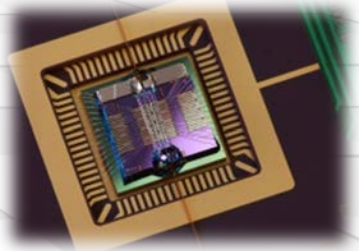




Nanosensor







VI Selected Research Areas

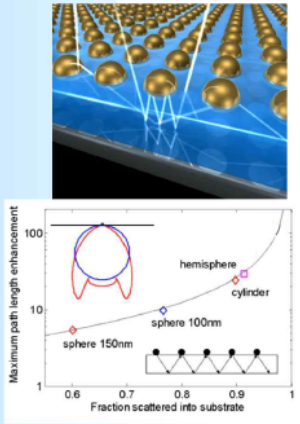
Assembly of Nanoparticles in Multiscales and Multidimensions (Multiscale Architecturng): Platform for Convergence Technology

Mansoo Choi

Global Frontier Center for Multiscale Energy Systems

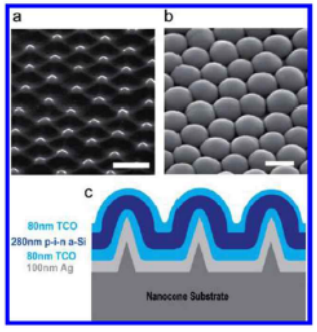
Plasmonic solar cell utilizes multiscale metal nanoparticle patterr enable physically thin but optically thick cells to maximize light trapping

Optical path length enhancement

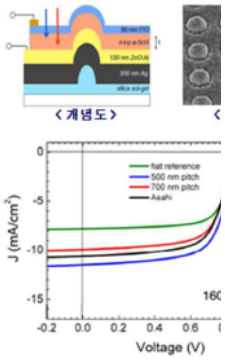


path length enhancement
Atwater et al., Nature Materials (2010)

Multiscale plasmonic solar cells

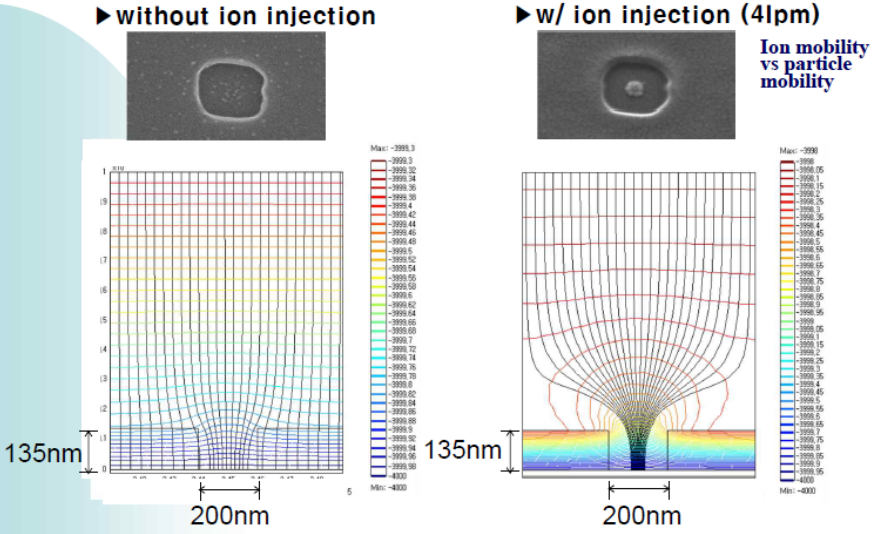


Cui et al., Nano Letters, 2010



Polman and Atwater, Optica America, 2010

Nanoscopic electrostatic lenses



VI Selected Research Areas

Simulation Platform as a Virtual Fab

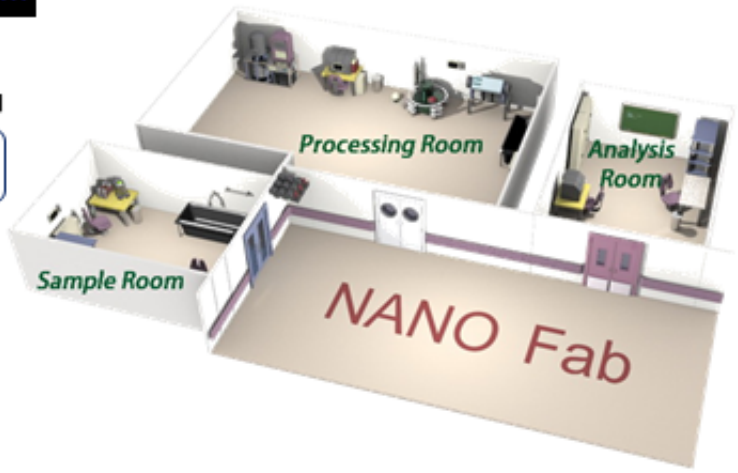
LAMMPS

siesta

SRIM & TRIM

RxFF

Home Made Codes



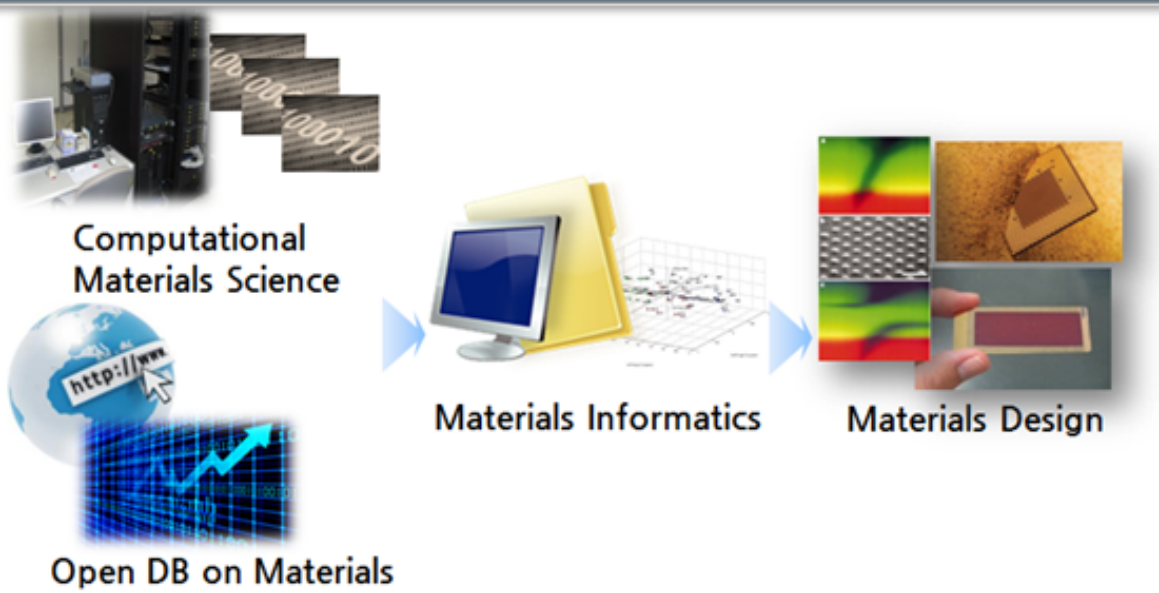
Trying to mimic the procedure of the experimental works in the FAB of real space,

As closely as possible!

VI Selected Research Areas

Goal of KIST Nano Virtual Fab

Web-based Platform for Materials Design by Computer Simulation and Materials Informatics

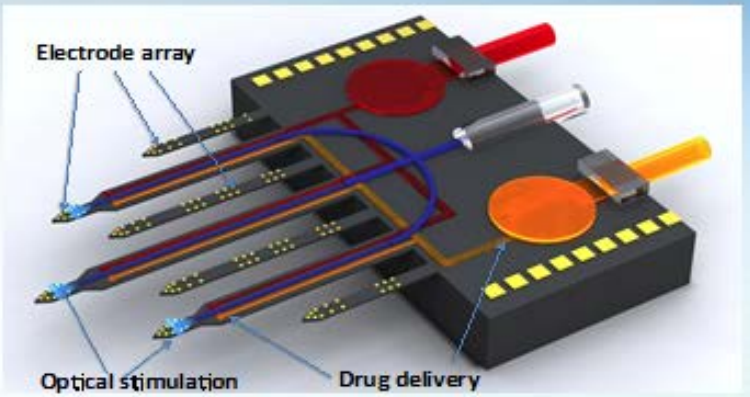


- Multiscale Simulation Environment
  - Virtual Fab for Everyone (QM, MD, MC, Meso, FEM)
- Material Informatics Environment
  - Database + Data Warehouse
  - Data Analysis Algorithm

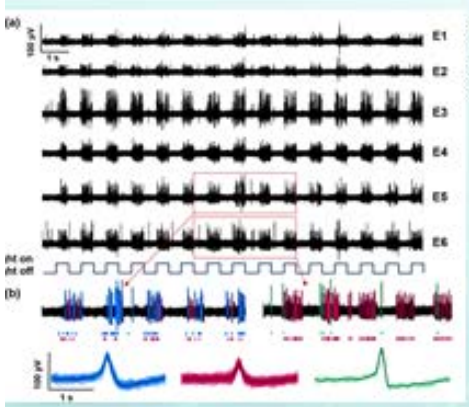
VI Selected Research Areas

MEMS Neural Probe for Brain Interface

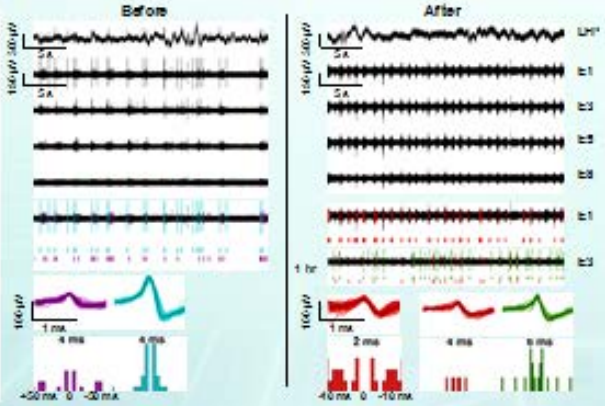
- MEMS neural probe for optical stimulation, drug delivery and recording of neural signal
- Integrated with optical waveguide, microfluidic channel and electrode array
- Small size for reducing brain tissue damage (100 μm x 40 μm x 7 mm)
- Essential system for studying neural circuits of brain disease by stimulating and recording at different brain regions simultaneously



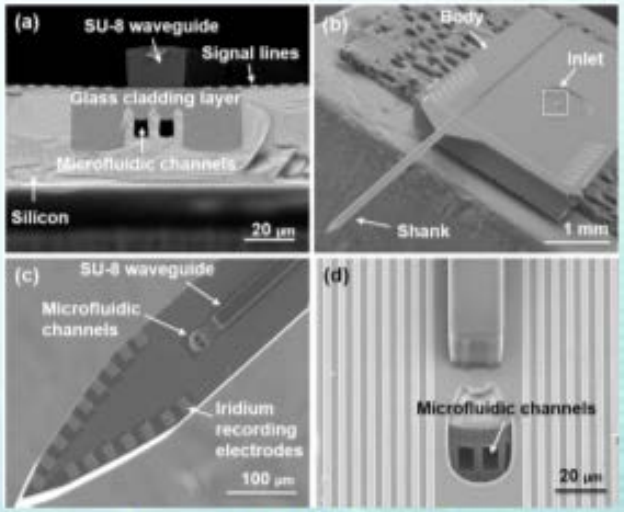
Schematic diagram of the multifunctional probe



Neural signal from optically stimulated neurons



Change of neural signals (before & after drug infusion)

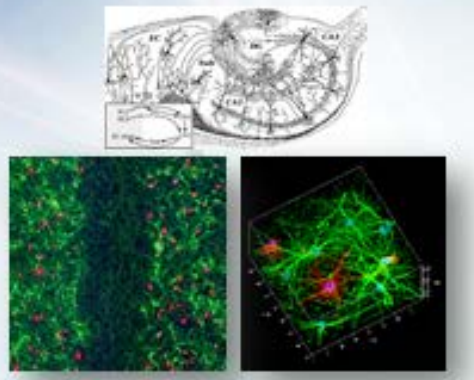


Fabricated MEMS neural probe

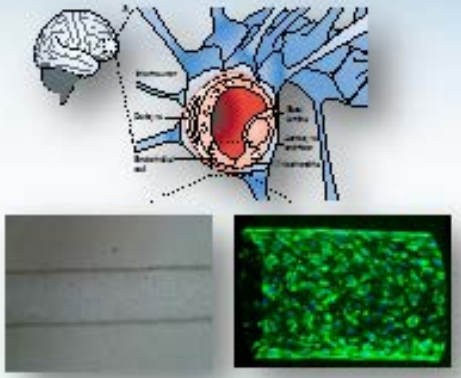
VI Selected Research Areas

Functional hydrogels for *in vitro* pathophysiological on-chip models of 3D brain tissues

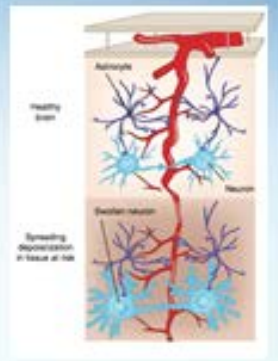
3D neural circuits (cortical layers, hippocampus, etc.)



3D blood-brain barrier (BBB)

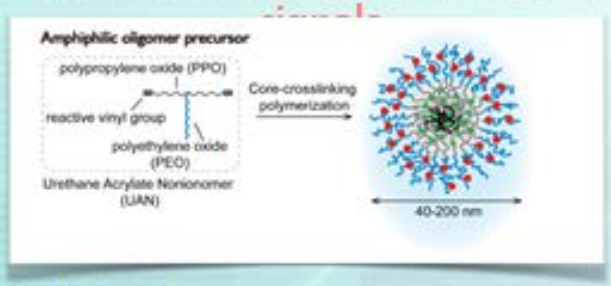


3D neurovascular units

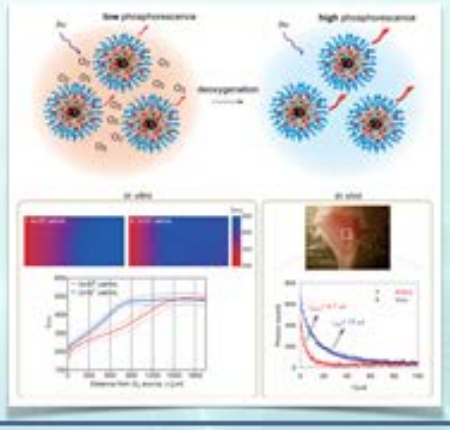


Fluorophores/phosphors and self-assembly organic-inorganic nanohybrid particles for multi-sensing of biological signals *in vitro* and *in vivo*

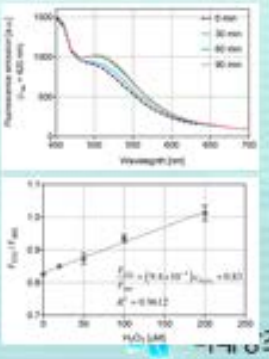
Modular materials bank for multi-sensing of biological signals



Oxygen in vasculature and tissues



H_2O_2, ROS, NOS, pH, etc.



素材强國
정의소재 디스커버리 사업

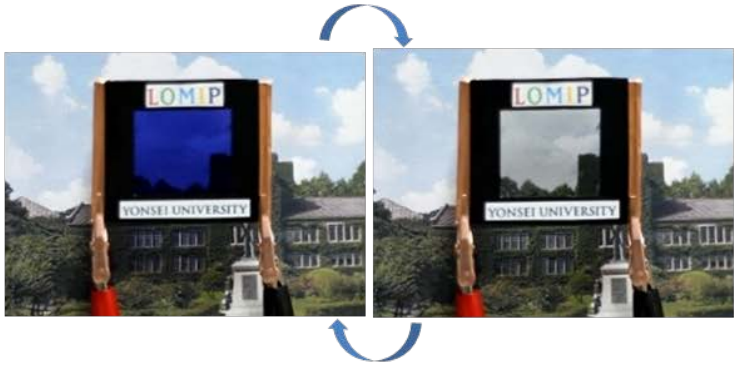
VI Selected Research Areas

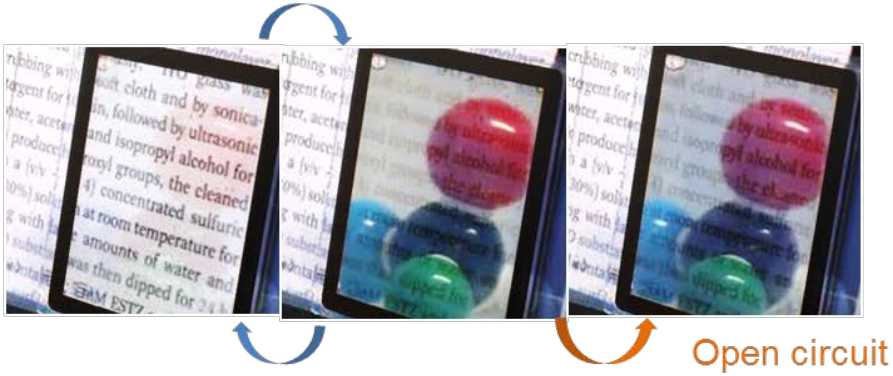
Eunkyoung Kim (Yonsei University)

Electrochemical Switching of Transmission in Thin Films with A Long Memory Effect

ETS

Electro-Transmittance Switching





Open circuit

Research Objectives

Polymeric ETS

- Enhance stability & contrast of ETS
- Design of multi-color electrochromic materials
- Fabrication of flexible & foldable ETS
- A long memory effect for an energy saving and low-power consumption ETS

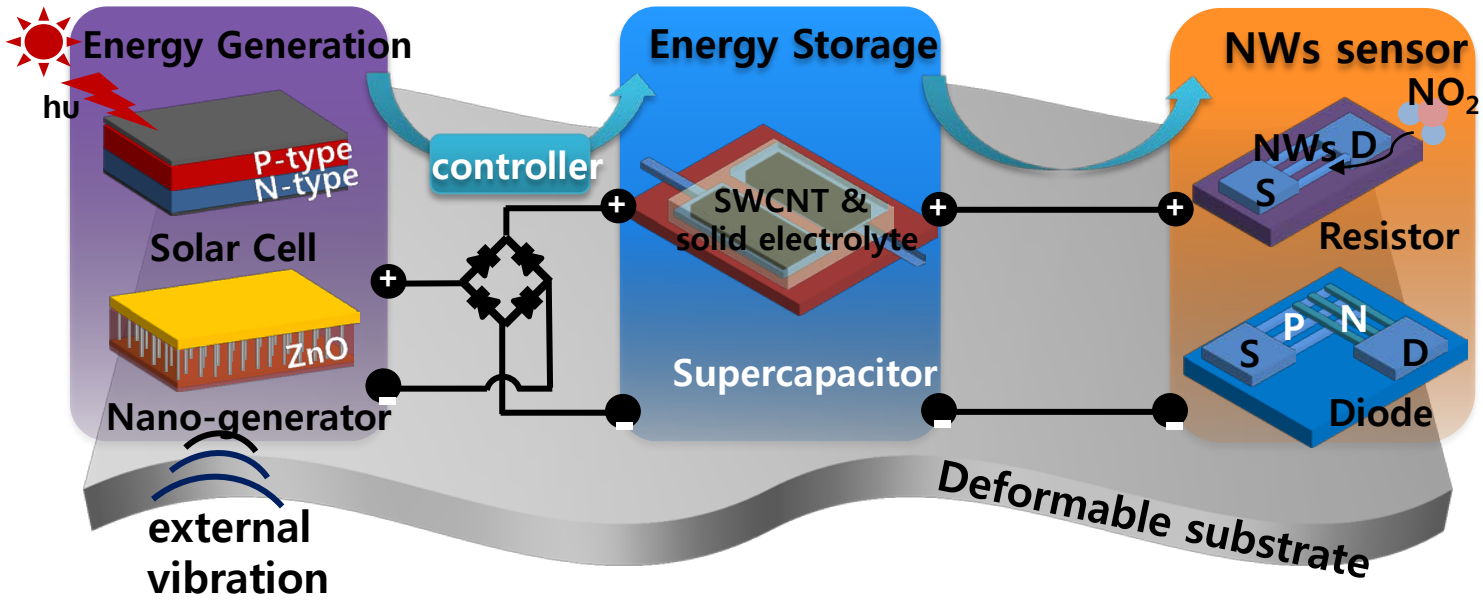
Metallic ETS

- Enhance electrochemical stability of mirrors
- Optimize device conditions for faster switching speed
- Fabrication of multi-mode ETS
- Enhance bistability for an energy saving and low-power consumption ETS

VI Selected Research Areas

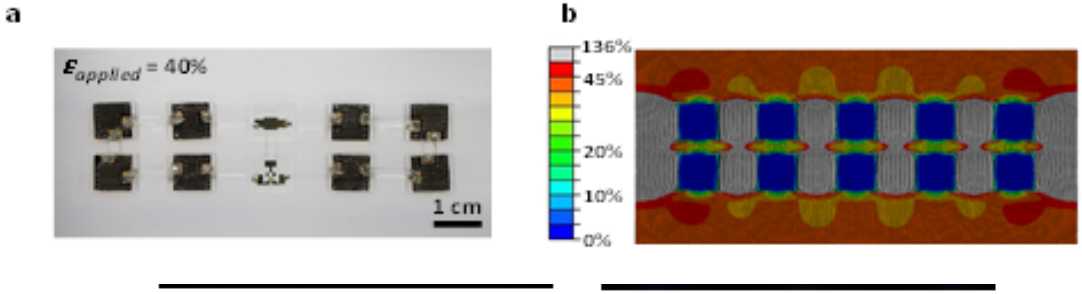
Stretchable electronics with integrated energy generation and storage devices

- Jeong Sook Ha (Korea University)



Stretchable array of LEDs & strain distribution

Stretchable micro-supercapacitor array



→ Stable electrochemical performance upon repeated stretching up-to 40%

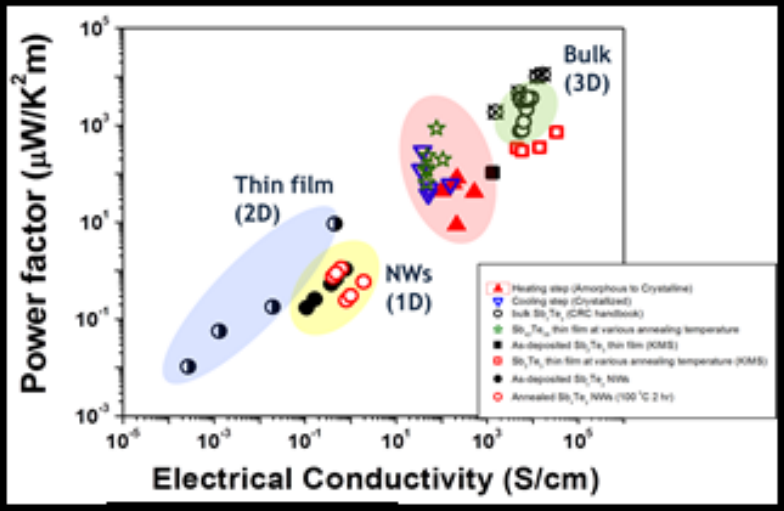
VI Selected Research Areas

KIMS Korea Institute of Materials Science

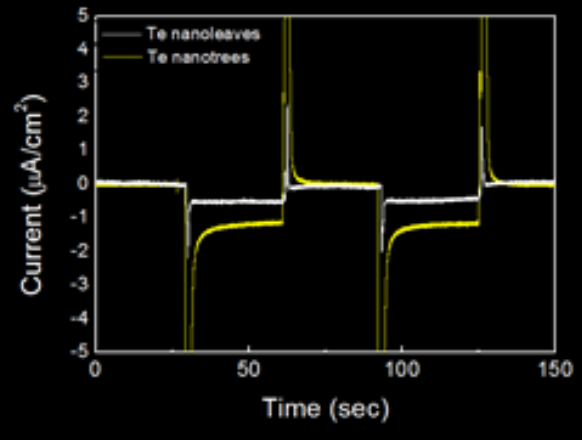
Electrodeposition of Semiconductor Materials

Jae-Hong Lim

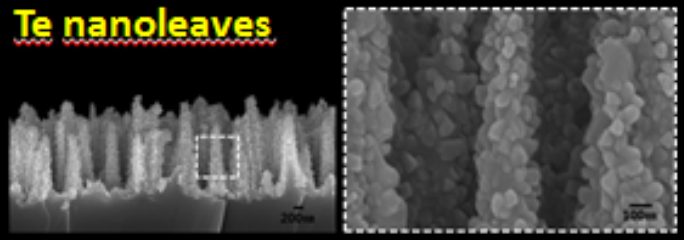
Improved thermoelectric property by nano-phase formation



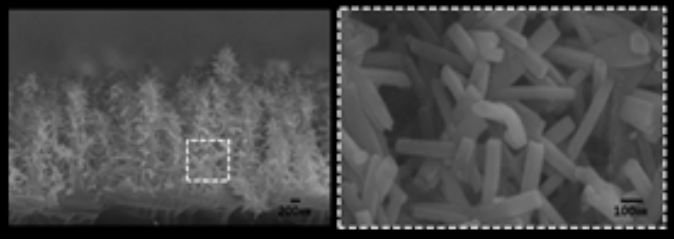
Improved photoelectrochemical property by nano-structuring



Te nanoleaves



Te nanotrees



Thank you very much
(감사합니다)