10 May 2024

Pioneering the future together

Engineering to pave the way for the future

Junichiro Shiomi
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The University of Tokyo

1.Telecommunications and Technology

Digital

AI・Big Data

Can hundreds of millions of parameters be optimized instantly?

$$Min. \quad -\sum_k y_k \log(f(x_k))$$

y_k : labels

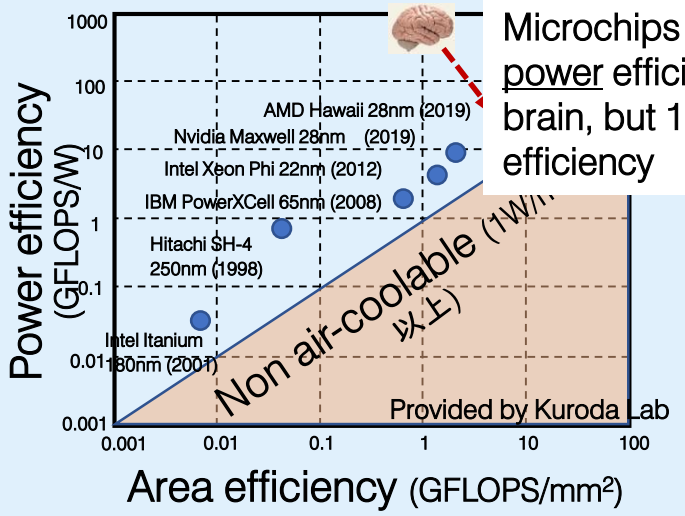
$f(x_k)$: outputs for input x_k

Minimize cross-entropy error (for classification problems)

⇒ how to calculate quickly and find good solutions

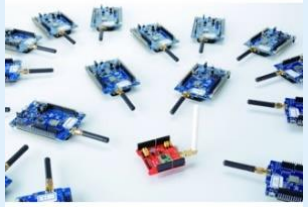
5G・IoT・Security

Will a microchip's power efficiency exceed that of the human brain?



Microchips have 1/100th of the power efficiency of a human brain, but 10 times the area efficiency

IoT Devices

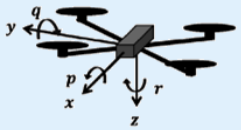


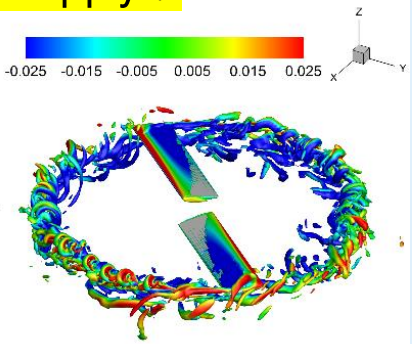
Provided by Morikawa Lab

Remote

Mobility・Logistics

Can drones fly long distances w/o power supply？





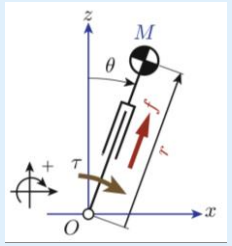
Provided by Rinoie, Imamura Lab

$$\frac{\partial \boldsymbol{v}}{\partial t} + (\boldsymbol{v}\cdot\nabla)\boldsymbol{v} = -\frac{1}{\rho}\nabla p + \nu\nabla^2\boldsymbol{v} + \boldsymbol{g}$$

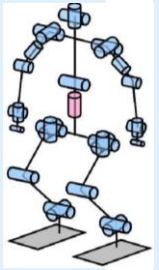
Robots・Digital Manufacturing

Can we make robots to be as flexible as living organisms?

Provided by Asama Lab



Kajita et al.,2004



Provided by Kuniyoshi, Niiyama Lab

$$\ddot{q} = \mathbf{M}^{-1}(q)\{\tau - \mathbf{C}(q,\dot{q})\dot{q} - g(q)\}$$

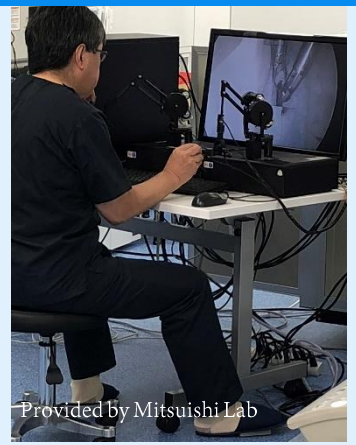
$$\tau \rightarrow (q, \dot{q}, \ddot{q})$$

2. Life and Society

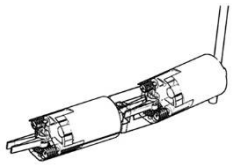
Life

Resilience

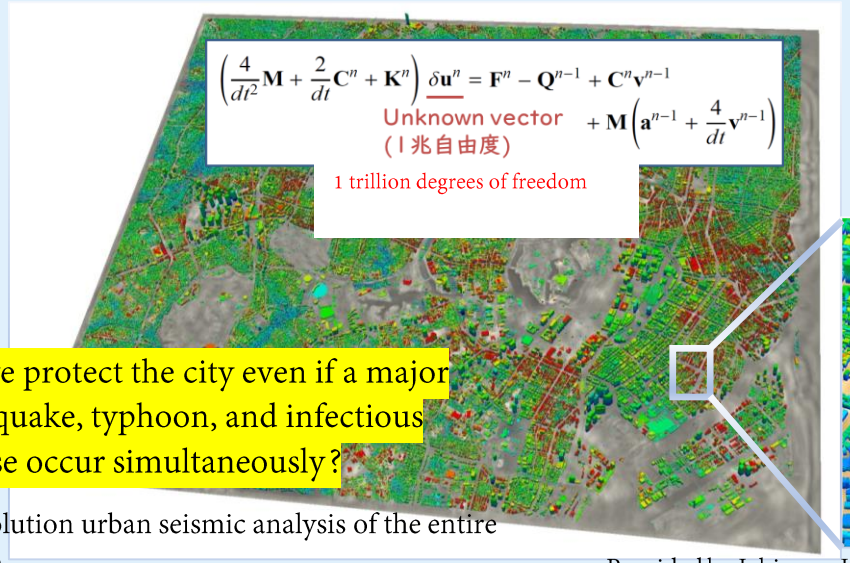
Health, Medical, and Nursing Care


Provided by Mitsuishi Lab

Can the sensations encountered while performing surgery be reproduced remotely?

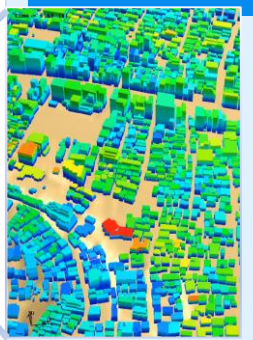

Provided by Sakuma Lab

City Disaster Prevention



Can we protect the city even if a major earthquake, typhoon, and infectious disease occur simultaneously?

Ultra-high resolution urban seismic analysis of the entire Yamanote Line


Provided by Ichimura Lab

Housing & Culture

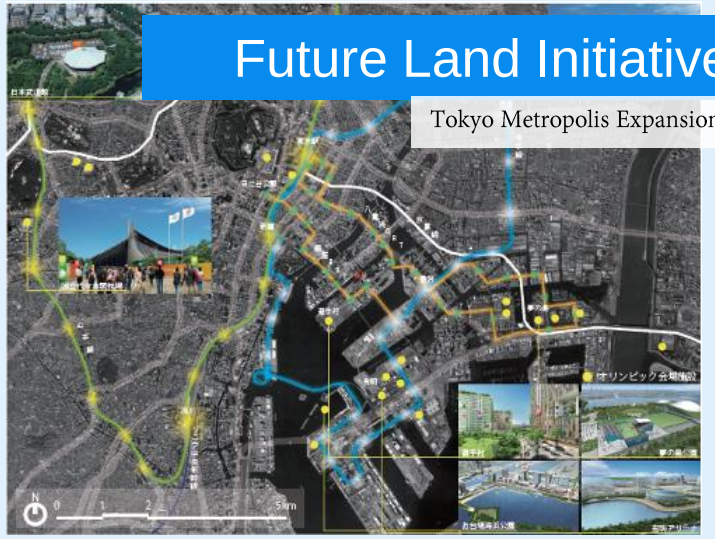

Kumamoto Earthquake Reconstruction "Minna no Ie"
(House for Everyone)
Photo by Vincent Hecht

What public spaces carry on local culture?

↓

Design collaboration between architects and residents.

Future Land Initiative


Tokyo Metropolis Expansion Plan 2050

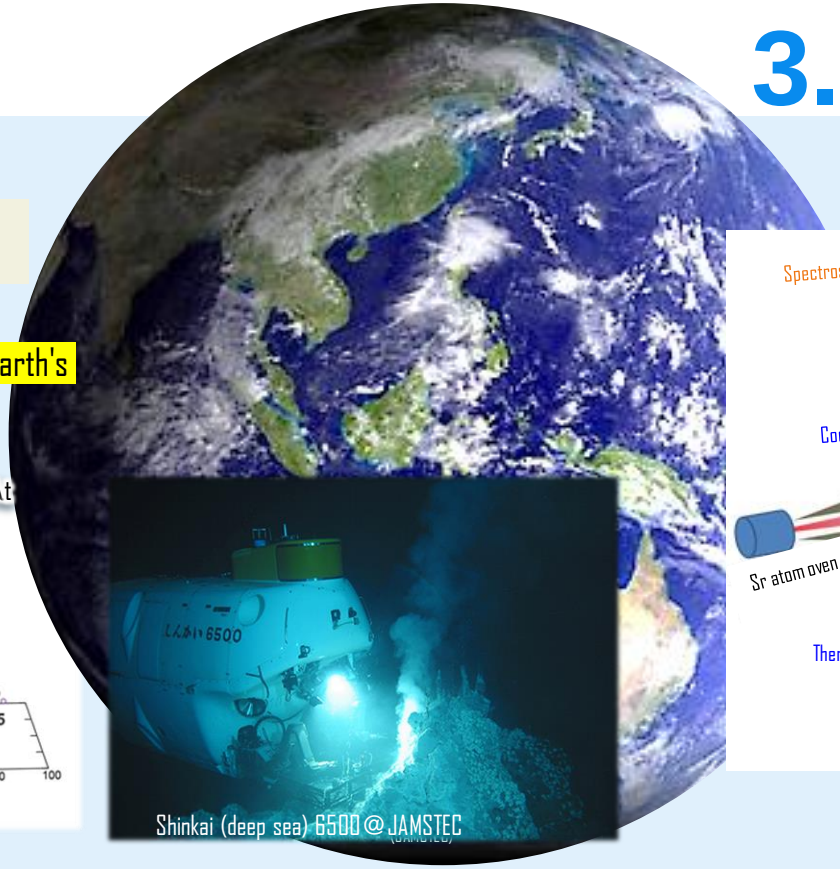
What is the land of the future? ↓

Policy Making and Social Implementation

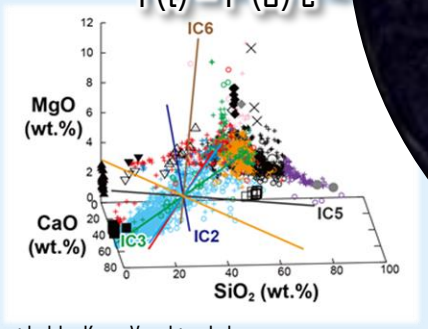
3. Earth & Science

Sustainability

What is the quantity and distribution of Earth's resources?



$$P(t) = P(0)\, e^{-\lambda t}$$



Provided by Kato, Yasuhiro Lab

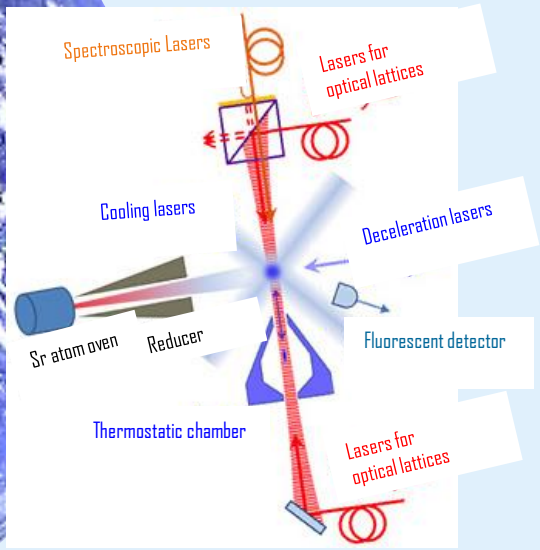
Science Link

Quantum & Matter

What is the most accurate clock in the world?

↓

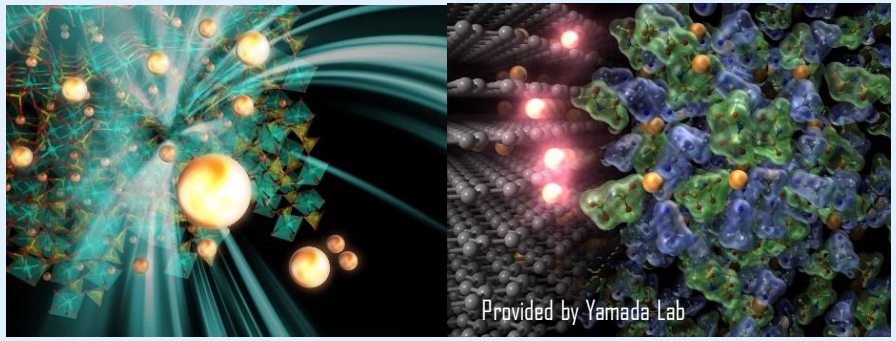
Laser cooling of Sr atoms
"Optical Lattice Clock"
A clock that is not off by a second in 13.8 billion years of cosmic age



Provided by Katori Lab

Environment & Energy

Can batteries be made without resource constraints?



Provided by Yamada Lab

Space & Nature

What complex systems can accomplish missions in unknown space environments?

↓

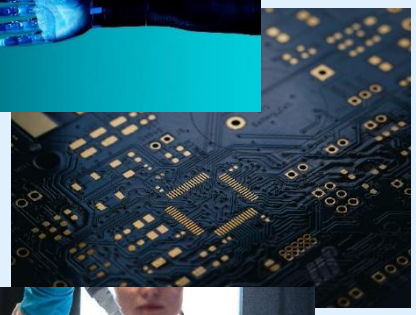
Humanity's frontier requires extreme performance

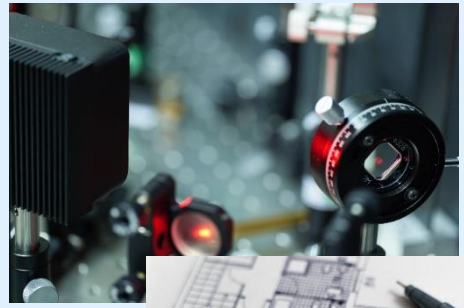
Provided by Nakasuka Lab

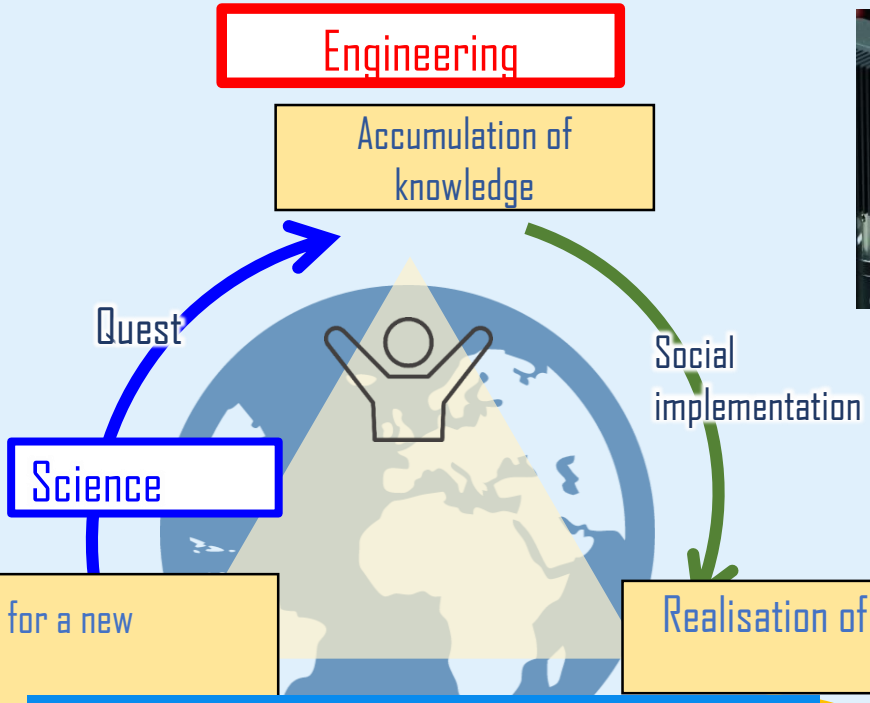
What is engineering?

Science = The study of exploring truth in nature

Engineering = The study that contributes to the development of human society on the basis of basic science





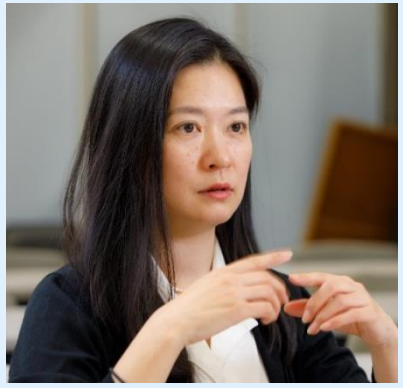


Transforming the society!

Engineering goes beyond exploration

Research at School of Engineering

Examples of research topics from 12 professors












Department of Systems Innovation
Professor Yasuhiro Kato

Ultimate frontier resource: discovery and exploration of rare-earth elements (REE-rich mud)

Towards development of REE-rich mud

Residual mud is used for landfill of remote islands

Neutralization with NaOH turns remaining acid into "salt"

$HCl + NaOH \rightarrow$ "NaCl" $+ H_2O$

Transportation (Leaching solution, Residual mud, etc.)

REE FPSO (Floating Production Storage and Offloading System)

Leaching of REE by HCl

Acid diluted with seawater

Leaching on the ship

Plant on land

Transportation tanker

Support vessel

Airlift system to lift REE-rich mud

ROV

AUV

Subsea mining by Under water backhoe

Under water backhoe

compressed air

bubble + mud + seawater

mining by backhoe

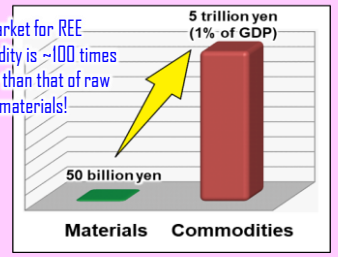
mining by backhoe

Pressure Regulating valve

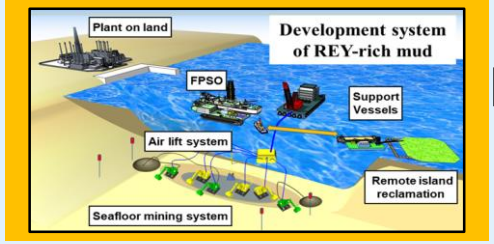
REE-mud (slurry)

Rare-earth elements (REE-rich mud) pioneer the future of Japan and the world

Economic scale of REE industry



Realisation of development of Minamitorishima REE-rich mud



Seafloor mineral resources development industry

- Highly advanced materials industry
- Marine research industry
- Marine development industry

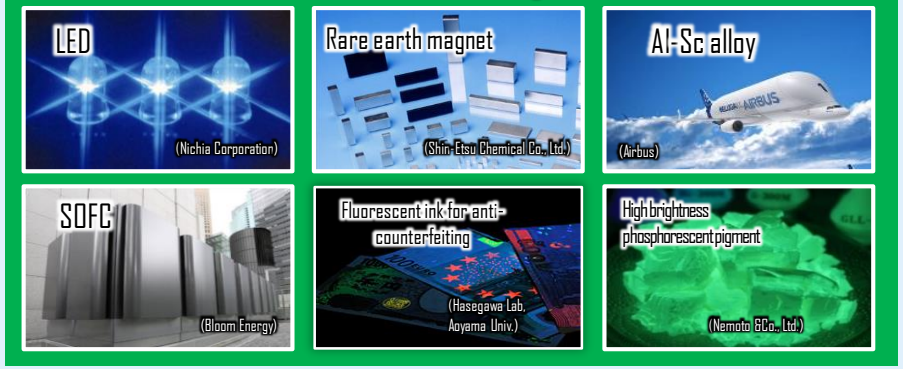
Expansion and creation of high-tech materials industry, related to next generation energy technologies

Success in creating a pilot product from rare-earth elements in REE-rich mud for the first time in the world!

Light of Minamitorishima !

(Broadcasted on 27 November 2017, NHK News 7, etc.)

Hi-tech materials industry



Developing rare-earth elements (REE-rich mud) to create a 10-trillion-yen-a-year industry

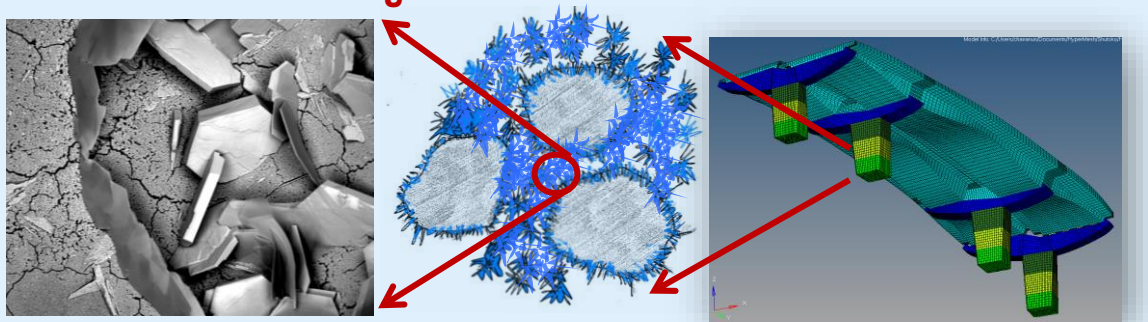
Developing innovative seafloor resources for a prosperous future

UTokyo

Department of Civil Engineering
Professor Tetsuya ISHIDA

Innovations in Concrete Technology: Multiscale Modeling, Digital Fabrication, Green Concrete

Multi-scale Modeling of concrete materials and structures

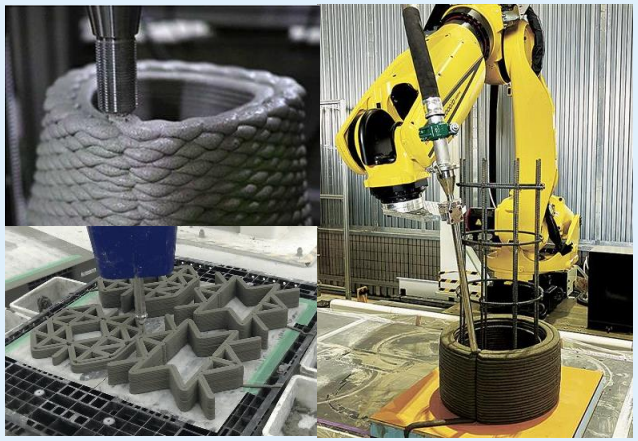


Size of the object

(nano meter) (micro-meter) (centi-meter) (meter)

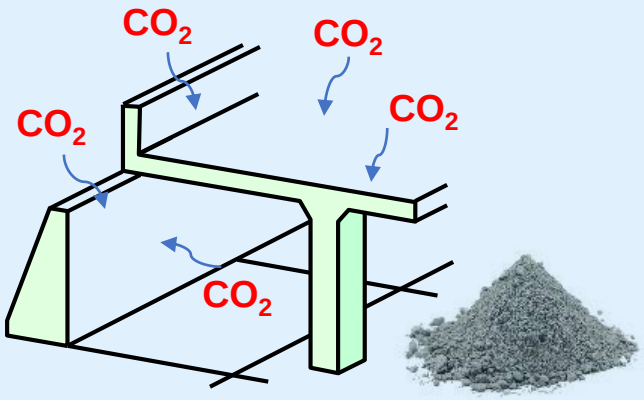
An innovative numerical method that simulates the process from concrete hardening to long-term deterioration, coupling 20 governing equations with thermodynamic, mechanical, and chemical models spanning from nanometer to meter scales.

Concrete 3D Printing Technology



Innovative additive manufacturing technology for concrete structures, enabling enhanced functionalities and metamaterial-like properties

CO2-adsorbing Concrete Like Plants



An innovative technology that achieves carbon neutrality by absorbing and fixing CO2 within the structure during the hardening and service phases of concrete.

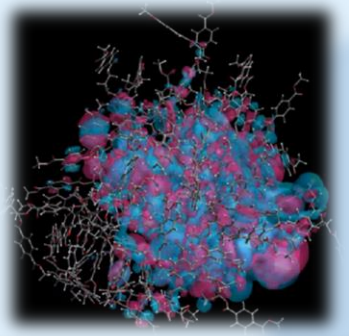
Achieving a sustainable society through innovative concrete technology

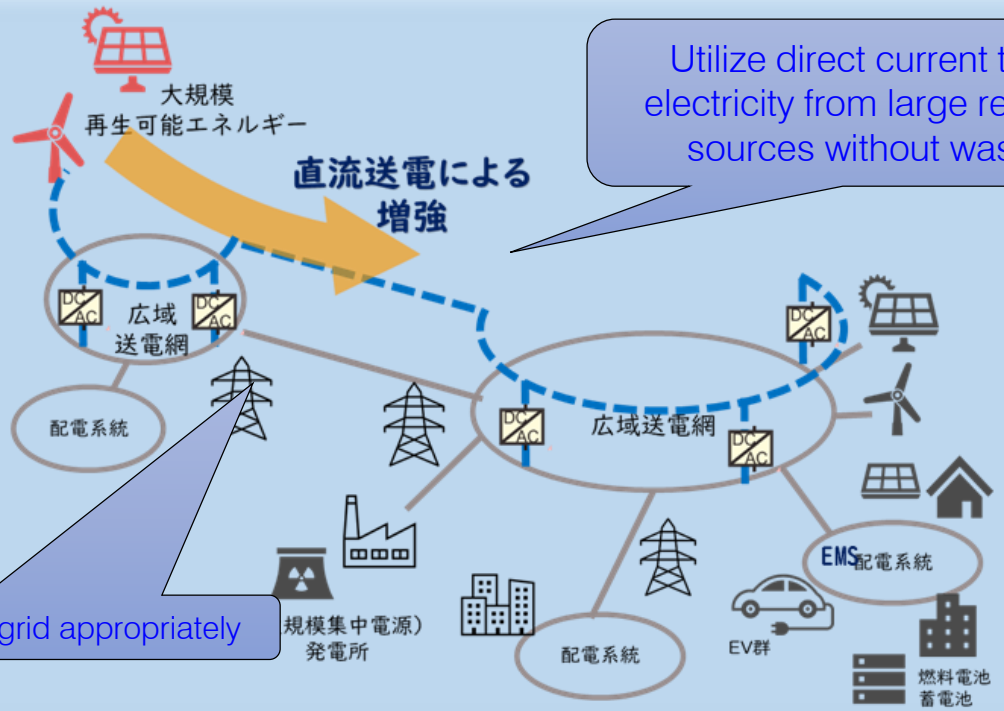
Department of Electrical and Electronic Engineering
Professor Akiko Kumada

Building a power grid to achieve carbon neutrality

- ✓ Electrical Materials x AI ⇒ Embodying the next-generation power grid (If it cannot be carried, it is thrown away)
- ✓ Discharge x Sensing ⇒ Life span assessment (Facilities must be maintained)
- ✓ Demand x Machine Learning ⇒ Energy management (Smart control based on the characteristics of electricity)

Development of new materials for DC high voltage





Utilize direct current to carry electricity from large renewable sources without wasting it

Upgrade existing AC power grid appropriately

Clarification of Large Current Phenomena

Next-generation power grid with an additional DC transmission layer

Creating a new power grid that carries electricity without waste

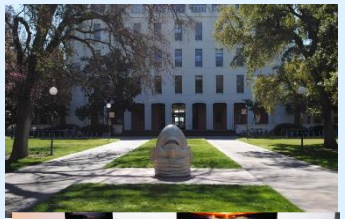
Department of Mechanical Engineering
Professor Junichiro Shiomi

Aiming to solve social problems through innovation in thermal energy materials!
〜A major appeal of engineering is that you can study abroad and work on a wide range of subjects〜

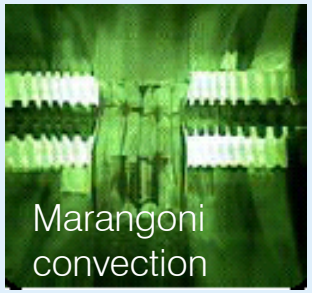
Next generation aircraft
(meter scale)

Undergraduate

Studied at University of California

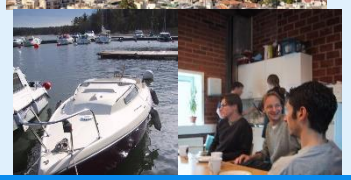


Single crystal growth @space
(millimeter scale)

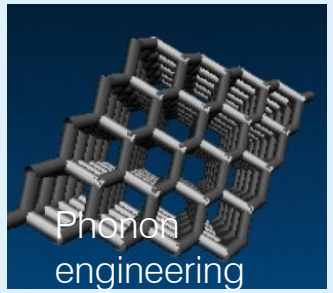


Graduate

Studied at National Technical University of Athens



Nano tech
(nanometer scale)



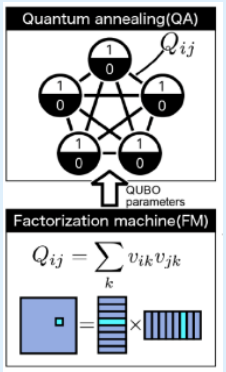
Postdoc

Studied at KTH Royal Institute of Technology

A new era of nanotechnology: Innovating materials with AI
“Materials・Informatics”

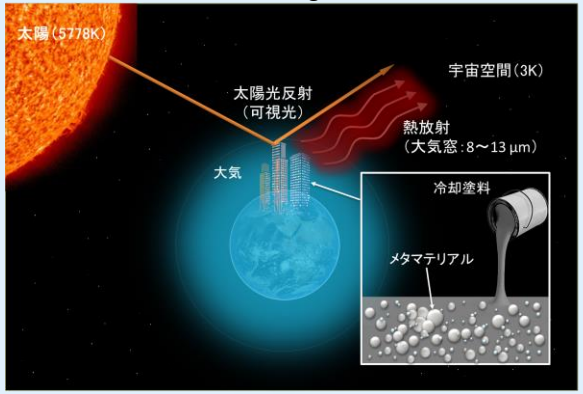
Optimal design through machine-learning methods for computational science

High-speed exploration using quantum computers



Robotic automated fabrication and performance evaluation

Application example: 'Earth-cooling' heat-radiating materials



Innovative computational science to create 'earth-cooling' materials

Department of Applied Physics Professor Eiji Saitoh

Physics × Engineering: Can "physical laws" be created?

Understanding the fundamental principles of physical laws

$$i\hbar \frac{\partial}{\partial t}|\psi(t)\rangle = H|\psi(t)\rangle$$

$$\delta\int_{t_1}^{t_2} L(q,\dot{q})dt = \int_{t_1}^{t_2}(\frac{\partial L}{\partial q}\delta q + \frac{\partial L}{\partial \dot{q}}\delta\dot{q})dt$$

$$= \int_{t_1}^{t_2}(\frac{\partial L}{\partial q}\delta q - \frac{d}{dt}(\frac{\partial L}{\partial q})\delta q)dt = 0$$

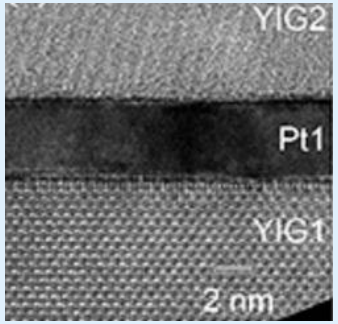
$$\frac{dA(t)}{dt} = \frac{1}{i\hbar}[A(t), H]$$

.....

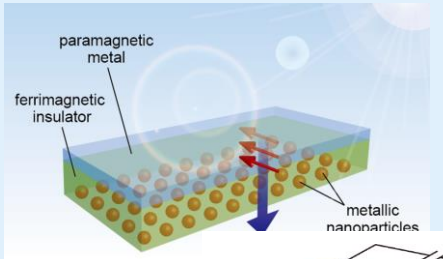
=

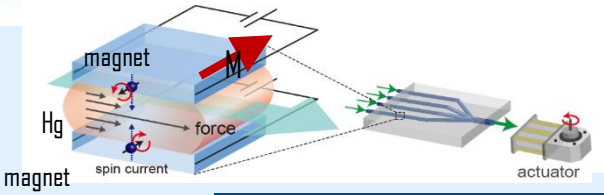
Fundamental principles of physical laws: Symmetry in space-time and quantum phase of wave-function

Creating new physical laws in materials !
Design, control and manipulate physical laws



Designing materials at the atomic level





magnet

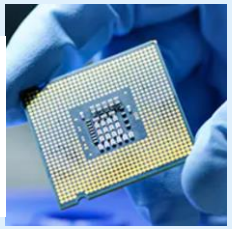
Design and operation in materials are now possible

New functions and phenomena in materials that were previously never considered
→ Technologies change the world

Electron spin

↓

Micro power generator and micro motor based on completely new principles



Emergence of Nanotechnology to arrange atoms in desired positions

Material synthesis at the atomic level

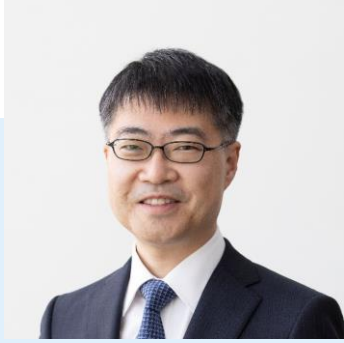
Supercomputer dedicated to a specific task

Create innovative materials and functions by creating new physical laws

Department of Electrical and Electronic Engineering

(Former Dean of Faculty of Engineering)

Professor Takao Someya

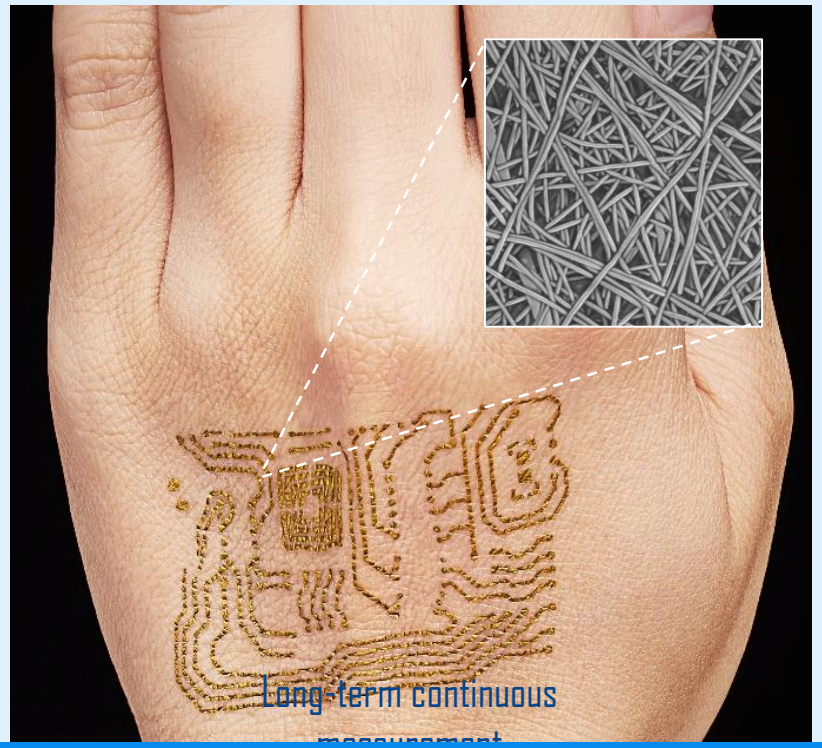


Collaboration between Medicine and Engineering

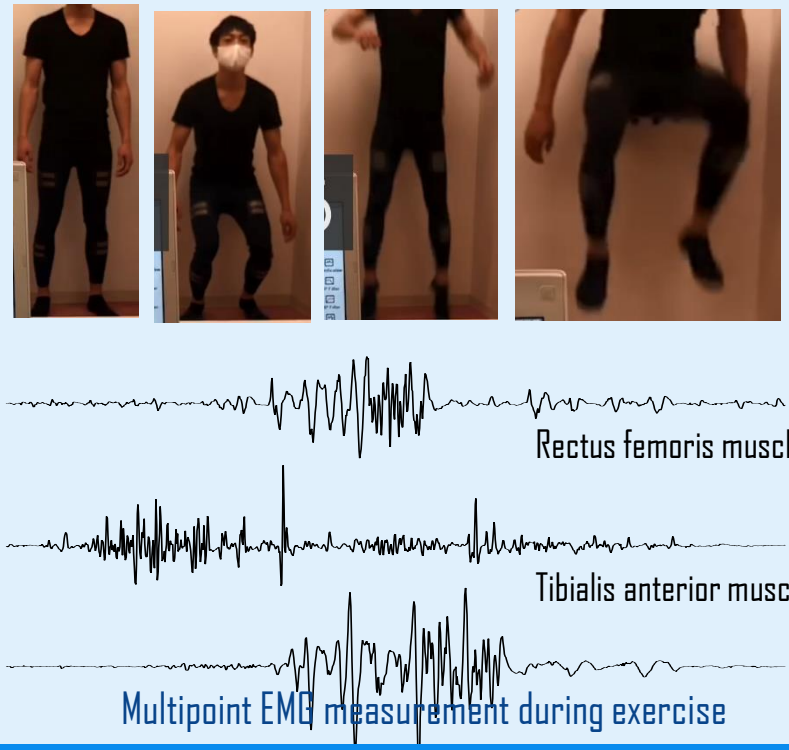
Inventing 'e-skin', a second skin with a natural fit, and laying the foundations for elastic electronics

Organic image sensor

Hypoallergenic skin-applied sensors



Wearable sensors

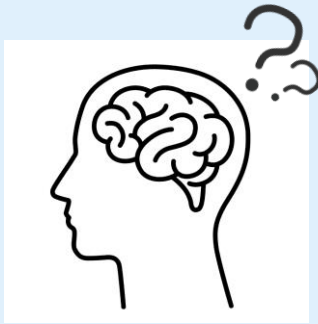


Creating innovative electronics which monitor long-term continuous body temperature, blood oxygen levels, pulse, etc.

Department of Systems Innovation Professor Yutaka Matsuo

Artificial intelligence: can intelligence be created artificially?

We can understand human intelligence better by making it ourselves.

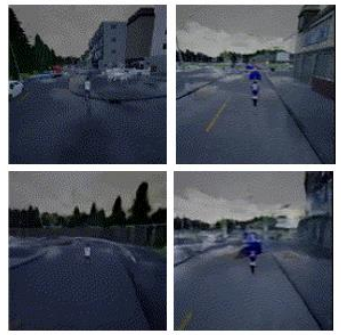


The mechanisms of intelligence and brain structure are not yet unraveled

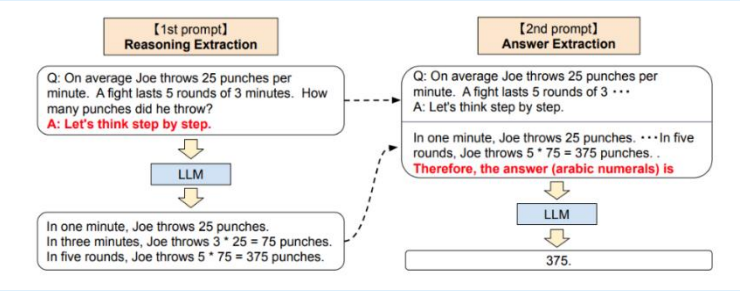
↓

At Matsuo Lab, they want to understand intelligence by "creating intelligence"

World model robotics research



Large language model



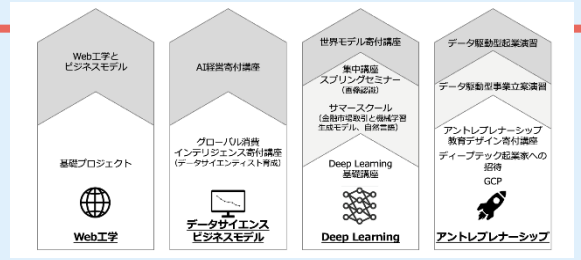
Discovered a dramatic improvement in accuracy by adopting "Let's think step by step"

From here, we can reach the realization of true intelligence.

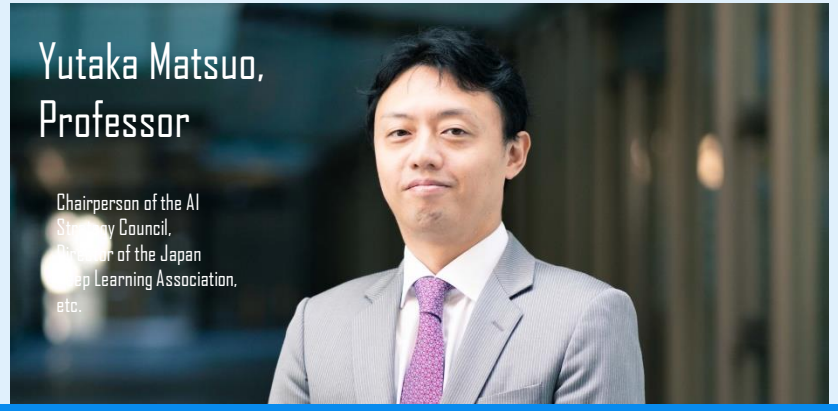
University corporate relations • Human resources development • Start-up incubation

Need for collaboration with academia and industry

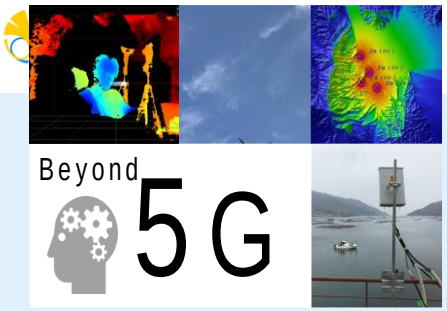
While at Stanford University, he witnessed the rapid growth of Google and Facebook closely. Now, he is determined to create an ecosystem in Japan on par with Silicon Valley.



Artificial Intelligence made dramatic increases in industrial competitiveness



New strategies for AI and ChatGPT will revive Japanese industry



Department of Systems Innovation
Professor Akio Nakao

Information and communication as a “lifeline”

The value of information and communication necessary for future society

1. Safe and secure society
2. Easy to use
3. Can be used anywhere
4. Can be updated quickly
5. Environmentally friendly

Research in progress

- Ultra-realistic communications, “autonomous networks” that predict failures and recover automatically
- “Super-intelligent networks” that optimally and automatically connect with AI
- “Communication that can connect anywhere on earth” utilizing outer space (low earth orbit satellites)
- “Upgradable communications” that make the most of software
- “Ultra-low power communications” that use AI to predict and optimize power consumption

Ultra-realistic communications

Enhance the sense of reality with large capacity and ultra-low latency!

Bring the country’s communications coverage to 100%

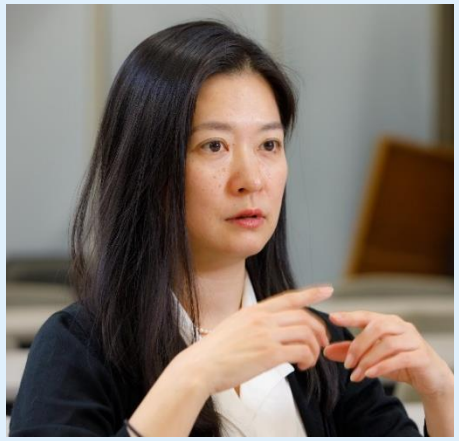
Mobile communications that connect anywhere on the ground!

Creation of a safe and secure future local society

Means of communication for victims of mountaineering accidents

Creating an information and communication network that connects anywhere in Japan

Department of Architecture
Professor Kaori Fujita



Architecture is a technology and an art!

Continue to preserve the value and beauty of historic wooden architecture and use it safely

Building investigations in Japan and abroad

International Collaborative Research
(Investigation of Wooden Churches in Ukraine)

Seismological Observation and Monitoring
(Kamakura, Kenchoji Temple)

Earthquake resistance tests

Experiment of shaking a five-story pagoda model with the same waves as those of an earthquake

Applied to buildings

Development of building reinforcement and repair components

Building an Urban Legacy

Kengo Kuma
University Professor
Photo (c) J.C. Carbonne

Engineering x Art to create strong and beautiful wooden architecture

Department of Mechanical Engineering

Professor Gentiane Venture

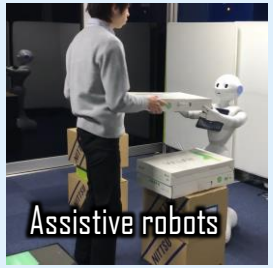
Connecting people with robots!

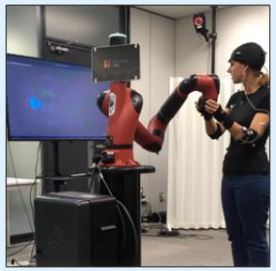
Born and raised in the south of France, after graduating from university, she came to Japan to engage in research and has remained active in Japan!

Understanding non-verbal communication and human behaviour

Connecting people and robots by enhancing the expressive power of robots

Connecting people through robots with "slow technology"





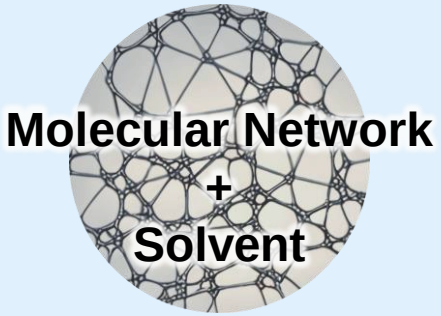
Robots that understand human feelings will help create a society friendly to all

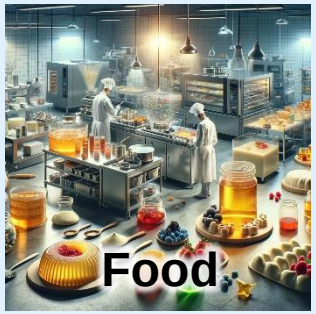
Department of Chemistry & Biotechnology Professor Takamasa Sakai

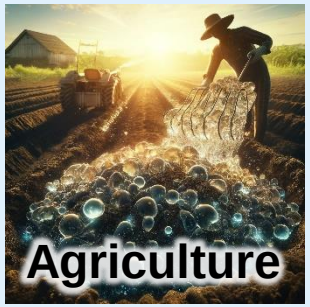
Collaboration between Medicine and Engineering

Sakai Lab – Gel Physics X Engineering = Gel Medicine

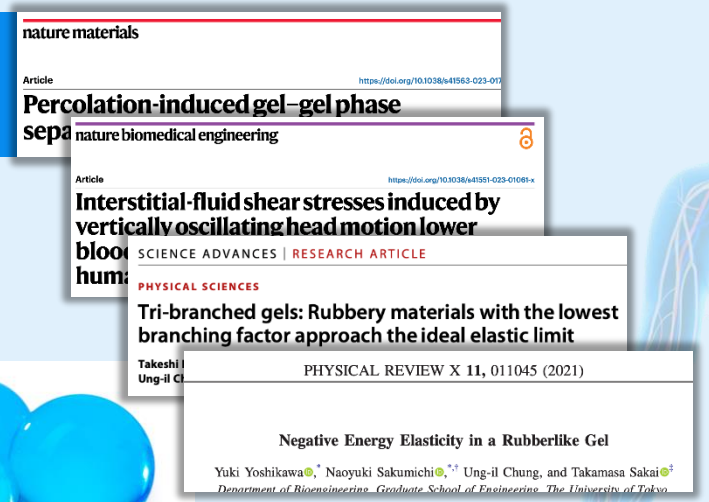
Gels are ubiquitous materials that can be found in a wide variety of applications across many different fields





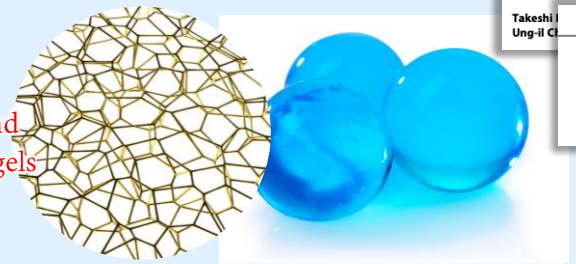


The most uniform gel in the world: Tetra Gel



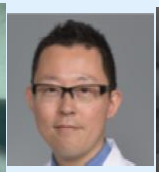
How is softness determined?
How far can it be stretched?
How strong is it?

Many formulas that defy long-held conventions and govern the properties of gels have been discovered

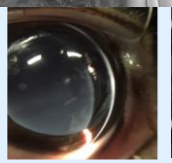


Medical applications of human-like materials - gels

Anti-adhesive agent

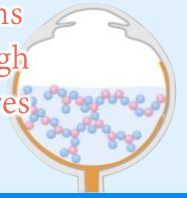


Hemostatic agent



Close collaboration between clinicians

Social implementation through ventures



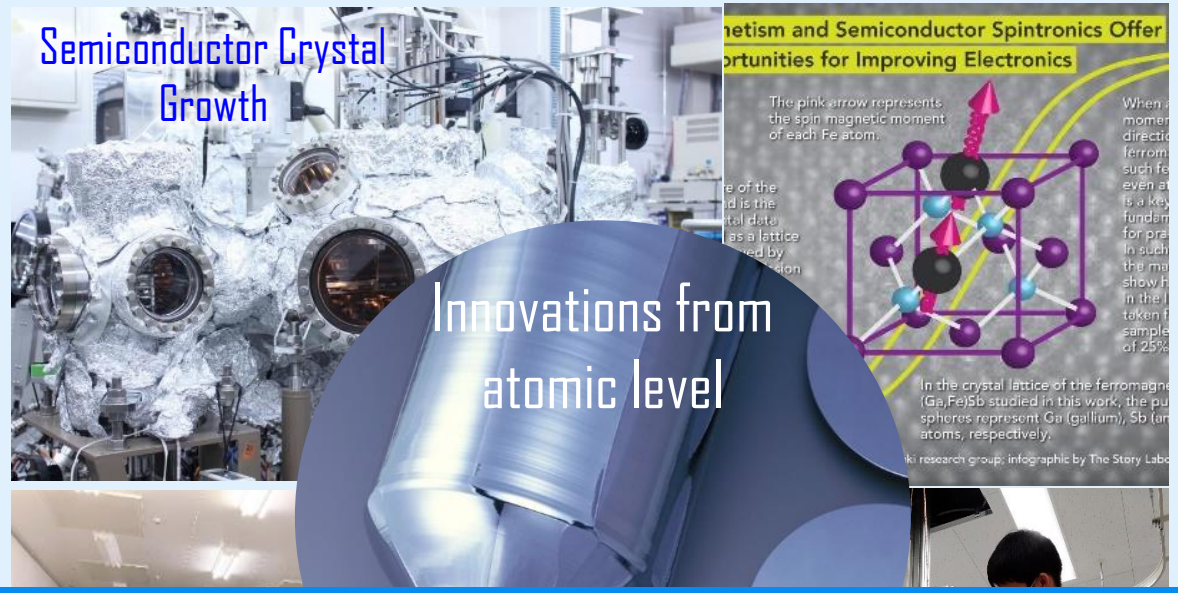
Artificial vitreous

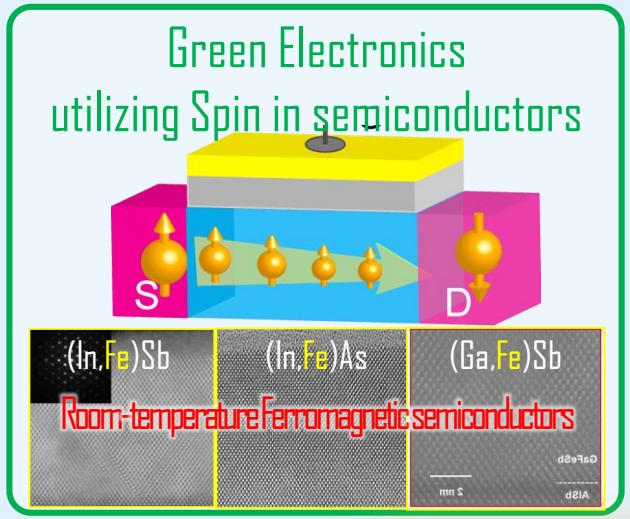
Creating innovative hemostatic and anti-adhesive agents with gel

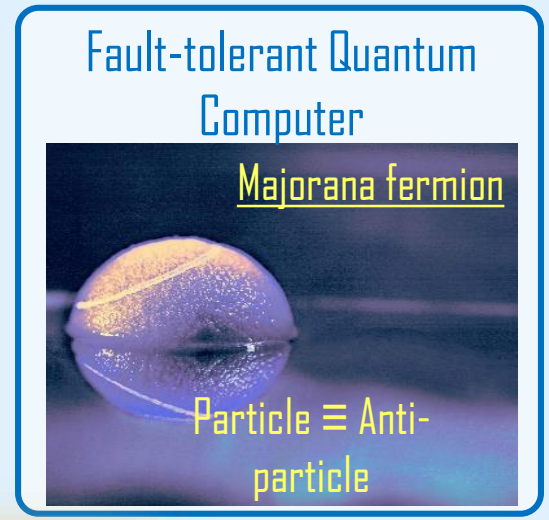
UTokyo

Department of Electrical and Electronic Engineering Assoc. Prof. Le Duc Anh

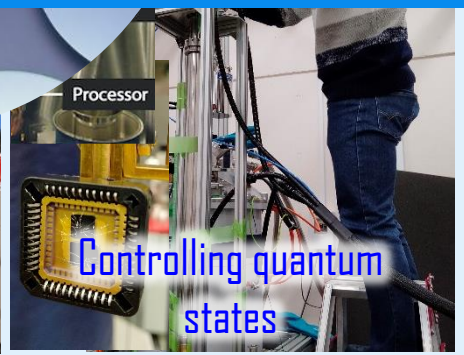
Bringing out the full potential of semiconductor materials







Empower semiconductors to create a sustainable future society



You pioneer the future

The University of Tokyo Faculty of Engineering is waiting for you