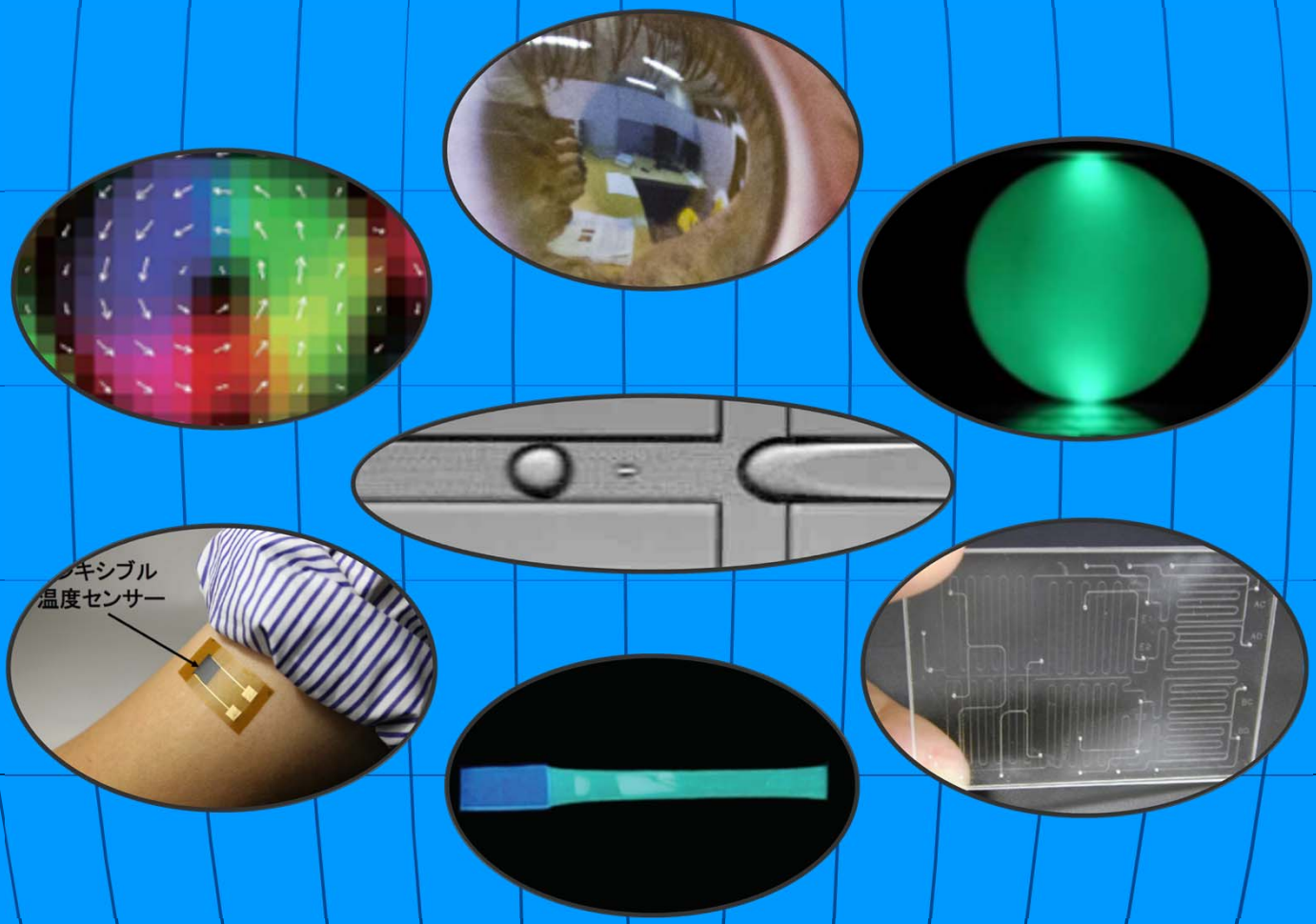
# Selected Novel Technologies for Licensing

2016 MRS Fall

# Innovative Technologies for Your Products




Japan Science and Technology Agency

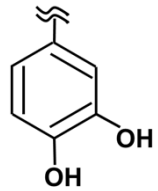
# Inorganic Nanoparticles

## Inorganic nanoparticles coated with block copolymers containing catechol segments

Associate Prof. Hiroshi Yabu (Tohoku University)

## 1. Introduction

**Catechol segment**

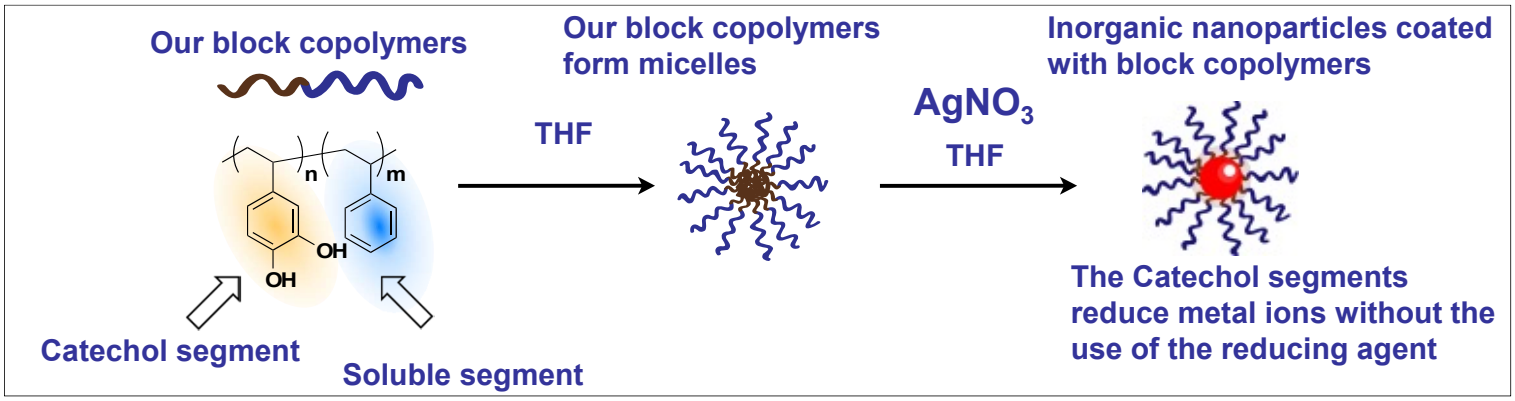



We invented new block copolymers containing Catechol segments. Major characteristics of the materials are…

1. No reducing agent is required.
2. No purification process is required.
3. The Catechol segments capture firmly inorganic nanoparticles(ex. metal ion).
4. The block copolymers with inorganic nanoparticles are adhered firmly to substrates.

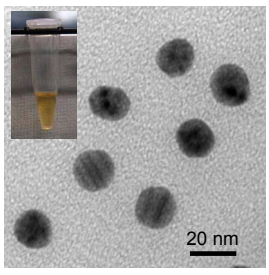
## 2. Process

The inorganic nanoparticles are formed in the micelles without using the reducing agent by our block copolymers containing Catechol segments in the side chain.

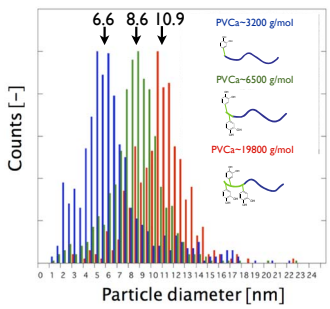


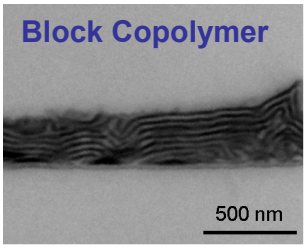

## 3. Experiment, Data, Characteristics

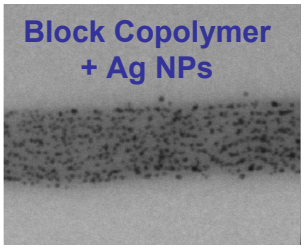
**Fine Metal Nanoparticles**




**Size Controllable**




## 4. Prospective Applications

- Wiring
- Catalyst
- Single-electron transistor

## 5. Patent Licensing Available

Patent No.: WO2015/129846

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# Mechanoluminescence

## Materials that emit light by mechanical stress

Dr. Chao-Nan Xu (National Institute of Advanced Industrial Science and Technology)

### 1. Introduction

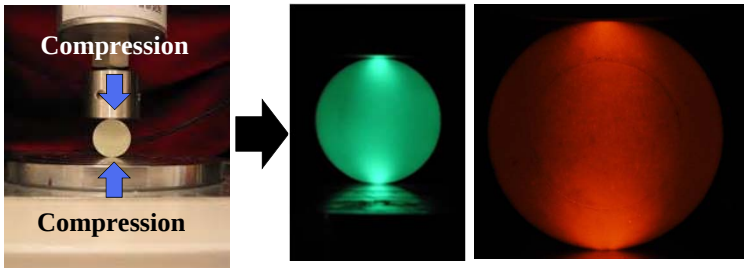
Our materials have the ability to emit light repeatedly in response to an external mechanical stress such as tension, compression, torsion, friction or impact.

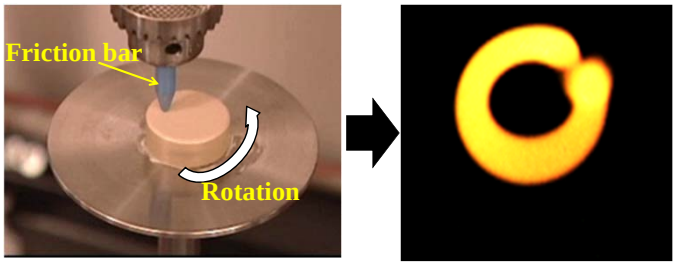

### 2. Mechanoluminescence Materials

We found several kinds of materials which exhibit a reversible highly bright luminescence in response to an external mechanical stress.

(Material Example)

$SrAl_2O_4$:Eu (Emission to green )
ZnS:Mn (Emission to yellow-orange ) etc.




### 3. Applications

Our materials (Powder)

Paints

Sheets

(Application Fields)
- Toys
- Sports goods
- Wearable items
- Infrastructure maintenance etc.

### 4. Patent Licensing Available

Patent No.: WO2004/007637 (US7297295, JP, EP, CN), WO2005/097946 (US8128839, JP, GB, CN)

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# Fluorescent Materials

## Mechanochromic Fluorescent Polymers

Associate Prof. Shohei Saito (Kyoto University) , Associate Prof. Hiroshi Yabu (Tohoku University)

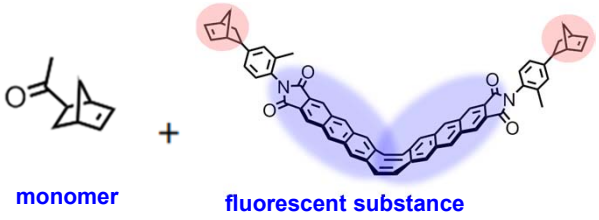
### 1. Problems of mechanochromic fluorescent polymers

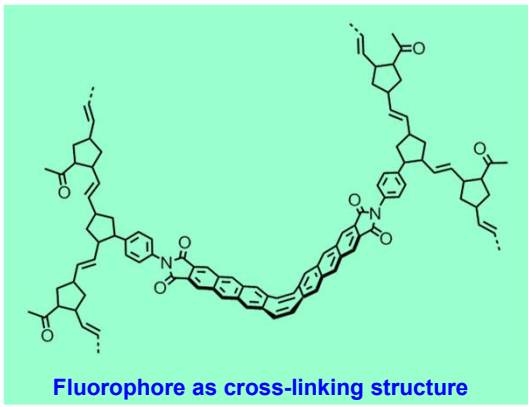
- Fluorescent color often changes when grinding the powder sample.(Irreversible fluorescence)
- By merely mixing the fluorescent material with the polymer, fluorescent colors do not change.
- Known fluorescent polymer is often irreversible polymer.
- Polymer that reversibly fluorescence known will take 2 hours to restore.

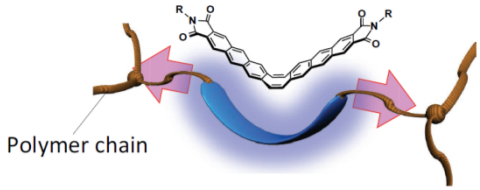
We have created **a rapid and reversible fluorescent polymers.**

### 2. Materials and Property

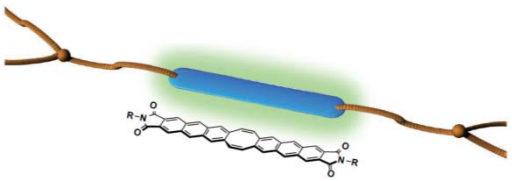
The polymerization reaction is initiated from both ends of the fluorescent substance, the fluorescent polymers were synthesized.

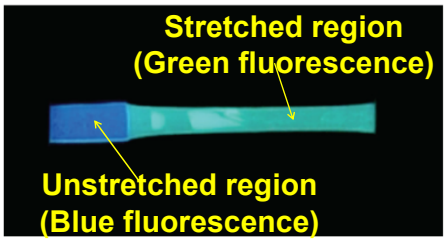


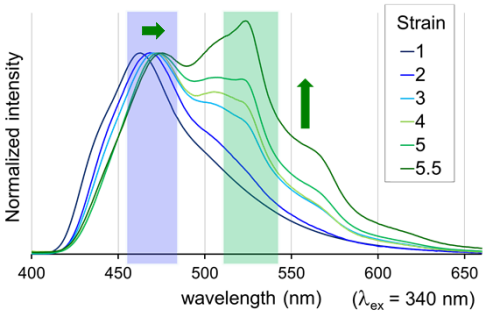





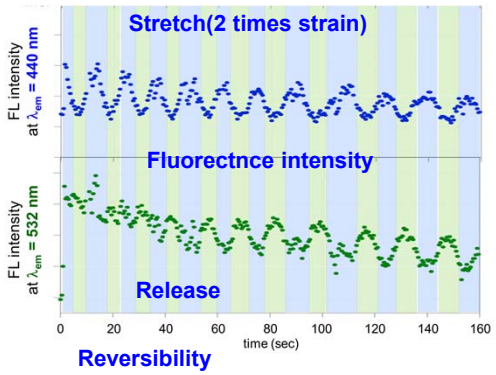





Reversible and rapid response




Strain and fluorescence spectral change




Reversibility

### 3. Possible applications:

- **Our polymer is one that can visualize the tension.**
- **Our polymer is one that can detect the distortion or destruction of the object**

- Visualization material distortion of the bridges and tunnels
- Visualization material of traction of undifferentiated cells

### 4. Patent Licensing Available

Patent No.: WO2016/080358

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# Mesocrystals (MCs)

## Self-assembly SUPERSTRUCTURES Metal Oxide

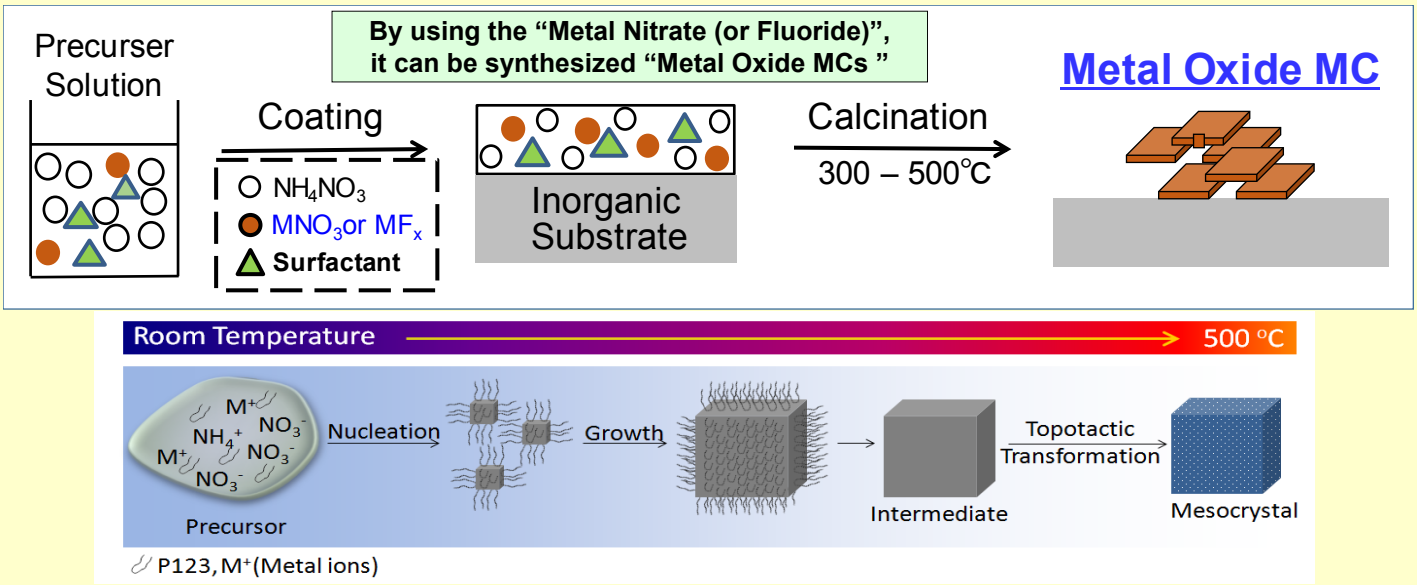
Prof. Tetsuro Majima (Osaka University)

## 1. Introduction

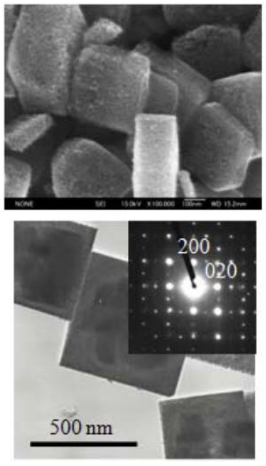
- Mesocrystals (MCs) are a superstructures with a crystallographically ordered alignment of nanoparticles and have some unique characteristics such as high-specific surface area, pore accessibility, good electronic conductivity and thermal stability.
- MCs are also an ideal platform for constructing functional materials that can solve a various tasks. The development of Metal Oxide MCs opens up exciting new opportunities for constructing much more efficient devices.

## 2. Newly Invented "Facile and General " MCs' Fabrication Method

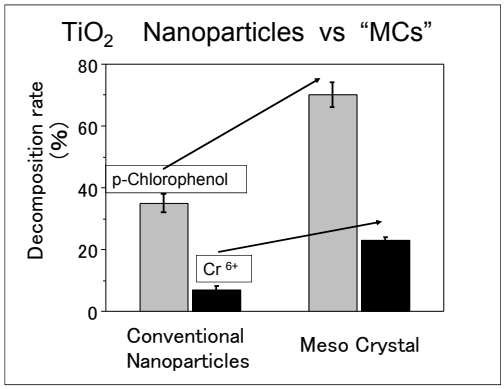
- The novel manufacturing method can synthesize Metal Oxide MCs facile and in a general way by utilizing topotactic structural transformation.



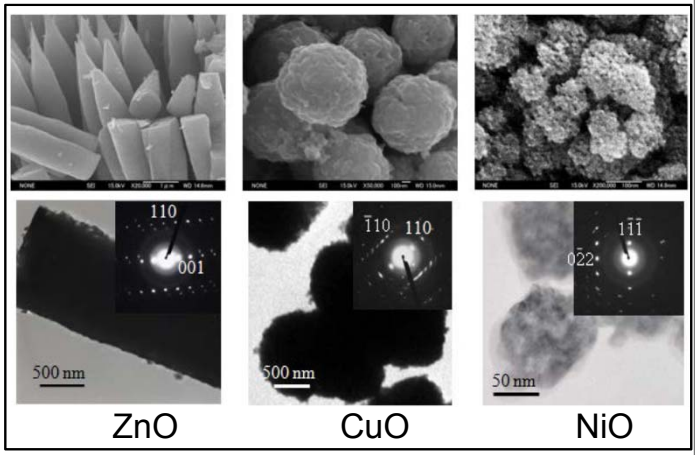

## 3. Characteristics of Metal Oxide MCs




$TiO_2$




The photodecomposition capability of $TiO_2$ "MC" has been greatly improved due to its large surface area(≧65m²/g) and its aligned [001] surface.




The variety of Metal Oxide MCs have been already produced.

## 4. Prospective Applications

- Catalysis
- Electrode
- Sensing
- Surface coating material

## 5. Patent Licensing Available

Patent No.: WO2014/119117 (US2016/001268, JP, CN)

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# Self-Assembled Electrolytes

## Ionic Switch by a Phase Transition in Liquid Crystals

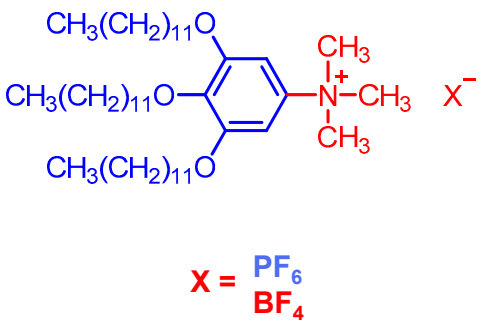
Prof. Takashi Kato (The University of Tokyo)

## 1. Introduction

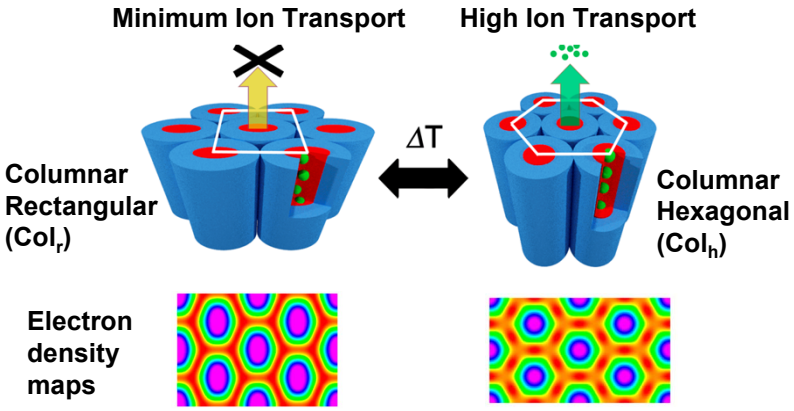
- Switching ionic conductivities in wedge-shaped benzenammonium liquid-crystal (LC).
- The ionic conductivities in the hexagonal columnar($Col_h$) phase are about four orders of magnitude higher than those in the rectangular columnar($Col_r$) phase.
- The switching behavior of conductivity can be ascribed to the structural change of assembled ionic channels.
- A thermoreversible phase transition between the $Col_r$ and $Col_h$ phases is used for the switch.

## 2. Principle of the Invention

### Molecular Structures

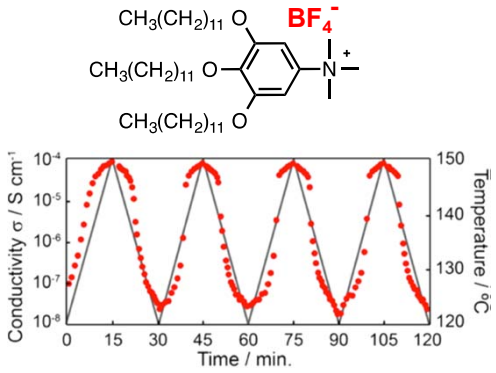



### Switching of Ion Conductivity of Liquid Crystalline Electrolytes by Temperature

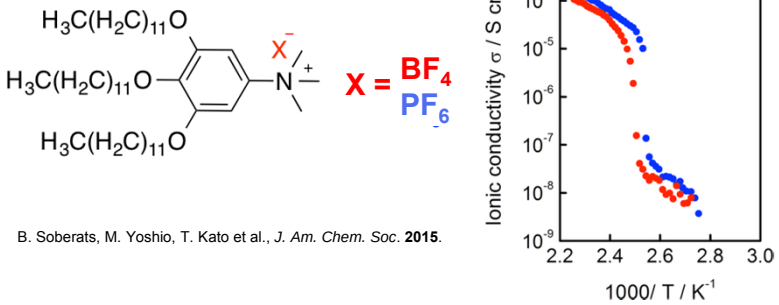



## 3. Characteristics

### Ionic Conductivity showing reversibility with $BF_4^-$, just like a switch




### Ionic Conductivity graph of the compound with $BF_4^-$(Red Line) and $PF_6^-$(Blue Line) anions




B. Soberats, M. Yoshio, T. Kato et al., *J. Am. Chem. Soc.* **2015**.

## 4. Application Examples

- ○Ionic devices
- ○Lithium-ion battery ○Electrolyte for solar sell
- ○Separation membrane material

## 5. Patent Licensing Available

Patent No.: WO2013/089174 (US8946480, JP, EP)

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# Micro-Fuel Cell

## High-Efficient proton conductor Nanochannels array based on a ferroelectric proton transfer phase substrate

Ph. D. Pihosh Yuriy, Ph. D. Yutaka Kazoe (The University of Tokyo)

## 1. Abstract

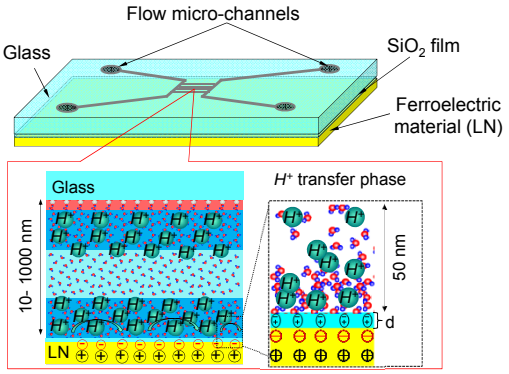
A micro-fuel cell (μ-FC) device on microfluidic chip platform with assistance of a $LiNbO_3$ (LN) material has been realized.

1. Realized high efficient protons conductor device based on LN material
2. Designed and fabricated a μ-FC device with assistant of LN material on microfluidic chip platform
3. Working principle of the μ-FC device was verified

## 2. Creation of high efficient $H^+$ conductor device

### Device Design

Proton conductor device based on LN material

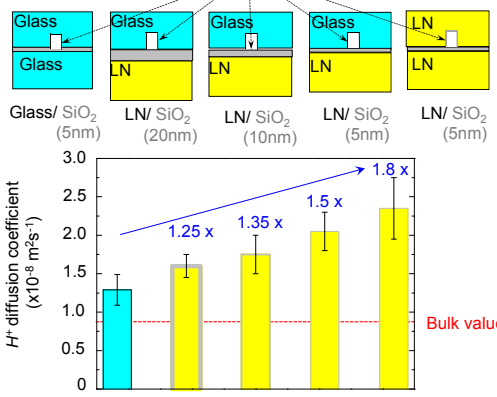



**Prediction**

Electrostatic potential addition
Eccentrically-located proton
Increase proton concentration near nano-channel wall
Increase proton transfer rate

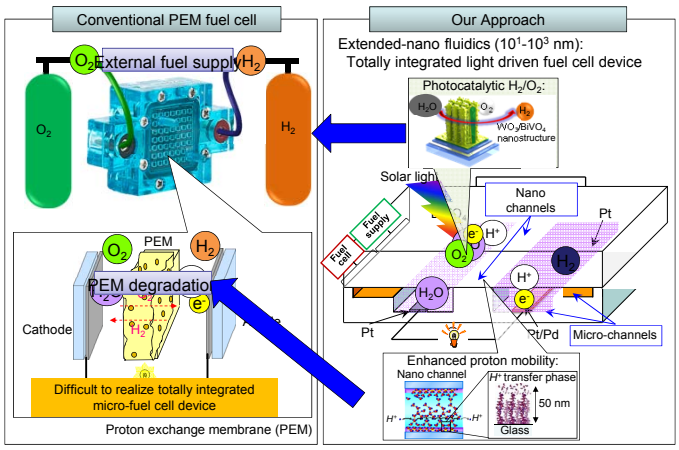
### $H^+$ Diffusion Coefficient

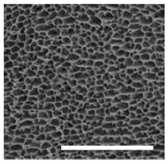
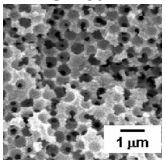
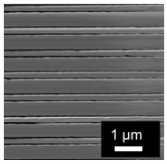
Device comparison: Nano-channels




1. Principle verification of a high efficient protons conductor device based on LN material
2. Verification of a proton transfer phase model

## 3. Comparison with the conventional Proton exchange membrane (PEM)




| | Conventional PEM | | Our Approach |
|---|---|---|---|
| | Nafion | Mesoporous Silica | Nano Channels |
| Material |  |   |   |
| Degradation | Easily | No | No |
| Temperature | 60-120℃ | 60℃ | r.t. |
| Proton conductivity [$10^{-2}$ S/cm$^2$] | 0.8 | 0.6 | 1.3 |

## 4. Application

- Next generation portable self-powered energy device

## 5. Patent Licensing Available

Patent No.: WO2016/063537
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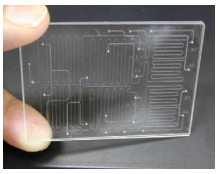
# Microchemical Chip

## Development of Microchemical Chips by Glass/glass Low Temperature Bonding Method

Associate Prof. Kazuma Mawatari (The University of Tokyo)

## 1. Introduction

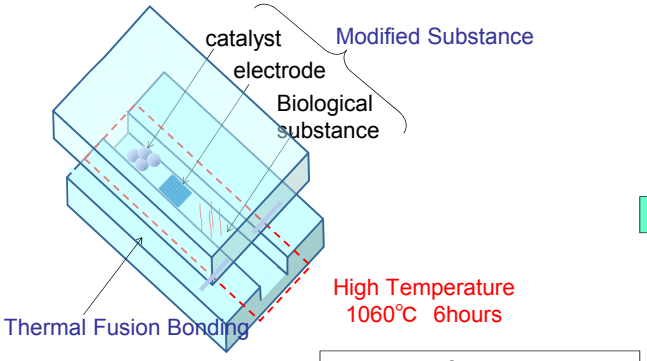


A microchemical chip is a chemical device in which a micro scale fine space is used in the field of diagnosis and analysis.
It is expected to realize a reduction in a mix and reaction time, a significant reduction in an amount of a sample and reagent, a reduction in the size of a device.

## 2. Key Features, Principle of the Invention, Structure of the Material

Glass substrate bonding method at low temperature(25~100℃) was newly developed to integrate functions in micro and extended-nano space.
The fabricated chips which a functional material such as a biological substance, or a catalyst, and an electrode is partially modified, achieve ultra-high performances in analytical and energy devices.

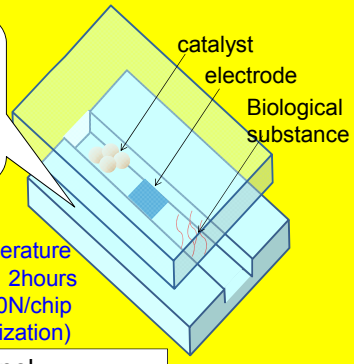
**Thermal Fusion Bonding Method (Conventional)**




-The modified substance is entirely burned off

**Low Temperature Bonding Method (New)**

The substrate surface treatment
1. $O_2$ plasma surface activation [The entire surface hydrophilic]
2. Addition of fluorine to the plasma [Hydrophilic adjustment]

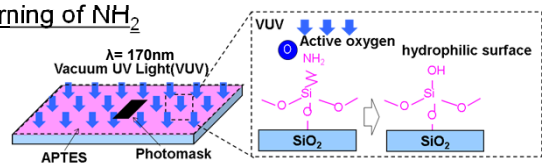



Low Temperature
25~100℃ 2hours
1000~5000N/chip
(Pressurization)

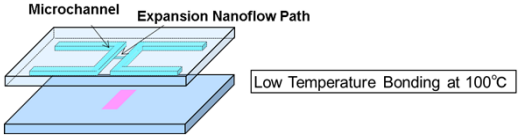
- Provide a leakproof microchannel
- Keep function of the chemical species such as modified substance, after bonding

## 3. Fabrication Process of the Microchemical Chip

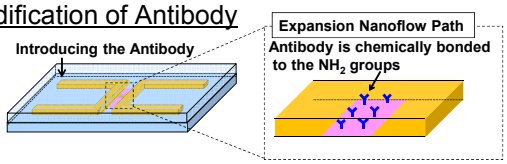
1.Patterning of $NH_2$



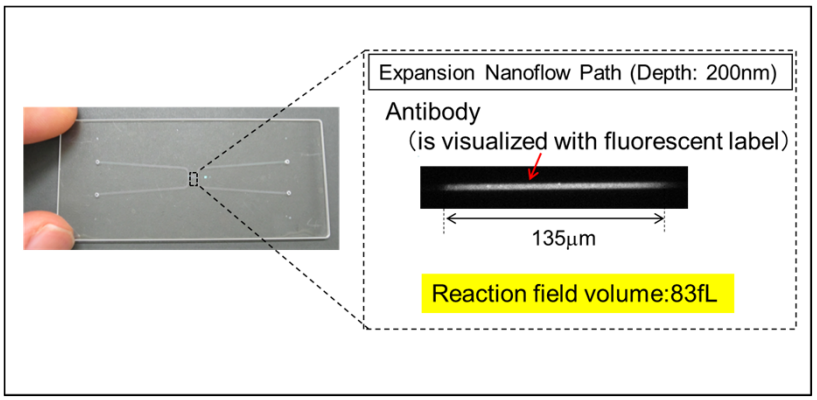

2.Low Temperature Bonding




3.Modification of Antibody




**Example: Fabrication for Immunoassay Chip**




Fabricated Microchemical Chip

## 4. Application Examples

-Biological analysis (as DNA, RNA, protein, and metabolite analysis)
-Medical diagnostics (as immunoassay)
-Single cell, single molecule analysis
-Personal health check at home

## 5. Patent Licensing Available

Patent No.: WO2014/051054 (US2015/0290641, JP, EP, KR, CN)
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# Tunnel Transistor

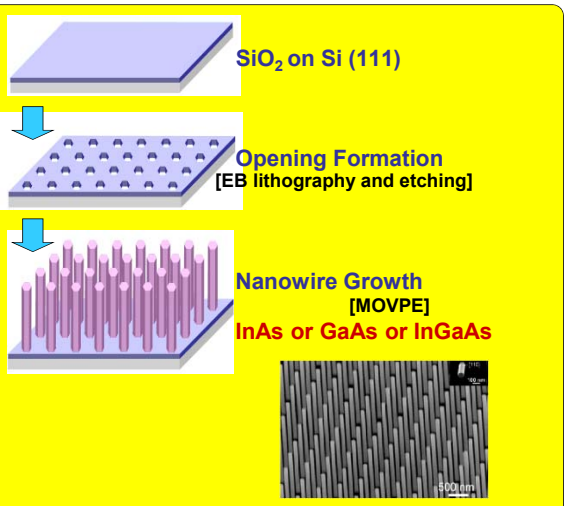
## Tunnel Field-Effect Transistor (FET) using III-V/Si Heterojunctions

Associate Prof. Katsuhiro Tomioka (Hokkaido University)

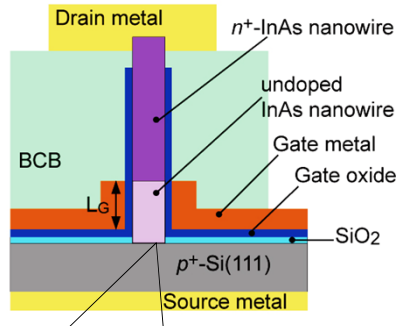
## 1.Introduction

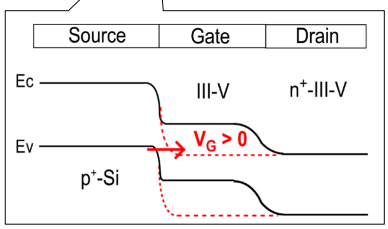
Conventinal MOSFETs have theoretical limit in subthreshold slope(SS) characteristics resulted from carrier diffusion (SS > 60mV/dec.). Our technology can realize steep-slope nanowire-based FET by controlling III-V/Si heterojunctions without misfit dislocations, which can be achieved with nano-heteroepitaxial methods.

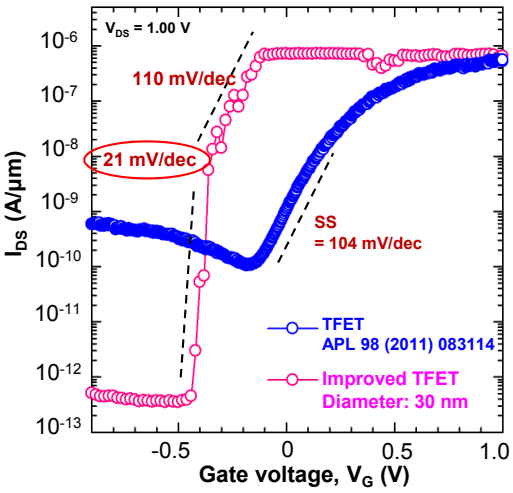
## 2. Device Structure, Performance of the Tunnel FET




III-V/Si Heterojunctions Growth Process



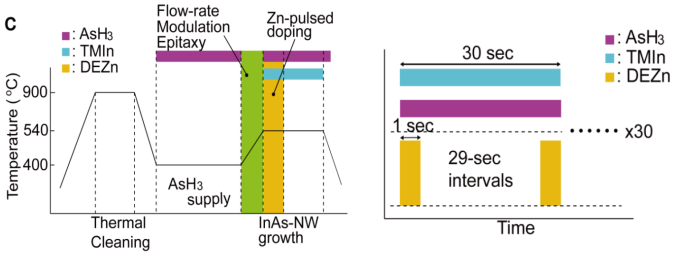



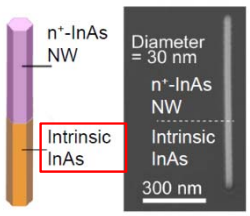

-The combination of a narrow band gap III-V with Si is a good system for boosting up the ON-state current and has high band-to-band tunneling efficiency.
-The subthreshold slope(SS) is far lower value than 60mV/dec.(theoretical limit value) of Si FET.

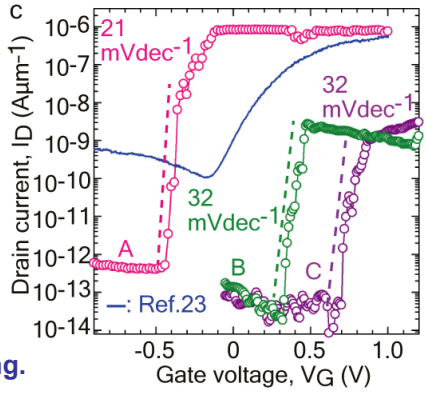
## 3. Synthesis of Nanowire by using Pulse Doping

With respect to the impurity density of undoped InAs nanowire, supply the p-type dopant of the $10^{16}cm^{-3}$ to compensate for the n-type dopant once for x seconds, to make the electrically neutral intrinsic layer.




Growth Process of Nanowire




InAs/Si Tunnel FET

-The turn-on voltage can be adjusted by the supply time of dopant in pulse doping.
-The leakage power in a standby state can be further reduced.

## 4. Application Examples

-Low voltage operation transistor
-Low power consumption LSI
-Sensing devices for IoT

## 5. Patent Licensing Available

Patent No.: WO2011/040012, WO2015/022777 (US2016/0204224, JP, EP, CN, KR, TW)
WO2015/064094 (US2016/0284536, JP, EP, CN, KR, TW)

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# Wearable Sensor

## Ultraflexible Temperature Sensors

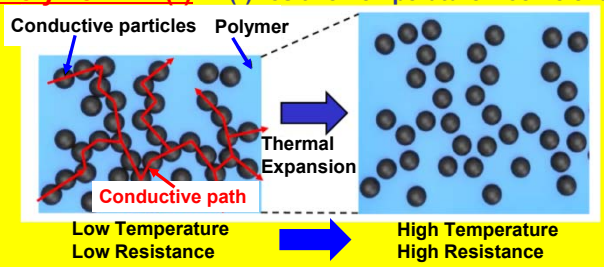
Prof. Takao Someya (The University of Tokyo)

## 1. Introduction

We have developed a flexible and printable temperature sensor based on composites of semicrystalline acrylate polymers and graphite.
This temperature sensor is expected to find healthcare and welfare applications in devices for monitoring body temperature.

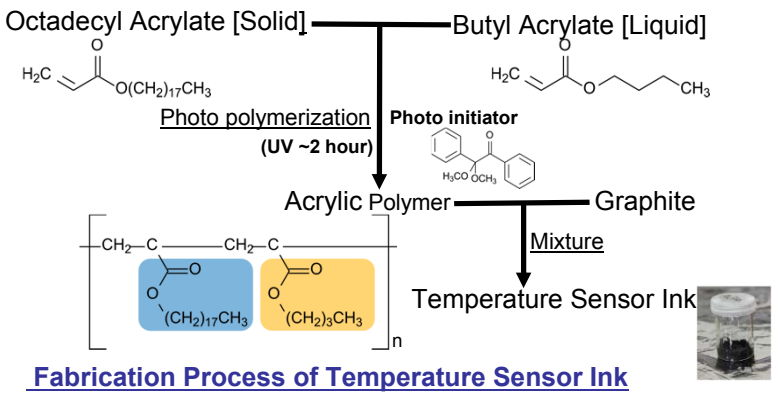
## 2. Key Features, Principle of the Invention, Structure of the Material

**Polymer PTC(*)** (*)Positive Temperature Coefficient

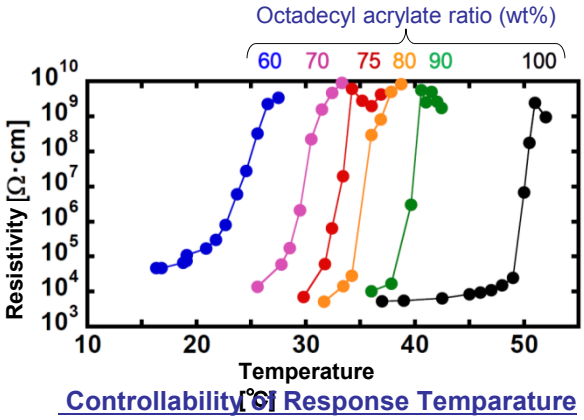



-The temperature sensor we have developed is used acrylic polymer mixed with graphite.
-Resistance value is increased by the thermal expansion due to the rise of temperature. (➔Polymer PTC)

-The sensor achieves a high sensitivity of 20mK and a high-speed response time of less than 100ms.



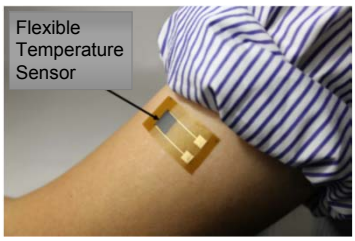

Fabrication Process of Temperature Sensor Ink




Controllability of Response Temparature

-Exhibit changes in resistivity by six orders at a change in temperature of 5℃.
-The response(target) temperature can be precisely controlled by altering the proportions of the two monomers.

## 3. A Printable, Flexible Sensor for Monitoring Body Temperature




- Printable (possible to manufacture in printing process)
- Flexible
  (possible to paste to the surface of the living body and the curved surface)
- Response Temperature: 25℃~50℃ (covering body temperature range)
- High-speed response time of less than 100ms
- High durability and repeatability: 1,800 times

## 4. Application Examples

-Healthcare and welfare applications for monitoring body temperature, for newborn infants or for patients in intensive care.
-Wearable electronic apparel application where the temperature sensor could be applied beneath fabric to measure temperature during sporting and other activities.

## 5. Patent Licensing Available

Patent No.: WO2015/119205 (JP, US, EP, KR, CN)
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# Skyrmion Memory

## Efficient Method to Write Skyrmion Bits in Magnetic Storages

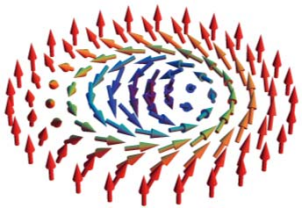
Associate Prof. Masahito Mochizuki (Aoyama-Gakuin University)

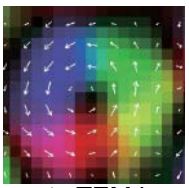
## 1. Introduction

- Topological spin vortices called ***skyrmions*** in chiral magnets have numerous advantageous properties for application to information carriers in next-generation magnetic memories.
- A new efficient method to create skyrmions on a thin-film specimen by applying an ***E***-field without Joule-heating energy losses.

## 2. Magnetic skyrmions with electric polarizations in chiral magnetic insulator

### 2.1 Magnetic Skyrmion



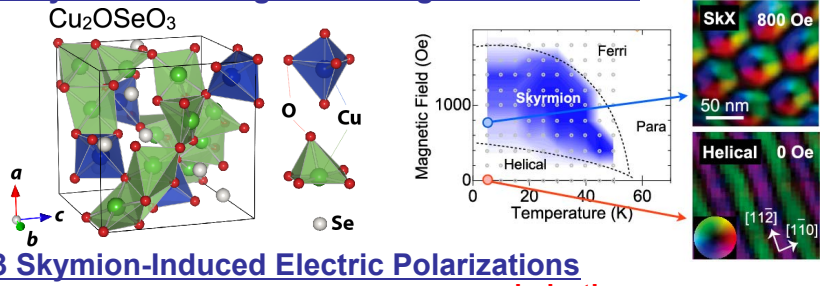


Lorentz TEM image

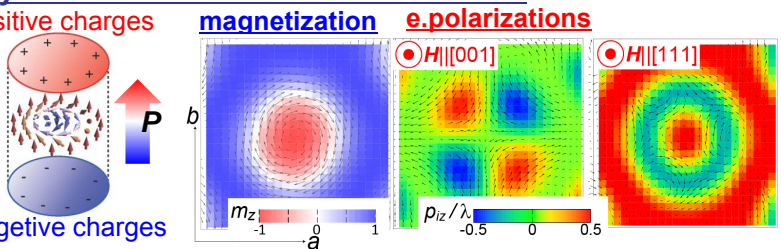
- **Nanometric small size (3-100 nm)**
  ⇒high information density
- **Topologically protected stability**
  ⇒robust against thermal agitations
- **Low fields to drive motions**
  ⇒low energy consumption
- **High transition temperature**
  ⇒high operational temperature

**⇒ Promising for memory application**

### 2.2 Skyrmion-Hosting Chiral Magnetic Insulator



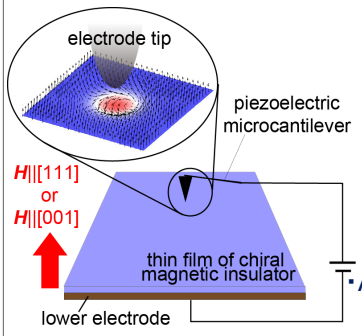

### 2.3 Skymion-Induced Electric Polarizations



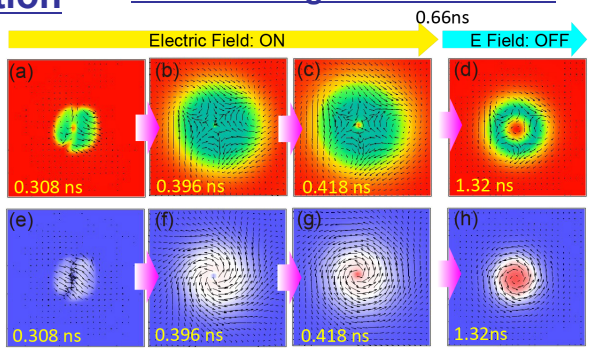

- Skyrmion induces electric polarizations, which renders the system magneto-electric and enables us to create and manipulate skyrmions with ***E***-fields.

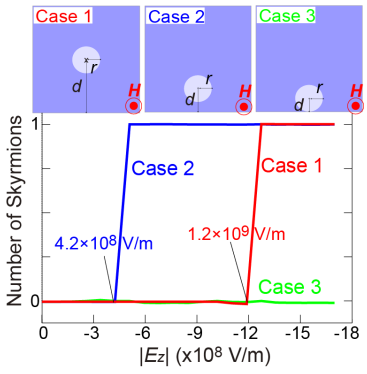
## 3. Proposal & Simulation

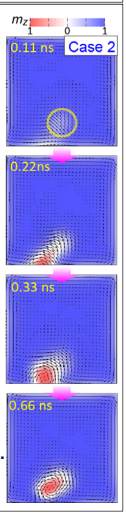
### 3.1 Proposed Setup




### 3.2 Micromagnetic Simulation



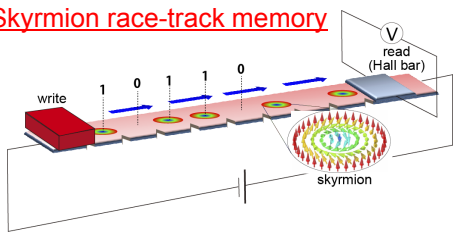




- A skyrmion bit is created by local application of an ***E***-field via a electrode tip, taking advantage of the magnetoelectric coupling between skyrmion spins and e. polarizations.
- Application of the ***E***-field at a sample edge reduces the threshold field significantly.

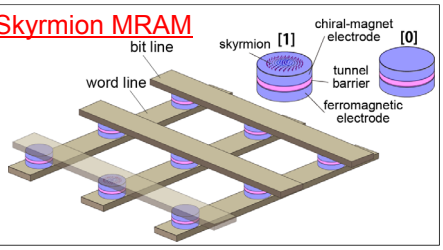
## 4. Application Examples

- **High-performance magnetic memory**
  - Ultra-high density,
  - Ultra-low energy consumption
  - Non-volatile, - Robust, -Random access
  - No mechanical elements

Skyrmion race-track memory




Skyrmion MRAM




## 5. Patent Licensing Available

**Patent No.: WO2016/158230**

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# Z Polarized Super Resolution

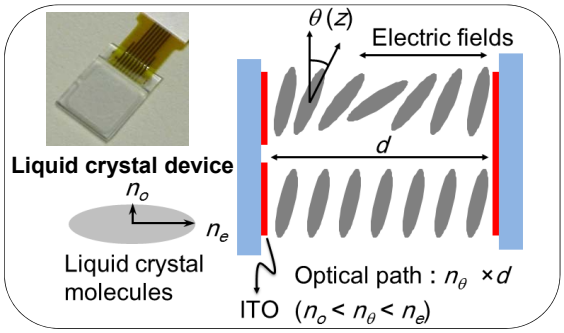
## Liquid crystal device for super resolution microscopy and Z polarization imaging

Dr. Nobuyuki Hashimoto (CITIZEN WATCH Co. Ltd), Prof. Tomomi Nemoto (Hokkaido University),
Prof. Shunichi Sato (Tohoku University)

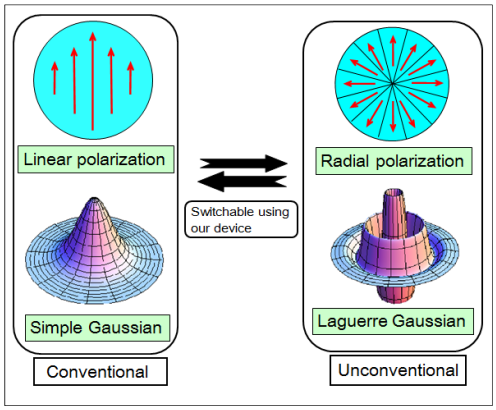
## 1. Introduction

Liquid crystal device that can attach easily to conventional laser scanning microscopy and then generate super resolution and Z polarization images. This device is useful for bio imaging and also material research.

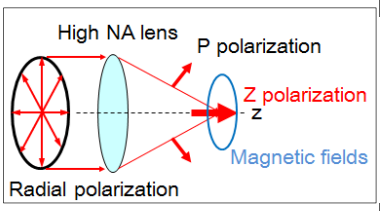
## 2. Principle of the Invention and Structure of the Device

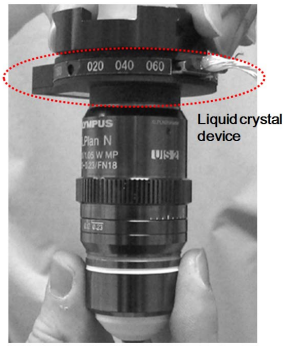



**Principle of Liquid Crystal Device**
Liquid crystal molecules have strong dielectric properties and orientation sensitive for electric fields. So this device can work as active phase plates using external electric signals. Then we can modulate phase and polarization of light.

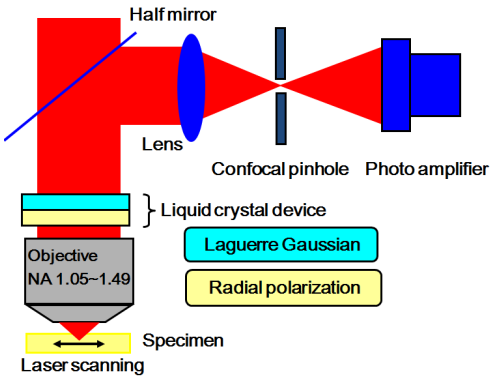



Our liquid crystal device can modulate Gaussian laser beam with linear polarization to Laguerre Gaussian beam with radial polarization.

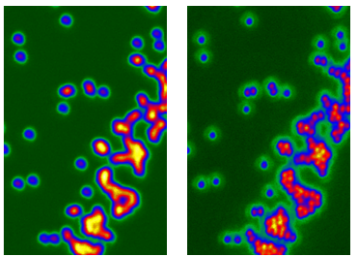


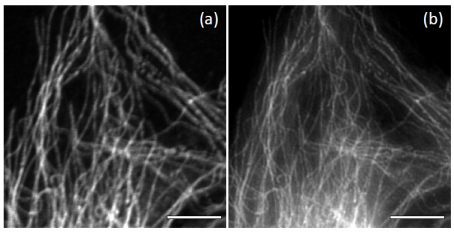

## 3. Experiment and Characteristics



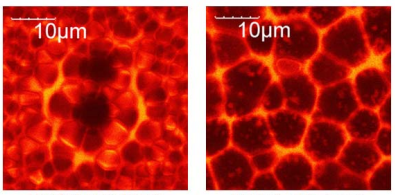

Super resolution laser scanning microscopy using the liquid crystal device




Observation of fluorescence beads of 173 nm diameter
NA 1.2 (Water immersion) λ 473 nm




Microtubules of fixed COS-7 cells (a) Switch off (b) Switch On
NA 1.2 (Water immersion) λ 800 nm




Observation of polymer dispersed liquid crystal using SHG mode

## 4. Application Examples

This technology can apply not only for bio-imaging and material research but also for high density optical recording and precision laser processing.

## 5. Patent Licensing Available

Patent No.: WO2011/105618 (US9182581, JP, EP, CN)
JST/ IP Management and Licensing Group Phone: +81-3-5214-8486 E-mail: license@jst.go.jp

# Eye Gaze Tracking

## Eye Gaze Tracking by detecting Eye Corneal Reflections

Associate Prof. Atsushi Nakazawa (Kyoto University)

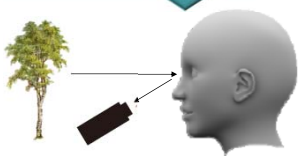
## 1. Introduction

The systems for estimating the "Where you are looking at" has been extensively required in the various fields i.e. market researches, medical diagnosis, automobile industries.

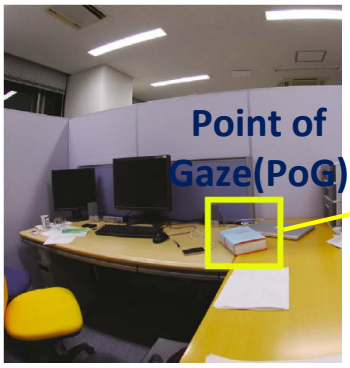
The commonly-used method called a PCCR (Pupil Center Cornea Reflection) has fatal disadvantages of the possible calibration problems.

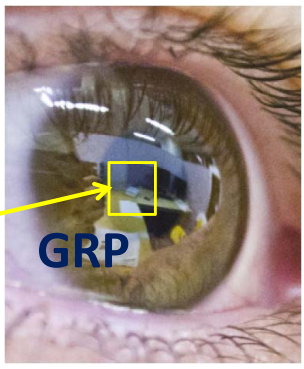
Our new invention, which uses a geometric model of the eyeball for the estimation of the point of gaze (PoG) by detecting the pupil contour, solves calibration problems of PCCR method.

To use the image that reflecting on the surface of the eye

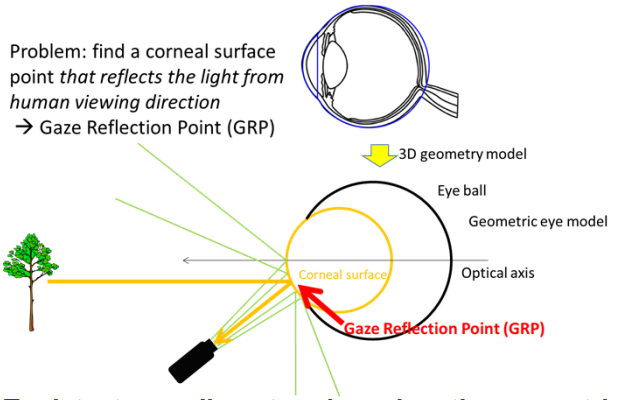


## 2. The outline of our Invention



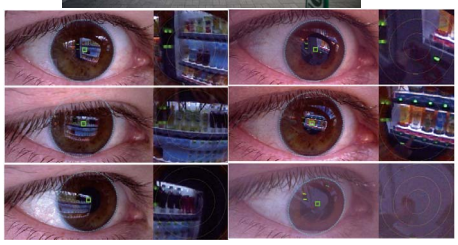

The PoG is determined by the gaze reflection point (GRP) in the eye corneal reflection



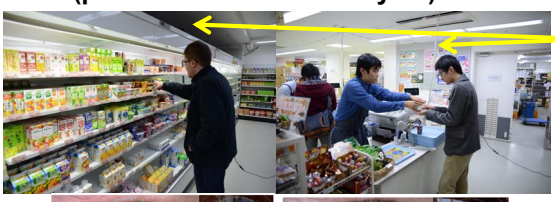

1. To detect a pupil contour based on the geometric model of the eyeball
2. To determine the three-dimensional position of the eye with a pupil profile
3. The PoG can be determined by using the 3-dimensional orientation of the GRP on eyeball surface.

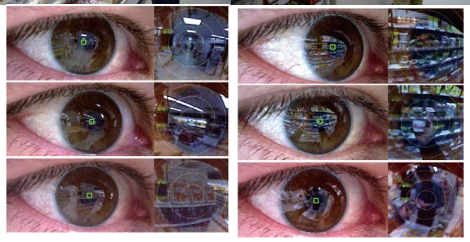
## 3. Application Example (Market Researches)

**Vending Machines**
**(customers behavior analysis)**



**Retail Shops**
**(purchase behavior analysis)**





The valuable/useful marketing information can be obtained by processing the recorded data of PoG's movements/trajectories.

## 4. Prospective Applications

1. Medical Diagnosis i.e. for developmental disorder
2. Supporting Systems for automatic operations i.e. machineries, automobiles
3. Entertainment & Amusement i.e. arcade games, simulation games

## 5. Patent Licensing Available

Patent No.: WO2014/021169 (US9262680, JP, EP, CA, CN, KR, TW)

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# Micro Droplet

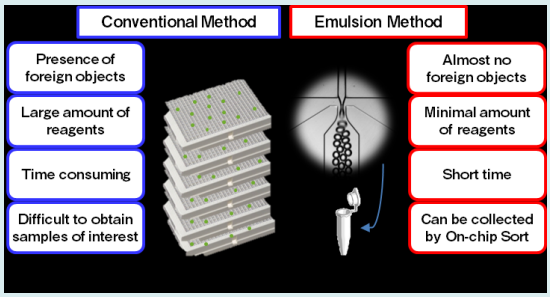
## Production Technology using Micro-channel

Prof. Takasi Nishisako (Tokyo Institute of Technology), Prof. Toru Torii (The University of Tokyo)

## 1. Background

- In order to scale up and realize a high-throughput, the Emulsion Method ("water-in-oil emulsion droplet technology") has been widely adopted in sophisticated Digital PCR systems.
- Micro Droplet production by using "Micro-channel" has been recognized as a de facto standard method in this field.

* Polymerase chain reaction (PCR) is an invaluable tool for nucleic acid detection and quantification.




* Advantages of assays using emulsion

## 2. An Innovative "Simple & Easy" Production Method

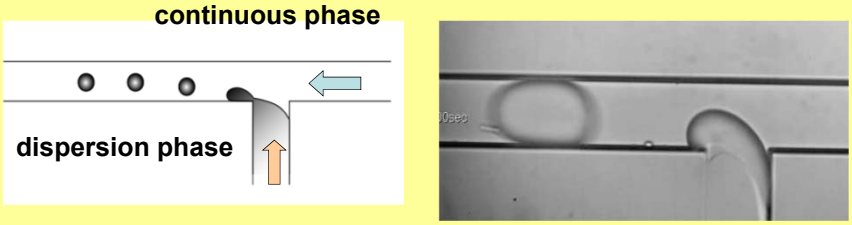



Fig.1 Micro droplets formation in the T intersection

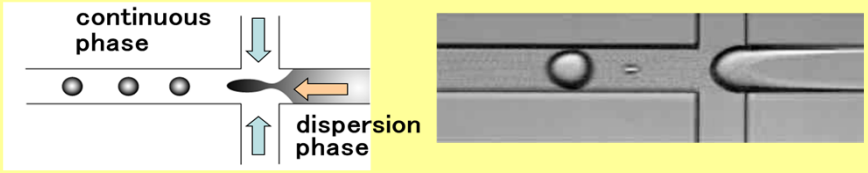



Fig.2 Micro droplets formation in the + intersection

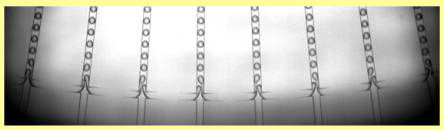


Fig.3 Micro droplets production in parallel arrangement of micro-channels

Fig.4 Size control with flow condition



Fig.5 Micro Droplets related systems
"use in the market examples"

## 3. Research Work Continues

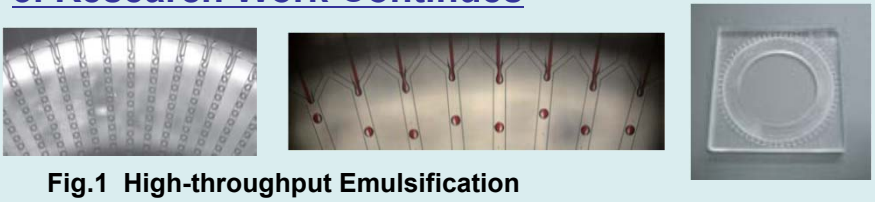


Fig.1 High-throughput Emulsification

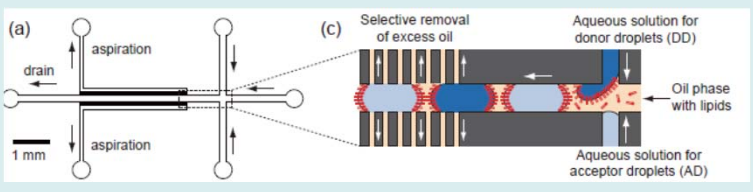



Fig.2 Microfluidic Platform for Membrane Permeability Assays

## 4. Patent Licensing Available

Patent No.: WO2002/068104 Patent Family
already granted in Japan/US/EP etc.
(more than 50 patents)

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## About JST

The Japan Science and Technology Agency (JST) is one of the core institutions responsible for the implementation of science and technology policy in Japan, including the government's Science and Technology Basic Plan. From knowledge creation—the wellspring of innovation—to ensuring that the fruits of research are shared with society and Japan's citizens, JST undertakes its mission in a comprehensive manner. JST also works to provide a sound infrastructure of science and technology information and raise awareness and understanding of science and technology-related issues in Japan.

Mission :
We contribute to the creation of innovation in science and technology as the core implementing agency of the fourth phase of the Science and Technology Basic Plan.

Visions :

1. To achieve innovation in science and technology through creative research and development.
2. To maximize research outcomes by managing research resources on the virtual network.
3. To develop the nation's infrastructure for science and technology to accelerate innovation in science and technology.

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**http://www.jst.go.jp/tt/EN/mrs2016.html**