2009 대한민국 과학기술 연차대회

기조강연

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장소 송도컨벤시아
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2009대한민국과학기술연차대회 개요

◆ 목 적

• 각 분야의 산·학·연 과학기술 전문가 및 정책 입안자들의 “만남의 장”
• 지난 1년동안의 과학기술정책, 연구개발실적, 관련 동향에 대한 “회고의 장”
• 향후 과학기술동향 및 바람직한 대응방안에 대한 “토론의 장”

◆ 주 제 과학기술 ! 미래를 향한 희망 콘서트

◆ 기 간 2009. 7. 6(월) ~ 7. 7(화)

◆ 장 소 송도 컨벤시아, 송도라마다호텔

◆ 주 최 교육과학기술부

◆ 주 관 한국과학기술단체총연합회

◆ 후 원 인천광역시
「Energy Enabling Technologies For a Sustainable Future」

이 성 규
미주리대 화공과 교수
Energy Enabling Technologies for a Sustainable Future

2009 Korea Science and Technology Annual Meeting
July 7, 2009
Incheon, KOREA

Sunggyu Lee
Missouri University of Science and Technology
(Formerly, University of Missouri-Rolla)

Sunggyu “KB” Lee

Past

MS&T Laboratory for Transportation Fuels and Polymer Processing

Homepage: http://web.mst.edu/~leesu/
Energy and environment are the two biggest threats to the sustainability of human civilization and prosperity. However, they are not separate problems.

**Humanity’s Top Ten Problems for the Next 50 Years**

1. ENERGY
2. WATER
3. FOOD
4. ENVIRONMENT
5. POVERTY
6. TERRORISM & WAR
7. DISEASE
8. EDUCATION
9. DEMOCRACY
10. POPULATION

Source: Dr. Richard Smalley, Energy & Nanotechnology Conference
Rice University, Houston, May 3, 2003

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Lessons from History and Relevant Statistics
Total US Energy Consumption

Year

Energy Consumption (quadrillion Btu)


Steady Growth
Fluctuating

World Crude Oil Production (in Million Barrels/day)

Trouble signs were there: A, B, C, and D.

Persian Gulf Nations

Source: U.S. DOE, Energy Information Administration (EIA)
Energy Sustainability

Can We Control Our Own Destiny in Energy?
Can We Really Predict the Energy Future?
Do We Have Alternative Technologies?
How Much is Wishful Thinking?
What is the Realistic View?
Is There Enough Time?

ENERGY FORECAST

There were substantial changes in future forecasts before and after the recent oil crisis.

Petro replaced by Liquids
Petroleum adjusted ↓
Natural Gas adjusted ↓
Coal adjusted ↑
Nonhydrorenewables ↑

These are the results of new assessments based on the current maturity level of technology, perceived impacts, investments, and government policy.

Data Source: US DOE, EIA
FUTURE for LIQUID FUELS

Projected Liquid Fuels Demand for the U.S.
(By Sector)

Is this too conservative or too optimistic?

1. Transportation fuels will still be the driver even in 2030.
2. Assuming the steady demand of petroleum, the increased portion will be met by biofuels. The success of biofuels technology is crucially important for the sustainable future.

Energy Enabling Technologies

A great process idea must be demonstrated on a realizable scale; till then it is still wishful thinking.
SIMILARITY IN CONVERSION CHEMISTRY BETWEEN BIOMASS AND FOSSIL FUEL

Biomass → Syngas → Liquid Fuels → Diesel, Gasoline → Premium Gasoline

MSW → Liquid Fuel

Coal → Liquid Fuel → Fuel oil, Diesel, Gasoline → Premium Gasoline

Natural Gas → Syngas → Methanol → DME → Premium Gasoline

- Other options

Deterrents Impeding Biofuel Technologies

1. RM energy density per volume is low → Logistical burden.
2. Chemical composition of RM is widely varying.
3. Excessive burden and impact on water system.
4. Often competing against food, raising questions of “oil vs. food”?
5. Input of energy and human efforts is high → Costly.

Examples of solutions include:
1. Indirect conversion; mixed feed; small-scale on-site utilization
2. Robust enzymes; high-energy conversion; down-stream technologies
3. Efficient separation technology; water purification technology
4. Use of low-value feedstocks; use of cellulose and agricultural wastes
5. Development of high value-added fuels; byproduct utilization; CHP; enhancement in agricultural technology

Enabling Technologies are sorely needed
Bioethanol

- Debates still on (1) NEV of bioethanol and (2) Oil vs. Food.
- Nonetheless, the bioethanol programs in the U.S. and Brazil are very successful with (1) income enhancement of rural America, (2) replacing substantial portions of petroleum import, (3) offering affordable oxygenate fuel, and (4) establishing a technological and marketing infrastructure for a future breakthrough technology.
- Enabling technologies are being developed.
  - Development of value-added byproducts
  - Refinement of ethanol and flex fuel vehicles
  - Utilization of lower-valued feedstocks such as cellulose, overcoming the inefficient fermentation and xylose formation
  - Efficient separation of ethanol
  - Further conversion to petrochemicals for an Ethanol Economy

Need for Enabling Technologies – An Example

A: Agriculture  B: Enzymolysis  C: Inferior Feedstocks  D: Product Development  
**Syngas Conversion to Liquid Hydrocarbons**

- Syngas originated from coal and biomass gasification as well as CO₂-rich low-value gases are to be converted.
- A good option for liquid fuels and petrochemicals.
- Advanced catalysis and enzymolysis provide alternative avenues for fuels and petrochemicals
  - Via Methanol and DME route
  - Via Fischer-Tropsch route
  - Direct reactions involving carbon dioxide

**Portable and Mobile Power Generation**

- Power generation at remote locations, in emergency situations, and for special missions.
  - Areas with no infrastructure
  - **Military** forward bases and silent watch missions
  - Emergency rescue and restoration at disaster areas
- Highly efficient, robust and compact devices are needed.
  - **Hydrogen generation** using fuel reformation and electrolysis
  - **Fuel cells, batteries**, and solid storage of hydrogen
- Efficient utilization and implementation of H₂ PEM fuel cells and solid oxide fuel cells, and others.
  - Technologies for **ultra-purification of H₂** and enhanced sulfur tolerance of PEM fuel cells
  - Infrastructure technology and relevant products to be developed
Microgrids and Smart Grids

- Electrical transmission systems are old and over-saturated in many developed nations. Grid powers are not reliable in peak times or emergencies and as a result, restoration may take days or weeks.
- Electrical power is essential in all human activities including military operations and emergency rescue missions.
- Power is no longer downloadable only; it can be and should be *uploadable*.
- Necessary component technologies are mostly available; however, efficient design and seamless implementation is a challenge.

**Examples of Challenges**
- Immediately Integrable with Vehicular Power and Generators
- Stand-alone Capability as an Isolated System and Own Mobility
- Integrable with Other Microgrids
- Capable of Incorporating Renewable Powers [*Solar*, *Wind*, *Biofuel*]
- Compatible with Both Forward and Backward Technologies
- Integrable with Existing Grid Power Infrastructure

Renewable & Carbon Neutral Energy Sources

**Carbon Neutral Energy Sources**
- Zero carbon footprint and carbon offsetting
- Not increasing the net GHG emission, in particular CO₂
- Biofuels, Hydrogen, Wind, Solar, Nuclear, Geothermal, Hydro

Virtually all forms of carbon neutral energy currently involve the burning of fossil fuels. The crops for biofuels are harvested using machinery that burns petro-diesel. The cost is to blame.

**Enabling technologies** to be developed for combined feedstocks, hybrid generation, synergistic integration of multiple technologies, energy storage, combined heat and power (CHP), smart and micro-grid integration, small-scale processors and devices, enhanced safety and reliability, enhanced life quality and style, and more.
CO₂ Sequestration and Conversion

- The most ideal solution for CO₂ would be its direct conversion into hydrocarbons or carbohydrates. CO₂ as a renewable fuel.
  - Fundamental research needed on catalysis and enzymolysis
  - Human mimicking of photosynthesis on an industrial scale
  - Conversion of CO₂-rich gases into useful hydrocarbons
- Until decisive technology becomes available for CO₂ conversion, sequestration and beneficial use may be the next best solution.
  - Sequestration is at best a temporary solution.
- CO₂ capture and controlled emission is quickly becoming a law in developed societies.
  - A top-down approach; but responsible manufacturing is urged.
- Enabling Technologies for CO₂ capture, reduced emission, beneficial re-use, and sequestration need to be upgraded urgently.
  - Potential leakage of CO₂ and brine as well as long-term toxicity need to be investigated and thoroughly assessed.

FutureGen™ Emission-Free Coal Plant
CO₂ Sequestration and Hydrogen Production

Photo: USA Today 1/6/2008
Underground Processing

- Specific to regional characteristics; Utilization of vast fossil resources
- Green River Formation oil shale, as an example
- Oil shale, coal, & natural gas.
- Environment & ecology; concerns.
- Potential underground waterway contamination
- Low-T process to be developed
- Need development of diverse enabling technologies including drilling and rubblizing, structural detection, and earth moving.


Approaches for Sustainable Energy Technologies
Sustainable Energy Technology Development

- **Multidisciplinary Collaboration**: Very complex and involved problems. Expertise in diverse areas needed.
- **Multi-institutional Collaboration**: No one has all the capabilities. Scientific/scholarly exchanges are vital.
- **Fundamental Understanding**: Achieve scientific breakthrough. Foundation for revolutionary technologies.
- **Learning Prior Developments**: Lots of significant work done earlier. Expediting new developments.
- **Prototype Demonstration**: Best way of learning and demonstrating. Quickest way of commercialization.
- **Lessons Learned Approaches**: Real life testing and learning from experience. Safe adoption of new technologies.
- **Environmental & Ecological Effects**: Costly mistakes can be avoided. Clean environment is equally important.
SUMMARY

1. The world is adopting energy-wise multiple solutions.
2. Regional strength and niche areas will play an important role.
3. Responsible practice of energy technologies will be mandated.
4. Environmental and ecological impacts must be considered.
5. New technologies will involve green processes and products.
6. Renewability and carbon neutrality will be selling buzzwords.
7. Fossil fuels will still hold grounds for at least the next 25 years.
8. Government subsidies in a variety of energy products are expected.
9. Energy related products will become highly tradable properties.
10. Breakthroughs in fundamental understanding of energy conversion as well as revolutionary enabling technologies are expected.
11. Combined, multi-product, hybrid technologies are promising.
12. Cost-benefit-risk analysis has to be done and updated frequently.
13. Energy education will become an important area of national needs.
14. Opportunities are wide open for international collaboration.

Thank you
Recent Progress of Semiconductor Engineering in Japan — Fourth part of my research life

니시자와 주니치
일본 슈도(首都)대 총장
Recent Progress of Semiconductor Engineering in Japan
(Fourth part of my research life)

Jun-ichi Nishizawa

Emeritus President, Tokyo Metropolitan University
Space-charge region and channel in a (n)p(n+) structure.

Structure of FET, only central horizontal region in conductive channel sandwiched by P space charge layers, which has no charge carriers till the external Gate regions.

$\Delta V_n + \Delta V_p = V_a$

Electron & Hole flow

in p - and n - type regions
(a)

(b)
UMOS SI thyristor

(a) Cathode

(b) Anode

(c) planar structure IGBT
SI thyristor

Wave form of SI - Thyristor

1. Wave form of turn-on by our SIT type thyristor

- Anode voltage: VAK, 200V/div
- Anode Current: IA, 200A/div
- Gate Current: IG, 5A/div

Turn on time t_{gt} = 2.0\mu s

Typical wave form of 1000A turn-on current

VD = 1250V, IA = 1000A
Wave form of Si - Thyristor

2. Wave form of turn-off by our SIT type thyristor

- Anode voltage \( V_{\text{AK}} \)
  \( V_{\text{AK}}: 500V/\text{div} \)
- Anode Current \( I_A \)
  \( I_A: 200A/\text{div} \)
- Gate Current \( I_G \)
  \( I_G: 50A/\text{div} \)

Turn off time \( t_{gq} = 3.1\mu s \)

Typical wave form of 1000A turn-off current

\( V_{\phi} = 1250V, I_A = 1000A \)

Efficiency of forward converter operated at 20 kHz

- Si Thyristor: 1802.1804 (Nihon Gaishi)
- Diode: S30L60 (double), SiC Schottky D12S60 (double)
- Transformer: 150 150, 0.3Φ
- \( T = 50 \mu s, 20 \text{ kHz} \)
- Duty factor: 40%
- Load resistance: 2 kΩ
- Circuit inductance, \( L: 1 \mu H \)
Chronology of laser

1957 April J. Nishizawa applied for the patent for semiconductor laser (Japanese patent 273217)

1957 Nov. G. Gould made a document to express idea of equipment for stimulated emission with simple formula and named it as LASER (Light Amplification by Stimulated Emission of Radiation)

1958 July A. L. Shalow & C. H. Townes applied for the patent for LASER

1959 April G. Gould applied for the patent for LASER

1960 March A. L. Shalow & C. H. Townes got the patent right for LASER (USP2.929,922)

1987 Nov. G. Gould got the patent right for LASER (USP4.704,583)

Similar situation
J. P. Eckert & J. W. Mauchly were the first to patent a digital computing device (ENIAC). But, J. V. Atanasoff and C. Berry are now recognized as the legal inventors of the electronic digital computer (Atanasoff-Berry Computer (ABC)).

Chronological Table for Terahertz wave Generation

<table>
<thead>
<tr>
<th>Year</th>
<th>Authors</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1957</td>
<td>G. Gould</td>
<td>First call as LASER (in notebook)</td>
</tr>
<tr>
<td>1958</td>
<td>J. Nishizawa</td>
<td>Proposal of TUNNETT diode</td>
</tr>
<tr>
<td>1958</td>
<td>A. Shawlow &amp; C. Townes</td>
<td>Proposal of gas laser</td>
</tr>
<tr>
<td>1960</td>
<td>T. Matsumoto</td>
<td>Realization of Ruby laser</td>
</tr>
<tr>
<td>1961</td>
<td>A. Javan</td>
<td>Realization of gas laser</td>
</tr>
<tr>
<td>1962</td>
<td>M. Nathan, R. Hall, T. Quist &amp; J. Pankove</td>
<td>Realization of semiconductor laser</td>
</tr>
<tr>
<td>1963 April</td>
<td>J. Nishizawa</td>
<td>Proposal of THz-wave generation via molecular and lattice vibrations</td>
</tr>
<tr>
<td>May</td>
<td>R. Loudon</td>
<td></td>
</tr>
<tr>
<td>1964</td>
<td>J. Nishizawa &amp; I. Sasaki</td>
<td>Proposal of optical fiber communication and focusing optical fiber (Graded Index)</td>
</tr>
<tr>
<td>1965</td>
<td>J. Nishizawa</td>
<td>Proposal of terahertz wave generation via molecular and lattice vibrations together with tunneling</td>
</tr>
<tr>
<td>1966</td>
<td>K. Kao</td>
<td>Estimation of low absorption loss optical fiber</td>
</tr>
<tr>
<td>1968</td>
<td>J. Nishizawa</td>
<td>Realization of TUNNETT diode</td>
</tr>
<tr>
<td>1969</td>
<td>R. Pantell</td>
<td>Observation of frequency shift via lattice vibrations</td>
</tr>
<tr>
<td>1973</td>
<td>P. Sokolkin, J. Wyne, &amp; J. Lankard</td>
<td>Four wave parametric effect in alkaline metals</td>
</tr>
<tr>
<td>1979</td>
<td>J. Nishizawa</td>
<td>Proposal of Ideal Static Induction Transistor (Ballistic SIT)</td>
</tr>
<tr>
<td>1979</td>
<td>J. Nishizawa &amp; K. Suto</td>
<td>Realization of semi-conductor Raman laser with lattice vibration</td>
</tr>
<tr>
<td>1980</td>
<td>J. Nishizawa</td>
<td>Realization of TUNNETT diode oscillating at 0.34 THz</td>
</tr>
<tr>
<td>1983</td>
<td>J. Nishizawa &amp; K. Suto</td>
<td>Difference frequency wave generation via semiconductor Raman laser (12.1 THz)</td>
</tr>
<tr>
<td>1999</td>
<td>J. Nishizawa, P. Plotka</td>
<td>Realization of Ballistic SIT (scattering free SIT)</td>
</tr>
<tr>
<td>2000</td>
<td>K. Kawase, J. Shikata, K. Imai &amp; H. Ito</td>
<td>THz wave parametric generation by injection seeding</td>
</tr>
<tr>
<td>2000</td>
<td>J. Nishizawa</td>
<td>Proposal of application of THz wave to diagnosis and medical treatment of cancer</td>
</tr>
<tr>
<td>2006</td>
<td>J. Nishizawa &amp; T. Tanabe</td>
<td>CW THz wave generation from GaP with using semiconductor laser diodes</td>
</tr>
</tbody>
</table>
Patent for laser

- Semiconductor Maser (filed in April 1957)

Electro-magnetic waves

Radio wave → Tera-hertz (THz) band → Light

molecular interaction

local vibrations

- 30 -
Semiconductor oscillator prepared in author’s laboratories

CW-THz wave generation with LD pumping

LD pumped CW-THz signal generation

THz spectroscopy with Higher-resolution of 1 MHz: superior to our present spectroscopy with ns pulse pumping
**Polymorphism analysis**

- Polymorphism... the same molecule, but other configuration
  - e.g. Different speed to solve → effective drug

Polymorphism Control... Essential for drug design
- e.g. Sulfanilamide
  - \( \alpha \)-form
  - \( \beta \)-form
  - \( \gamma \)-form

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**THz spectroscopy for Racemic compound**

- enantiomer
  - Even the same molecules have different effects as medicine or poison with different atomic arrangement
  - e.g. Thalidomide

- R (hypnotic)
- S (teratogen)

---

Different spectrum between DL and D/L

Different spectrum due to each atomic connection

Available for chiral recognition
THz spectra of glucose with/without γ-ray irradiation

<table>
<thead>
<tr>
<th></th>
<th>①</th>
<th>②</th>
<th>③</th>
<th>④</th>
<th>⑤</th>
<th>⑥</th>
<th>⑦</th>
<th>⑧</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not irradiated</td>
<td>1.455</td>
<td>2.595</td>
<td>2.772</td>
<td>3.060</td>
<td>3.419</td>
<td>3.915</td>
<td>4.052</td>
<td>4.698</td>
</tr>
<tr>
<td>γ-ray irradiated</td>
<td>1.455</td>
<td>2.590</td>
<td>2.763</td>
<td>3.043</td>
<td>3.414</td>
<td>3.902</td>
<td>4.032</td>
<td>4.687</td>
</tr>
<tr>
<td>frequency shift</td>
<td>0</td>
<td>-5GHz</td>
<td>-9GHz</td>
<td>-17GHz</td>
<td>-5GHz</td>
<td>-13GHz</td>
<td>-20GHz</td>
<td>-11GHz</td>
</tr>
</tbody>
</table>

C (cytosine)
A (adenine)
G (guanine)
T (thymine)
U (uracil)
THz spectral images of liver cancer tissue

Liver sample containing tumor metastasis

![Image of liver sample with normal and cancer areas labeled]

- t = 200μm

![Graph showing transmittance vs. frequency with cancer and normal lines]

- 1.56THz
- 3.70THz

THz reflection spectra

![Diagram illustrating setup for reflection spectroscopy]

- Sucrose measurement and calculation
- Scallop shell with CaCO₃

![Graphs showing reflection vs. frequency for sucrose and scallop shell]
Attenuated Total Reflection (ATR) spectroscopy

- Measurement only in evanescent field
  - Measurement of sample with large absorption
  - Detection with a small amount of species
  - Surface analysis of thin films

Refractive index @ 1 THz

<table>
<thead>
<tr>
<th>Material</th>
<th>Refractive Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyethylene</td>
<td>1.6</td>
</tr>
<tr>
<td>Si</td>
<td>3.4</td>
</tr>
<tr>
<td>Ge</td>
<td>4.0</td>
</tr>
<tr>
<td>H₂O</td>
<td>2.1</td>
</tr>
<tr>
<td>Alcohol</td>
<td>≈ 1.5</td>
</tr>
</tbody>
</table>

Condition for ATR (total reflection condition)

\[ \theta_{in} > \theta_{critical} = \sin^{-1}\left(\frac{n_2}{n_1}\right) \]

\[ n_1 > n_2 \]
**THz spectroscopy for hydration/dehydration**

![Graph showing absorbance vs frequency for D-glucose monohydrate](image)

- α-D-glucose has changed to monohydrate stored in normal atmosphere
- The reaction is reversible by drying in vacuum

**THz spectroscopy for Racemic compound**

**Enantiomer**

Even the same molecules have different effects as medicine or poison with different atomic arrangement.

*E.g.* Thalidomide

![Graph showing absorbance vs frequency for Thalidomide](image)

- Different spectrum between racemic and R/S
- Different spectrum due to each atomic connection
- Available for chiral recognition
기조강연