# Selected Novel Technologies for Licensing

2013 MRS Fall

# Innovative Technologies for Your Products

| | |
|---|---|
| **Instruments** | Nano-suit<br>Magnetic Field Imaging<br>Electrically-induced micro-bubble knife |
| **Batteries** | $Na^+$ Rechargeable Batteries |
| **Magnetic Devices** | Half-Metallic Films and Magnetoresistive Devices<br>Giant TMR Device with Crystalline MgO Barrier<br>CPP-GMR Devices Using Synthetic Antiferromagnet |
| **Photonic Crystal** | Ultra-High-Q Nanocavity using Two-dimensional Photonic Crystals<br>Surface-emitting Diode Laser using Two-dimensional Photonic Crystals<br>Conversion of Broadband to Narrowband Energy |
| **Quantum Entanglement** | Non-degenerate polarization-entangled photon pair generation device<br>Photon Pair Generation in Biexcitonic Cavity QED and Device |
| **Optical Manipulation** | Quantum dot manipulating method & production/manipulation apparatus |
| **Super-conductor** | $MgB_2$ as superconducting Materials<br>Electro-conductive & Transparent Nano-porous Compound C12A7<br>Iron-Based New Superconductors |
| **Oxides** | Novel Materials； $BaTiO_{3-x}H_x$ （$0<x<0.8$）<br>$CsLiB_6O_{10}$(CLBO) Single Crystals for UV Light Generation |
| **Organic Materials** | Ladder π-Conjugated Materials for OLED<br>Bucky Gel Actuator |

**Japan Science and Technology Agency**

Instruments

# Nano-suit: a thin polymer film to observe the fine structure of living organisms in FE-SEM

Dr. Takahiko HARIYAMA ( Hamamatsu University School of Medicine )

## 1. We can observe living and moving specimens with SEM

Various complex procedures with fixing tissues have precluded the real fine structure of organisms by a field emission scanning electron microscope.
Here we present a new method to observe living organisms; their surfaces were covered with thin-layers of amphiphilic solution.
Our method permits the use of a high vacuum (10-5～10-7Pa) and achieves fine structural observations on live specimens.

## 2. Procedure

Specimens: Larvae of the northern house mosquito, *Culex pipiens molestus*, and fruiting body of soil-living amoeba, *Dictyostelium discoideum*.
Treatment: Specimens were dipped into 1% (v/v) Tween 20 solution for 1 min and irradiated by plasma to construct a Tween 20 film.
SEM observation: Both specimens tolerated the high vacuum well, exhibiting fine structures (Max. x50,000).

Before　Plasma treatment　After

## 3. Electron micrograph of mosquito larvae

untreated

treated

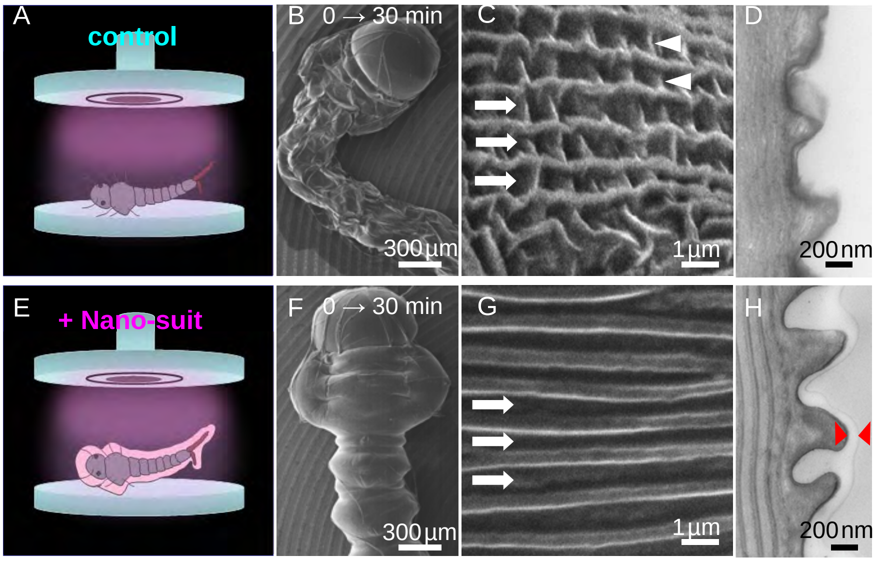


Figure 1

・Untreated larvae quickly shrank and ceased to move under SEM observation (Fig.1 A, B). There are many wrinkles in the furrows (Fig.1 C), and no extra barrier on the surface observed by TEM (Fig.1 D).
・Treated larvae formed a nano-suit (Fig.1 E, H), showed rapid movements during 30±10min of SEM observation and suffered no observable morphological change (Fig.1 F). There are no wrinkles in the treated specimen (Fig.1 G). Tween 20, covering the animal (Fig.1 E) played a significant role as an extra barrier (Nano-suit) alleviating the influence of high vacuum.

## 4. Electron micrograph of Dictyostelium discoiodeum

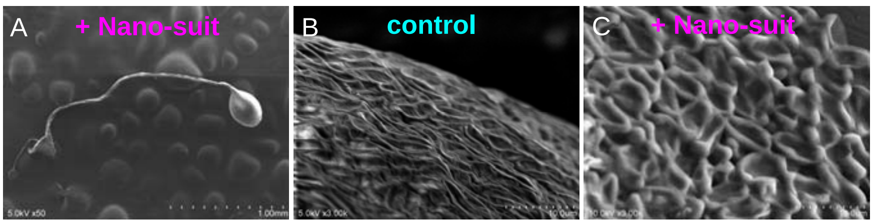


Figure 2

SEM observation of *Dictyostelium discoideum*. Higher magnification of the electron micrograph clearly showed, with the assistance of Nano-suit, the spore tolerating the high vacuum well (Fig.2C).

## Patent Licensing Available

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**Patent No. : WO2013/035866**
Inventors:Takahiko Hariyama, Masatsugu Shimomura, Yoshinori Muranaka, Hiroshi Suzuki, Yasuharu Takaku, Isao Ohta, Daisuke Ishii, Yuji Hirai

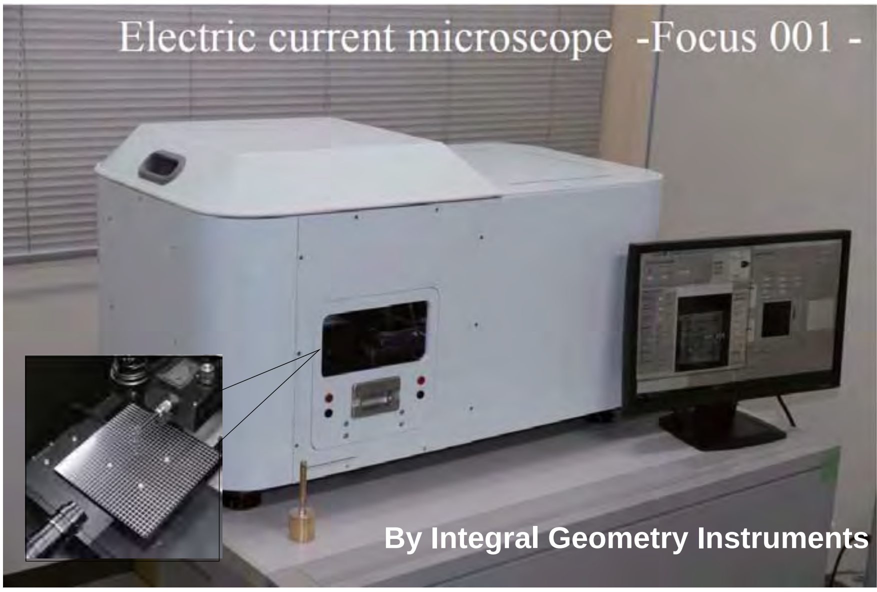
Instruments

# Magnetic Field Imaging using Magnetic Field Reconstruction Software

Associate Prof. Kenjiro KIMURA (Kobe University)

## 1. Magnetic Field Imaging Equipment Overview

- **Magnetic field image is obtained by two-dimensional scanning with magnetic field sensor. Our reconstruction software enables the clear visualization of the current distribution and the image of internal magnetic sources.**



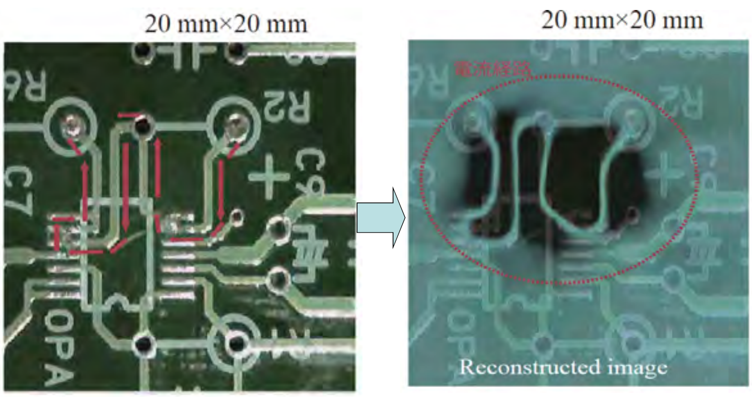

### Magnetic Field Imaging Equipments

| | Imaging of electric current | Spatial resolution | Sample size | 3D Imaging |
|---|---|---|---|---|
| Our equipment | ○ | ○ (10nm) | ○ | ○ |
| Microfocus X-ray CT | × | × (100nm) | △ (0.5−1mm) | ○ |
| 3D−TEM | × | ○ (1nm) | × (10−300nm) | ○ |
| Scanning SQUID | ○ | × (~30μm) | ○ | △ |
| Scanning Near-Field Ultrasound Holography | × | ○ (10nm) | ○ | × |

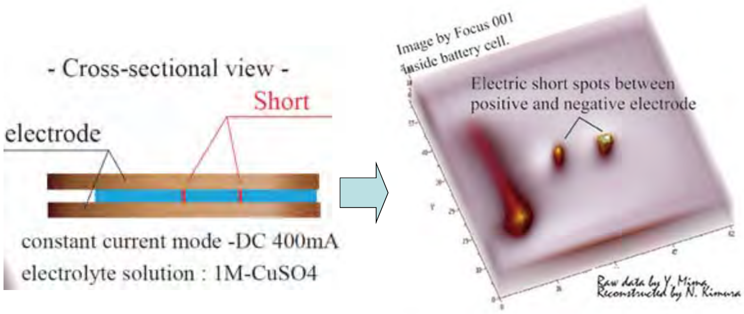
**Sample size: 200x200x30mm**
**Measurement range: 150x150x12mm**
**Scan speed: Max.100mm/sec**

## 2. Measurement Examples

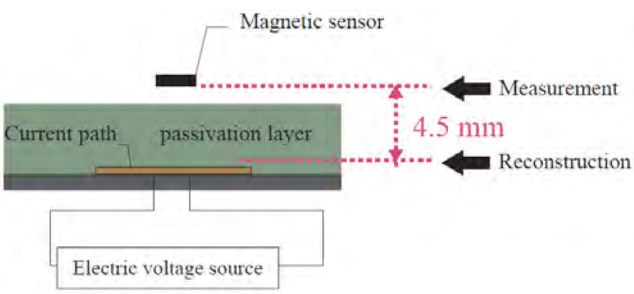
- **Imaging the path of electric current**

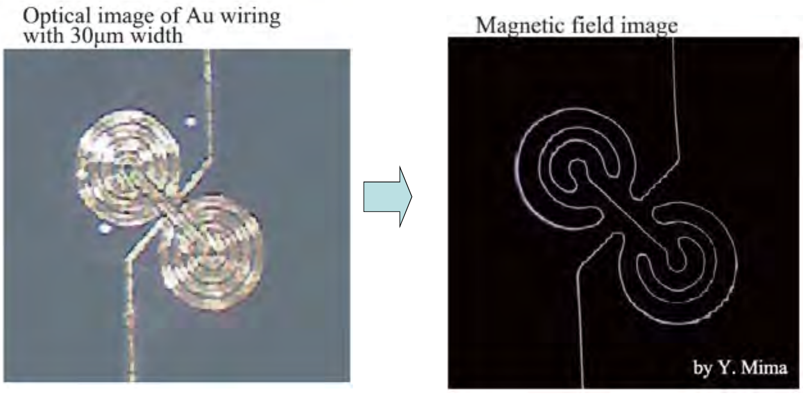



- **Imaging electric short spot inside battery cell**




- **Imaging internal magnetic sources**




## Patent Licensing Available

**Patent : WO2008/123432**

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Instruments

# Electrically-induced micro-bubble knife enables ablation and injection for biomedical applications

Dr. Yoko YAMANISHI (Shibaura Institute of Technology)

## 1. Abstract

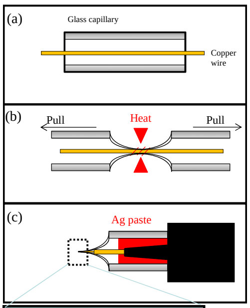
Ablation and injection was successfully operated by using electrically-induced micro-bubble knife for biomedical applications. The novelties of the technique are:

(1) Mono-dispersed directional micro-bubbles attack on a cytomembrane and penetrate into it which enables ablation,

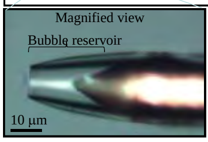
(2) The reagent is successfully introduced to the interface of the bubble surface.

The technique has advantages over the conventional technologies in terms of localization of ablation and injection sites and also ability of material transportation.

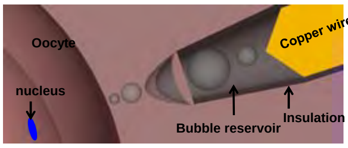
## 2. Bubble knife



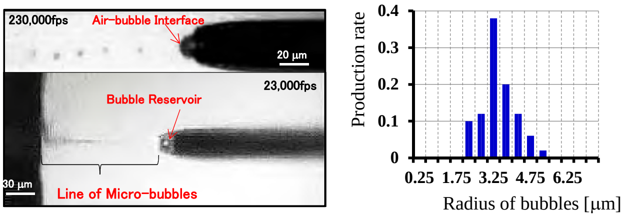

Fabrication of electrically-induced **bubble knife**



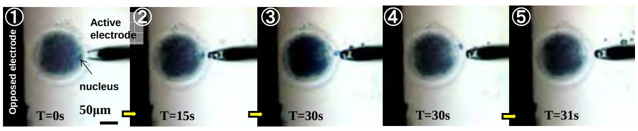

Magnified view around the tip of the knife



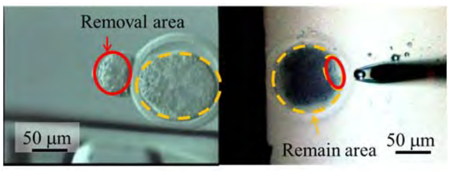

Conceptual diagram of the electrically-induced bubble knife and processing of cell




Photographs of mono-dispersed directional bubbles and the size distribution of bubbles

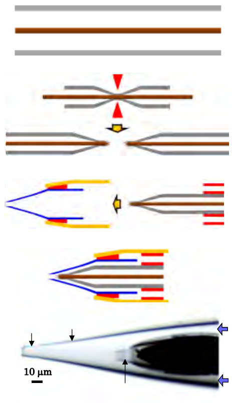



Enucleation of oocyte by using bubble knife (nucleus is dyed by fluorescent dye)

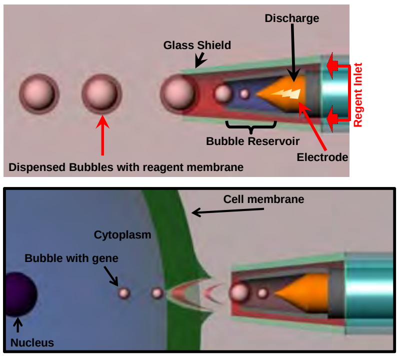



Comparison of the removed area of bovine oocyte (left: conventional glass capillary, right: by using bubble knife)

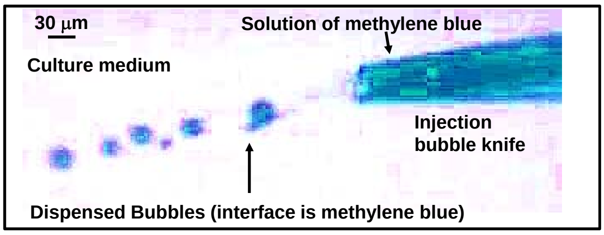
## 3. Injection bubble knife



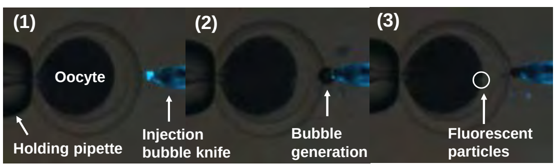

Fabrication method to produce **injection bubble knife**




Conceptual diagram of the micro- bubble knife for injection (upper) and injection mechanism (lower).




A photo of dispensed reagent-laden bubbles in the culture medium and its transportation in liquid phase without diffusion




Injection of fluorescent particles (diameter: 100 nm) into bovine oocyte.

## Patent Licensing Available

Patent No. : WO2013/129657

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Batteries

# $Na^+$ Rechargeable Batteries using Novel $Na_3PS_4$ Glass-ceramic Electrolytes

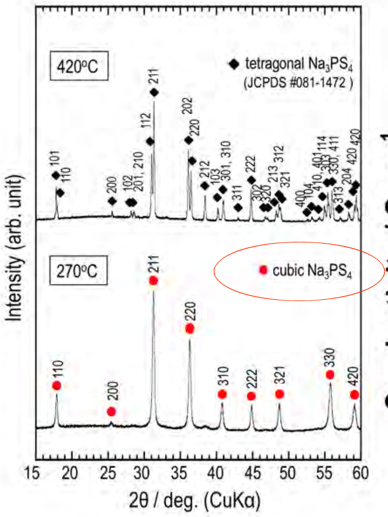
Associate Prof. Akitoshi HAYASHI (Osaka Prefecture University)

- **We discovered a novel electrolyte of a cubic $Na_3PS_4$ with $Na^+$ superionic conductivity.**
- **The conductivity is over $10^{-4}$ S/cm obtained in a glass-ceramic structure.**
- **All-solid-state Na batteries, with a powder-compressed $Na_3PS_4$ electrolyte, functioned as a rechargeable battery at room temperature.**

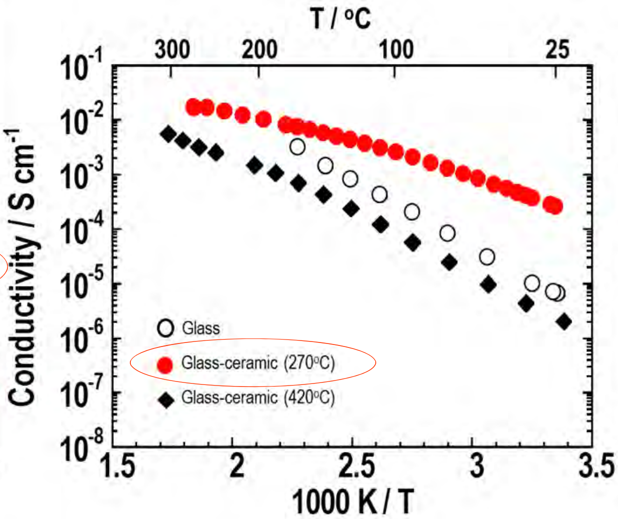
## 1. Novel $Na_3PS_4$ Electrolytes

- **Cubic $Na_3PS_4$ phase is precipitated by the crystallization of the $75Na_2S \cdot 25P_2S_5$ (mol%) glass with heat treatment at 270℃ for 1Hr. The $Na^+$ conductivity is over $10^{-4}$ S/cm.**
  (Tetragonal phase of $Na_3PS_4$ is known to be formed at 420℃, which has a low conductivity of $10^{-6}$ S/cm.)
- **A higher conductivity is obtained by a partial substitution of $Na_4SiS_4$ for $Na_3PS_4$, which is $(100-x)Na_3PS_4 \cdot xNa_4SiS_4$.**

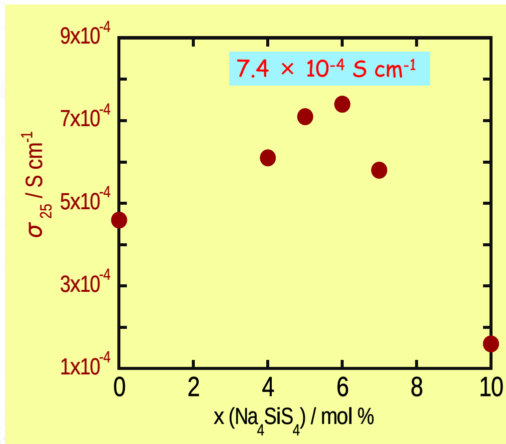
XRD patterns




$Na^+$ conductivity of $Na_3PS_4$




$Na^+$ conductivity of $(100-x)Na_3PS_4 \cdot xNa_4SiS_4$




## 2. Rechargeable $Na^+$ Battery (⊖Na-Sn / $Na_3PS_4$ / $TiS_2$ ⊕)

- **The $Na^+$ battery shows a capacity of ~90 mAh/g (theoretically 240 mAh/g for $TiS_2$) with V=1.7 volts (theoretically 1.9V). By a partial substitution of $Na_4SiS_4$ for $Na_3PS_4$, the higher capacity of 300mAh/g (theoretically 550mAh/g for amorphous $TiS_3$ active material) is obtained.**

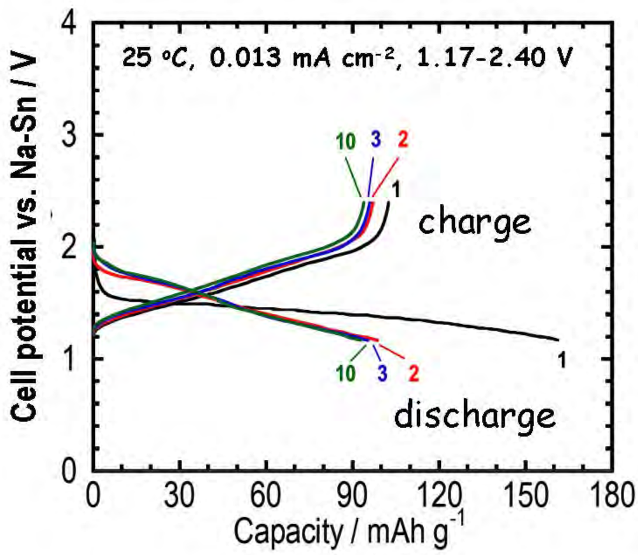
$$TiS_2 + Na_{15}Sn_4 \underset{\text{charge}}{\overset{\text{discharge}}{\rightleftarrows}} Na_xTiS_2 + Na_{15-x}Sn_4$$

Positive electrode: $TiS_2$

$$TiS_2 + xNa^+ + xe^- \underset{\text{charge}}{\overset{\text{discharge}}{\rightleftarrows}} Na_xTiS_2$$

Negative electrode: $Na_{15}Sn_4$ alloy

$$Na_{15}Sn_4 \underset{\text{charge}}{\overset{\text{discharge}}{\rightleftarrows}} Na_{15-x}Sn_4 + xNa^+ + xe^-$$




## Patent Licensing Available

Patent No. : WO 2013/015321
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Magnetic Devices

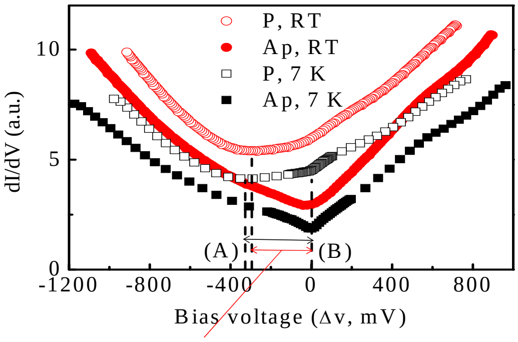
# Half-Metallic Films and Magnetoresistive Devices

Prof. Emeritus Koichiro INOMATA (Tohoku University)

## 1. $Co_2FeAl_{1-x}Si_x$ ( 0≦ x < 1) Heusler Alloy Films

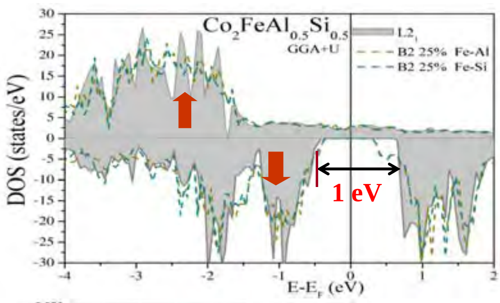
1) Large half-metallic gap up to about 1 eV
2) Half-metallic for $L2_1$ or B2 structure
3) High $T_c$ > 1000 K
4) High Magnetization > 1000 emu/cm$^3$
5) Low Gilbert Damping Constant

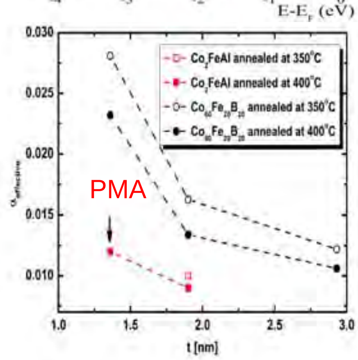
Conductance curves for $Co_2FeAl_{0.5}Si_{0.5}/MgAl_2O4/CoFe$ MTJ




**Half-metallic gap at RT verified ! !**

Density of states for $Co_2FeAl_{0.5}Si_{0.5}$ (Calc.)



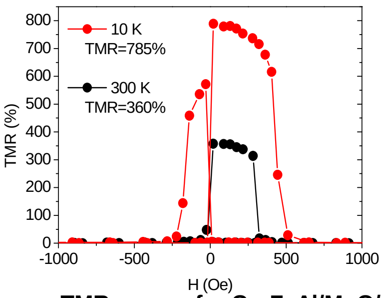




Low Gilbert damping constant for $Cr/Co_2FeAl/MgO$ and CoFeB/MgO

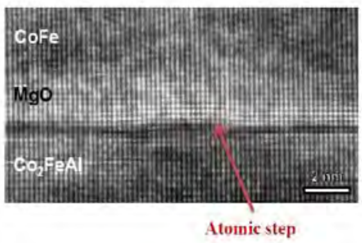
After Y. Cui et al., Appl. Phys. Lett. **102**, 162404 (2013).

## 2. Spintronics Devices

### 1) Magnetic Tunnel Junctions (MTJs) with a Large TMR at RT

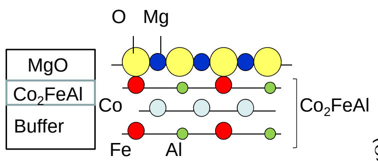



TMR curves for $Co_2FeAl/MgO/CoFe$ MTJ

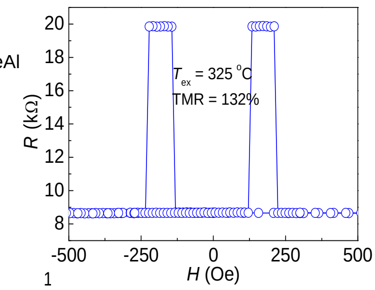



Cross-sectional TEM image

### 2) Perpendicular MTJs for Gigabit STT-MRAM

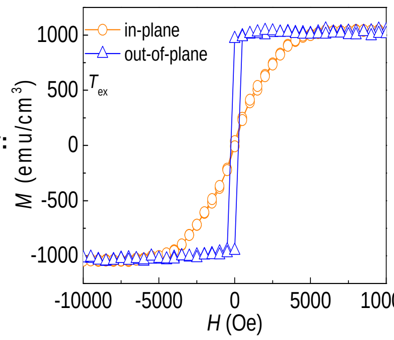



**TMR Curve for $Co_2FeAl/MgO/CoFe$**




**Interface anisotropy for $MgO/Co_2FeAl$: $K_i$= 2.2 erg/cm²**

**Perpendicular anisotropy: $K_u = 4.5\times10^6$ erg/cm³ where $K_u = K_v - 2\pi M_s^2 + K_i t$**

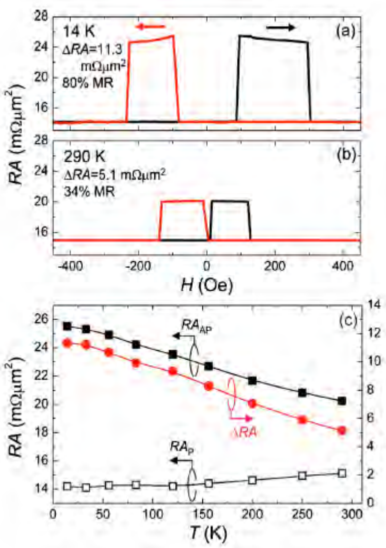


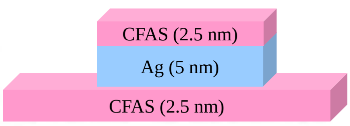

■Large PMA
■Large TMR
■Low damping

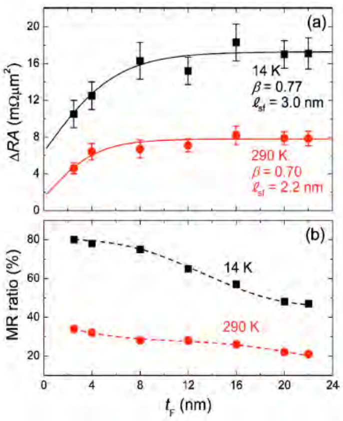
**Gigabit STT-MRAM**

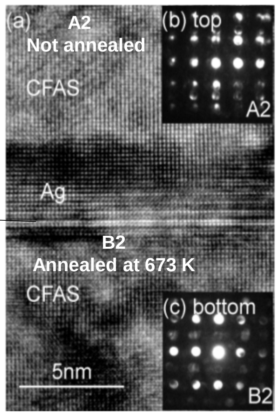
### 3) CPP-GMR Devices for HDD

CFAS: $Co_2FeAl_{0.5}Si_{0.5}$




## Patent Licensing Available

**Patent No. : JP 4061590, JP 4582488, US 8125745**

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Magnetic Devices

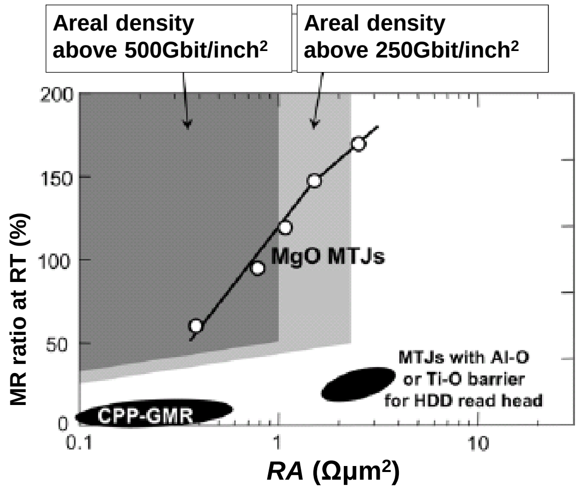
# Giant Tunnel Magneto-resistance (TMR) Device with Crystalline MgO Barrier

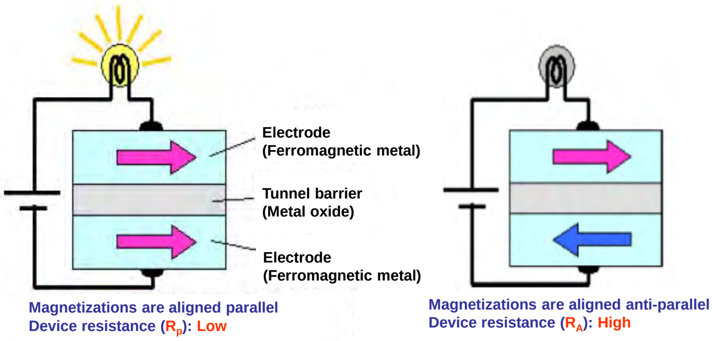
Dr. Shinji YUASA (National Institute of Advanced Industrial Science And Technology)

## 1. Tunnel Magneto-resistance(TMR) Device

- TMR device applications to HDD read-head, MRAM Memory, Microwave device etc.
- MR characteristics of MgO-TMR Device

**High MR ratio (＞50%) with ultralow resistance (0.4-1Ωμcm2)**

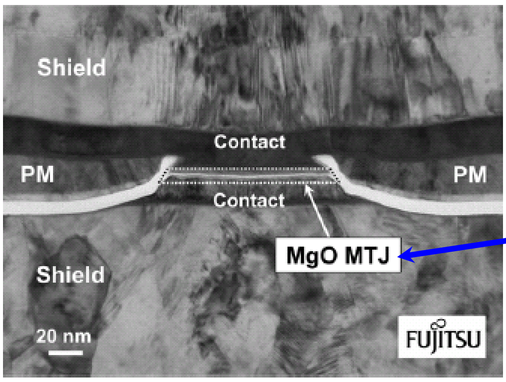


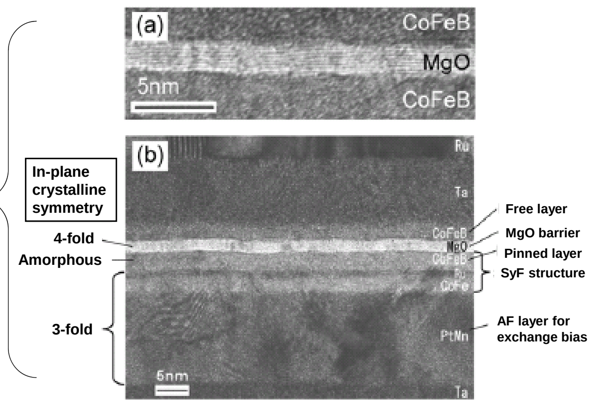

MR ratio $= (R_A - R_P) \div R_P\,(\%)$

Device resistance $= R_P\,(\Omega(\mu m)^2)$

## 2. Device structure of MgO-TMR → a-CoFeB /MgO/ a-CoFeB

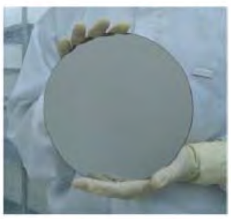



Cross-sectional TEM image of MgO-TMR read head for HDD(250Gbit/inch²)

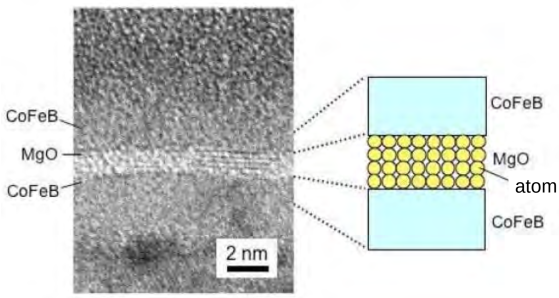



## 3. Mass production of HDD read-head (MgO-TMR)

Sputtering deposition machine (Canon ANELVA Corp.)



CoFeB/MgO/CoFeB MTJ film on 8 inch thermally oxidized Si wafer




Cross-sectional TEM image of CoFeB/MgO/CoFeB MTJ

## Patent Licensing Available

Patent No. : WO2005/088745, WO2006/022183

Apply country : JP, US, EP, KR, CN, TW, MY

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# CPP-GMR Devices Using Synthetic Antiferromagnet

Magnetic Devices

Prof. Emeritus Koichiro INOMATA (Tohoku University)

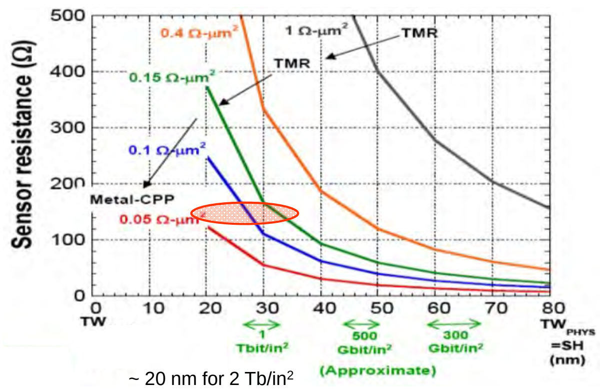
## 1. Ultra high Density Hard Disk Drive (HDD)

- **CPP MR heads are required for HDD with bit densities over 2 Tb/in$^2$**
  - **Large CPP-GMR**
  - **Reduction of spin-torque (ST) noise**
  - **Increase $J_{STT}$ (> $10^8$ A/cm$^2$) $J_{STT}$: Switching current density by spin transfer torque (STT)**
- **Our synthetic antiferromagnet (SyAF) free layer meets above requirements**

**Trend of read heads for high density HDD**

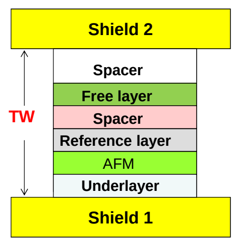
| CIP-GMR (1997) | TMR (up to date) | **CPP-GMR (future)** |
|---|---|---|

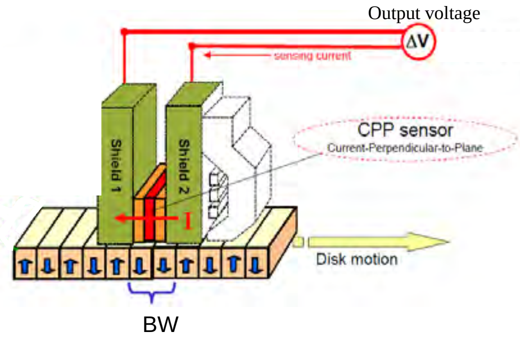
**Bit density of HDD in 2010: 600 Gb/in$^2$ using TMR head**




(By courtesy of J.Childress to K. Inomata)

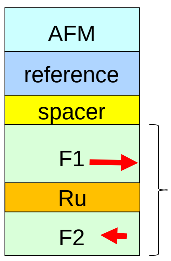
**Spin-valve CPP- MR head structure**




TW: Track width
BW: Bit width

## 2. CPP-GMR Structure with Synthetic Antiferromagnet(SyAF) Free Layer



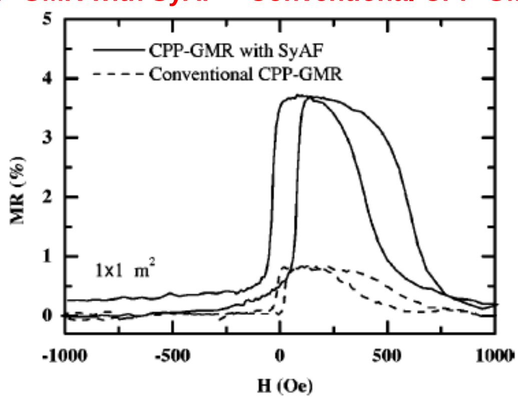

AFM: Antiferromagnet

Spacer: Nonmagnetic conducting layer

SyAF free layer (AF-coupled)

F1, F2: Ferromagnets
with different magnetization to each other

**CPP-GMR with SyAF > Conventional CPP-GMR** **Spacer: Cu**



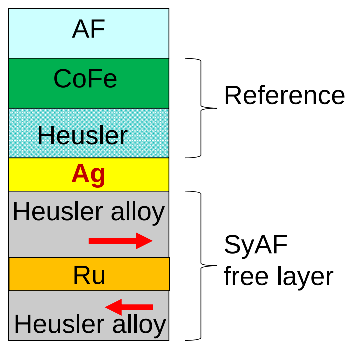

- **Potential reduction of ST noise due to enhancement of STT switching current density**
- **Enhanced thermal stability**
- **Single domain structure**

## 3. Application to Epitaxial CPP-GMR Devices with Half-metallic Heusler Alloys

### Advantages

- **Very large CPP-GMR**
  **> 50% at RT**
- **ST noise reduction**

**Structure (Ag spacer)**




**Epitaxial growth of Heusler on a Ru layer is possible**

## Patent Licensing Available

**Patent No. : US 7385790 , EP 1589594**

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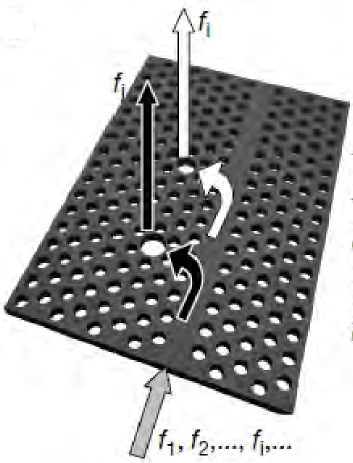
Photonic Crystal

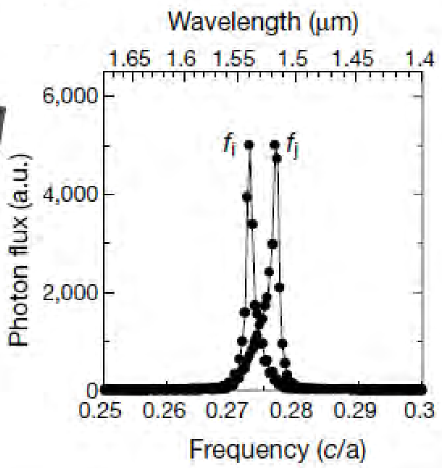
# Ultra-High-Q Nanocavity using Two-dimensional Photonic Crystals

Prof. Susumu NODA (Kyoto University)

- Photonic crystal is a new type of optical material with a periodic refractive index, where a photonic band gap is formed to selectively block optical wavelengths.
- Trapping and emission of photons in 2D photonic crystals provide various devices for photon control and manipulation such as optical-waveguide, resonator, (de)multiplexer etc.

## 1. Trapping and Emission of Photons



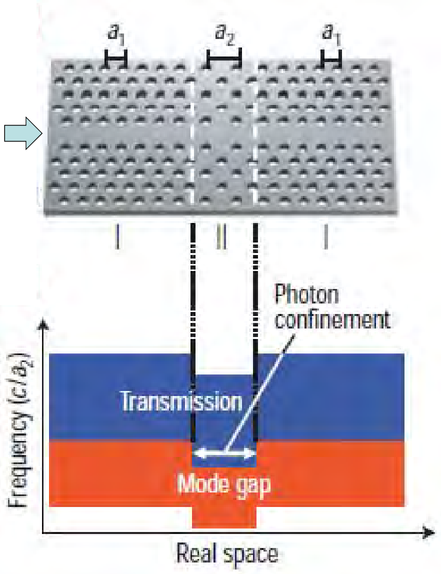



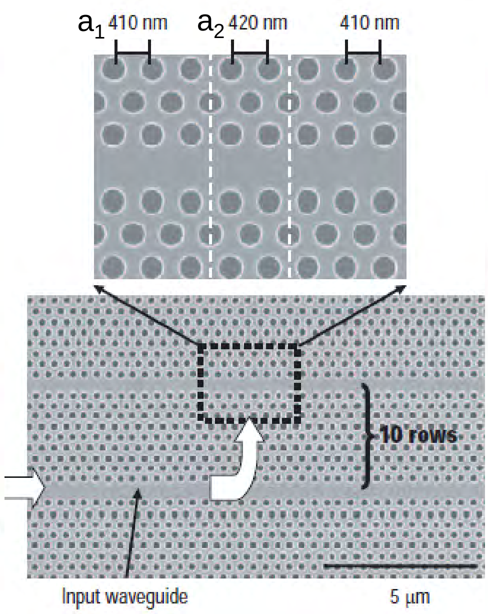

- The photon flux is trapped and emitted to free space by the defect in the vicinity of waveguide.
- The defect acts as an optical resonator with resonant frequency(f) and quality factor(Q).
- By two different defects (3.5% larger defect) photons with different frequencies(fi,fj) are trapped and emitted to free space by the corresponding defects. It works as wave-length demultiplexer.

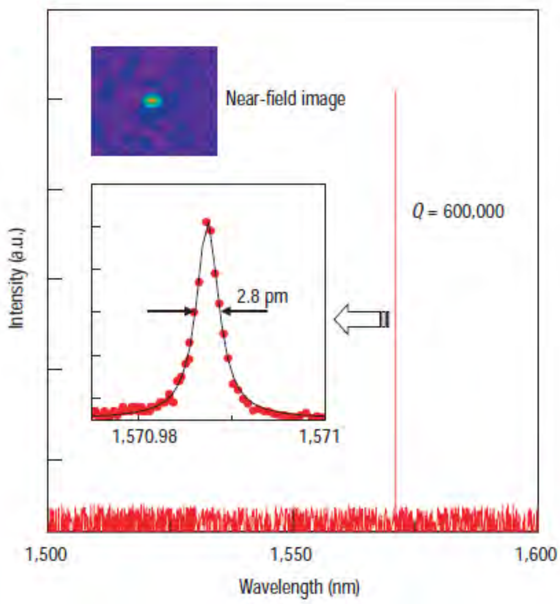
Hole pitch (a)=0.42µm, Hole radius (r)=0.29a, Slab (InGaAsP) thickness=0.6a
The distance between the defect and waveguide=$(3\sqrt{3}/2)a$
i defect: r=0.56a ⇒ fi=0.2729(c/a) =1.539µm
j defect: r=0.58a ⇒ fj=0.2769(c/a) =1.517µm

## 2. Ultra-High-Q Nanocavity

- Photons of a specific energy can theoretically exit only in the waveguide of photonic crystal Ⅱ of doubleheterostructure.
- A doubleheterostructure cavity fabricated using the silicon-on-insulator ($SiO_2$) material shows an ultra-high-Q value (theoretically calculated value of $10^6$).




## Patent Licensing Available

Patent No. : US6738551, WO2003/081304, WO2003/081305, WO2004/053549 etc.
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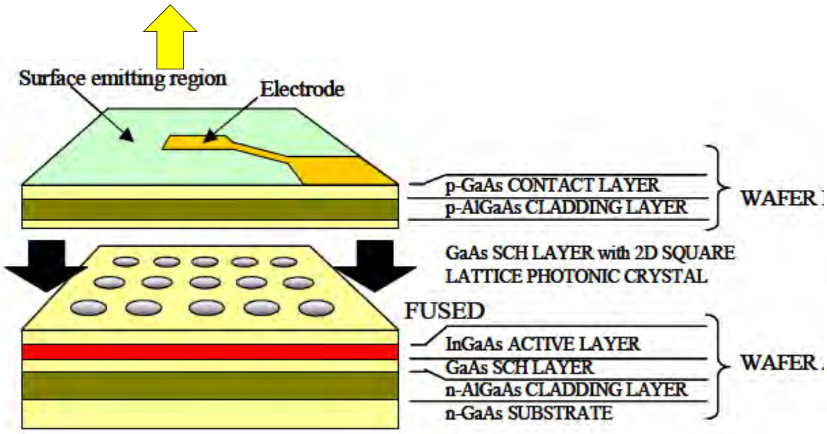
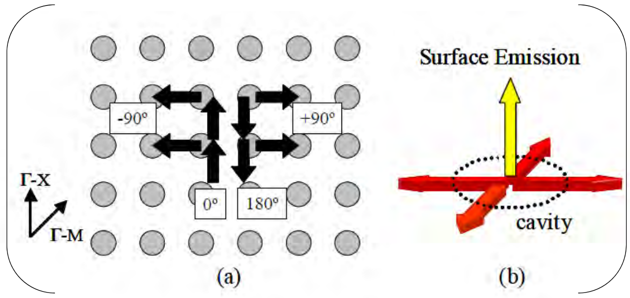
# Surface-emitting Diode Laser using Two-dimensional Photonic Crystals

Prof. Susumu NODA (Kyoto University)

## 1. Surface-emitting 2D Photonic Crystal Diode Laser

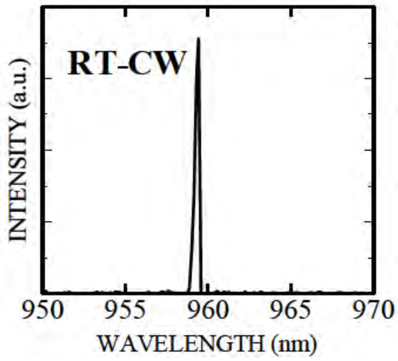
- The Surface-emitting 2D crystal lasers are operated with continuous wave at room temperature by current injection and have a single mode oscillation over a broad area due to the 2D DFB effect.
- Light waves in four equivalent Γ-X directions are coupled with each other and a 2D large area cavity is formed. Consequently, the surface emission is observed to be diffracted toward the vertical direction by first-order Bragg diffraction.

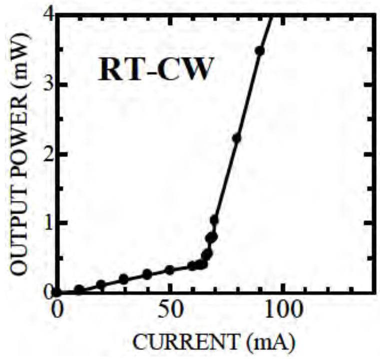



Schematic of a square lattice photonic crystal

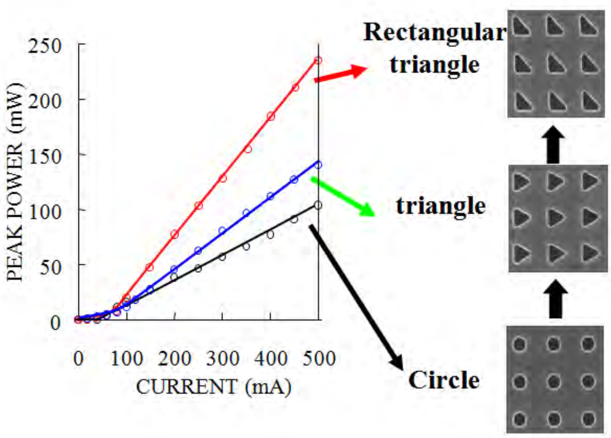
Surface-emitting laser characteristics

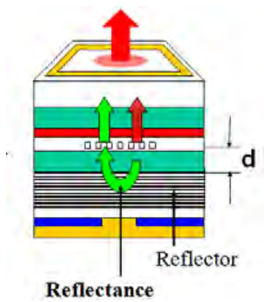


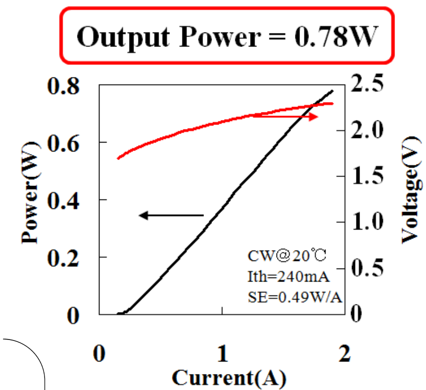



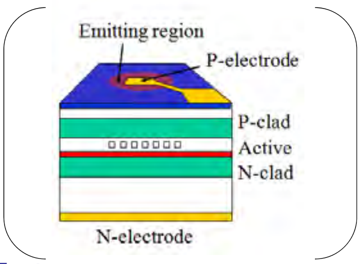

## 2. Improvement for High Efficiency and High Power Lasers

- Light output-current efficiencies of 2D photonic crystal lasers are improved by the cavity forms at lattice points and by the optimization of laser structures such as upside-down structure, using reflection layer etc.




## Patent Licensing Available

Patent No. : WO2004/086575, JP3833953, JP4185697 etc.

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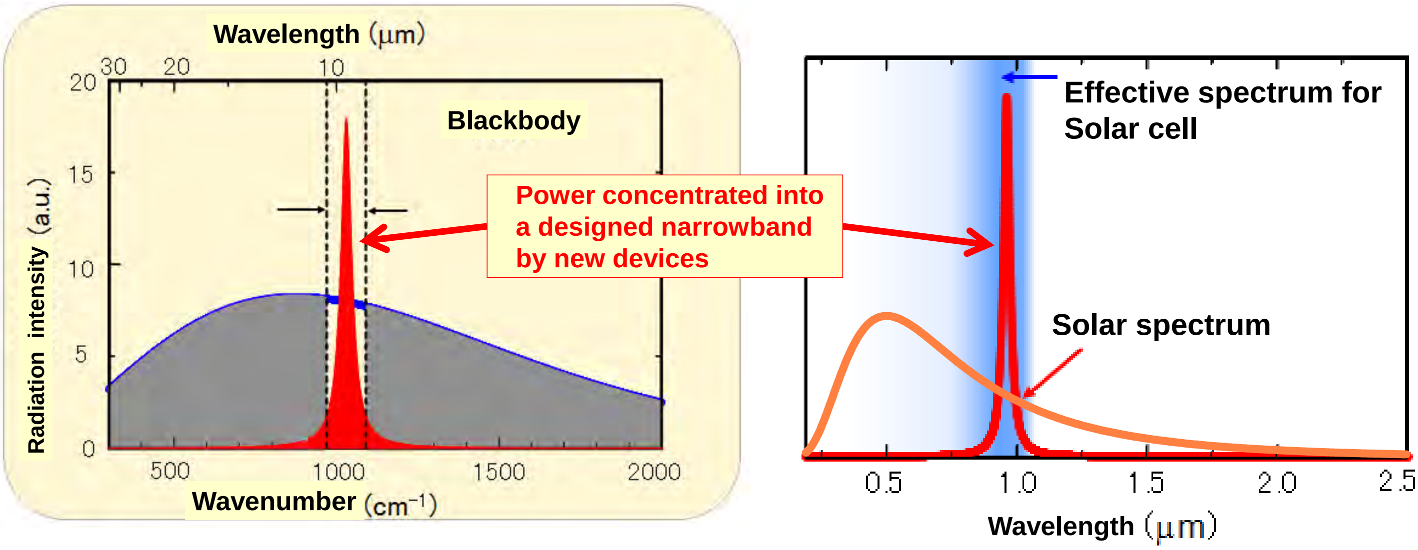
# Conversion of Broadband to Narrowband Energy using Two-dimensional Photonic Crystals

Prof. Susumu NODA (Kyoto University)

## 1. Ideal Energy Emission Control

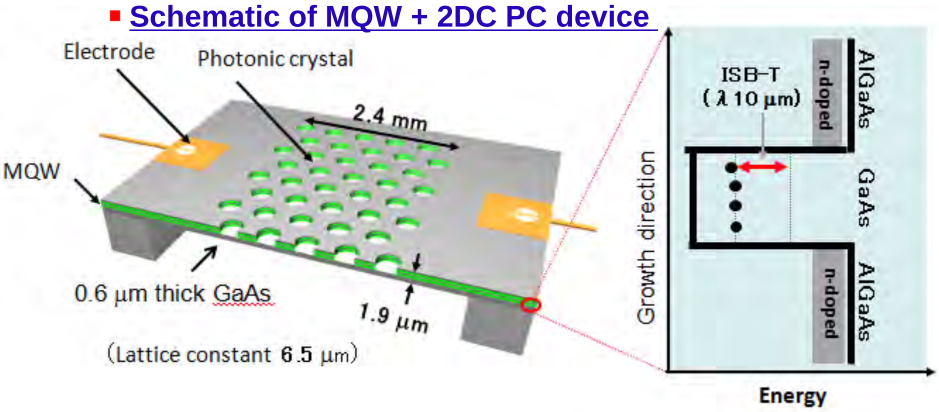
- Converting from a broadband to a narrowband emission spectrum is important in the applications of highly efficient environmental sensors and thermo-photovoltaic power generation system etc.



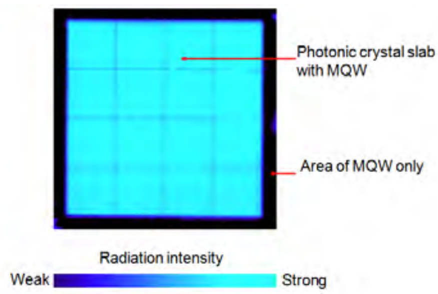

## 2. Conversion of Broadband to Narrowband Thermal Emission

- Thermal emission control device is composed of the MQW layer combined with the photonic crystal resonant effect, and its thermal emission peak intensity shows to be more than 4 times greater than that of a blackbody sample.

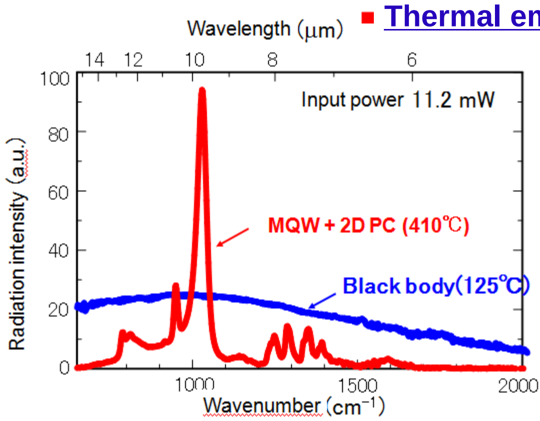
- Schematic of MQW + 2DC PC device

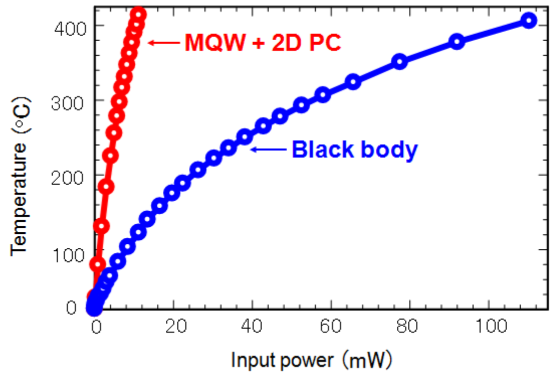



- Optical image of thermal emission of the device




- Thermal emission characteristic of the device




## Patent Licensing Available

Patent No. : Patent Pending

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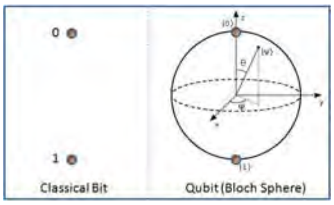
# Non-degenerate polarization-entangled photon pair generation device

Quantum Entanglement

Prof. Kei-Ichi EDAMATSU (Tohoku University)

## 1. Introduction: Development of a simple but deterministic device is awaited!

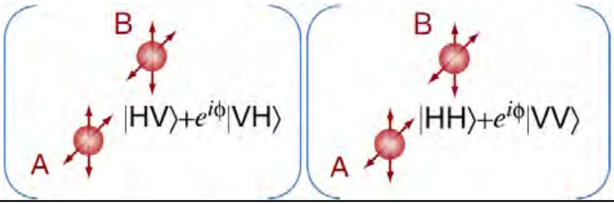
- Qubit: Quantum bit or two-state system
  1) Electron spins,
  2) photon polarizations
  etc.




- Entanglement: Concept of Quantum-mechanical non-locality

  In 2-qubit system (A,B),
  1)Entangled : $|\psi\rangle = \frac{1}{\sqrt{2}}(|0\rangle_A|0\rangle_B + e^{i\theta}|1\rangle_A|1\rangle_B)$
  2)Non-entangled (separable): $|\psi\rangle = |0\rangle_A|0\rangle_B,\ |1\rangle_A|1\rangle_B$

- Polarization-entangled photon pair: a photonic system on which 2-qubit entanglement is encoded.
  1) So far, the most reliable source of entanglement
  2) one of the key components in the future quantum information and communication technologies (QICT)

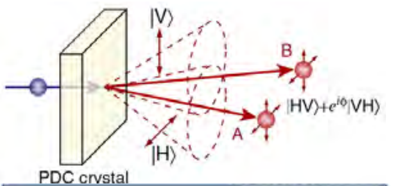


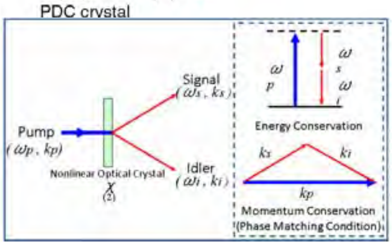

(if $e^{i\varphi}=\pm1$, these states are called maximally entangled)

## 2. A new scheme to generate polarization-entangled photon pair

- Basic physics:

  Type-II parametric down-conversion

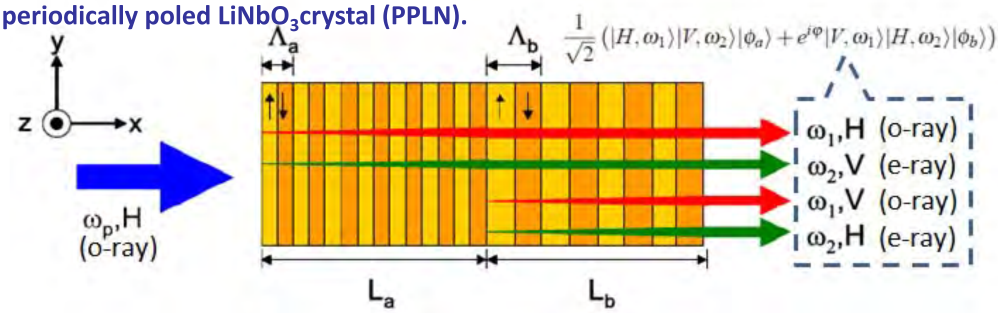



- Real Implementation:

  Type-II two-period quasi-phase-matched spontaneous down-conversion (QPM SPDC) via periodically poled $LiNbO_3$crystal (PPLN).

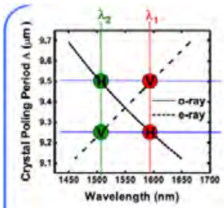
$$\frac{1}{\sqrt{2}}(|H,\omega_1\rangle|V,\omega_2\rangle|\phi_a\rangle + e^{i\varphi}|V,\omega_1\rangle|H,\omega_2\rangle|\phi_b\rangle)$$



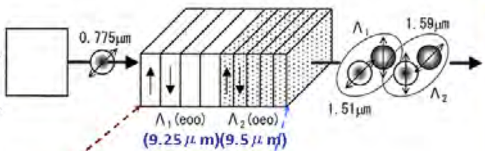

$|H,\omega_1\rangle|V,\omega_2\rangle|\phi_a\rangle \quad |V,\omega_1\rangle|H,\omega_2\rangle|\phi_b\rangle$

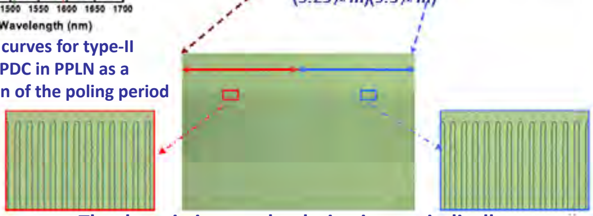
Quasi Phase Matching Condition: $\Delta k_{QPM} \equiv k_p(\omega_p) - k_s(\omega_s) - k_i(\omega_i) - \frac{2\pi}{\Lambda} = 0.$

## 3. Demonstration of a new device in telecommunication wavelength (1.59μm)



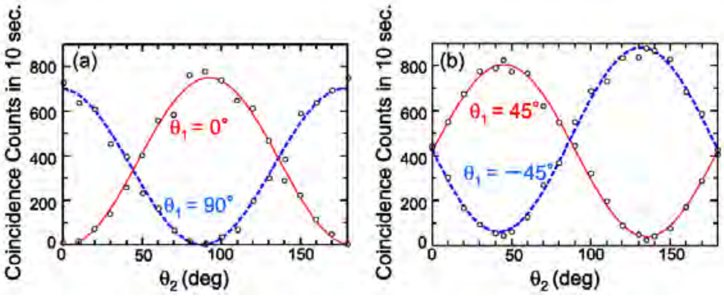

Tuning curves for type-II QPM-SPDC in PPLN as a function of the poling period



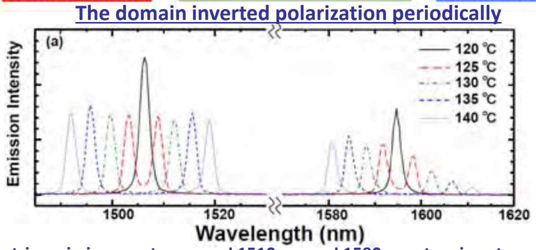



The domain inverted polarization periodically

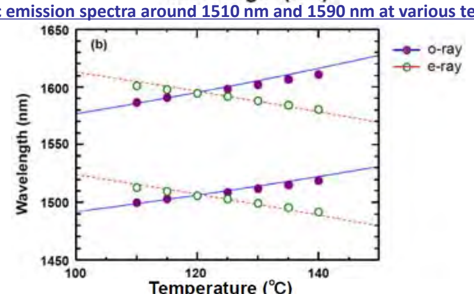
### Polarization correlation measurement
*(indistinguishability and visibility)*




Slight degradation of visibility caused by distinguishability of wave packets

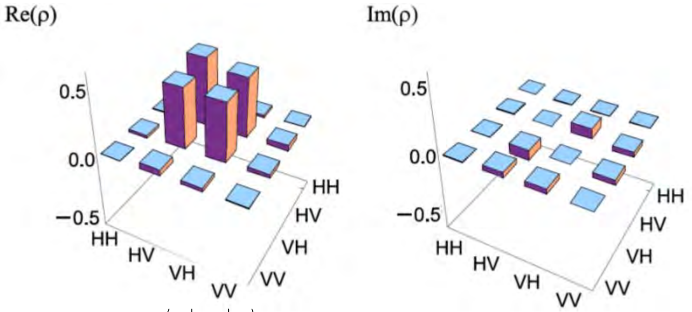



Parametric emission spectra around 1510 nm and 1590 nm at various temperatures




Temperature dependence of the peak positions in the parametric emission spectra

### Evaluation of polarization entanglement
*(Fidelity of the density matrix using a Michelson interferometer)*




$F_{exp} = \langle\Psi|\rho_{exp}|\Psi\rangle = 94.2\%$ Concurrence 0.932

**High degree of entanglement is achieved**

## Patent Licensing Available

Patent No.：WO2009/09339（JP, US, EP)

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Quantum Entanglement

# Photon Pair Generation in Biexcitonic Cavity QED and Device

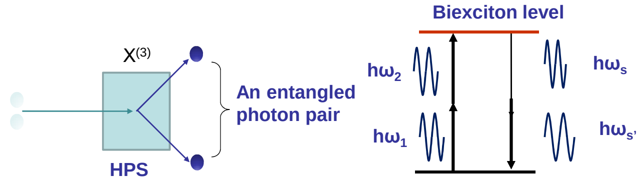
Prof. Hiroshi AJIKI (Osaka Univ.), Prof. Hajime ISHIHARA (Osaka Prefecture Univ.)

## 1. An entangled photon pair generation → Much higher efficiency is expected !!

### (1) Parametric Down Conversion: PDC


- Well known method.
- Output photon's wave length becomes halved.

### (2) Hyper - Parametric Scattering: HPS

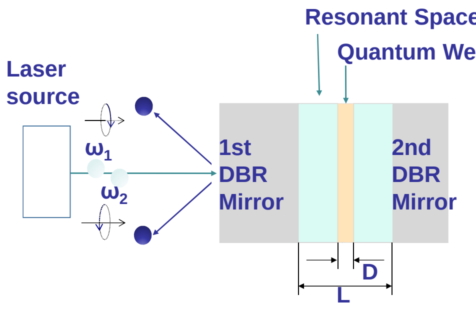



- Utilize Biexciton level. (ex. CuCl bulk/nano crystal )
- Output photon's wave length is almost same as the input one.

## 2. Novel Patented Technology

New architecture, the combination of HPS and the Microcavity with Quantum Well / Dots enhances the generation efficiency drastically

### Device 1: A quantum well in a DBR cavity




Design Parameter:

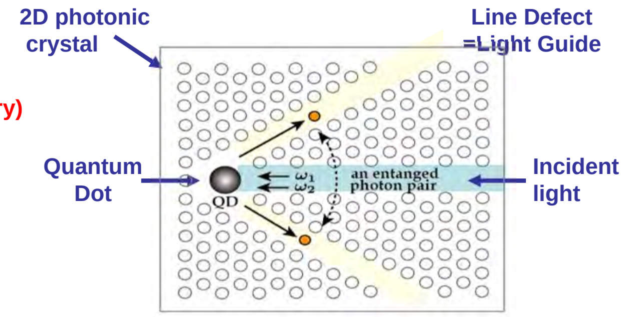
(Optimal Conditions are Necessary)

$$L = \frac{c\pi}{\omega_0}\sqrt{\varepsilon_C}$$

$$d = \frac{\pi^2}{8}\left(\frac{g_{ex}}{\omega_0}\right)^2 \frac{hc\varepsilon_C^{3/2}}{2\varepsilon_\omega \Delta_{LT}}$$

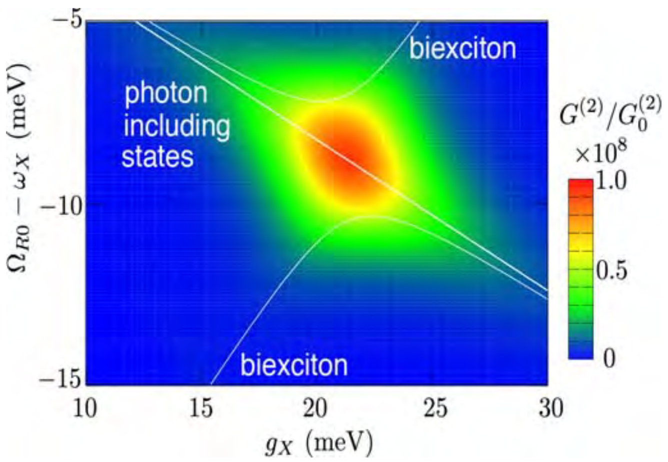
DBR: Distributed Bragg Reflector

### Device 2 : A quantum dot in a photonic slab cavity




## 3. Normalized Efficiency enhances up to the order of ~ $10^8$

•The optimal entangled-photon generation exists at the level-crossing region of the biexciton and the photon including states.




gx: Coupling const. between the exciton and the cavity photon (~ω1)

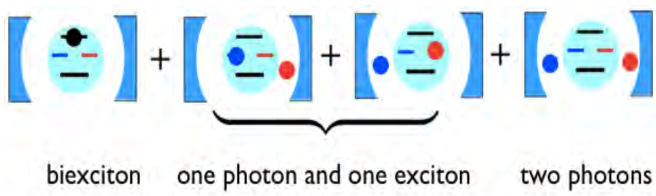
$\Omega_{R0}$-$\omega_X$: ω2 - ω(exciton)

$G_0^{(2)}$ : the intensity without the cavity effect.

$G^{(2)}$ : the intensity with the cavity effect.

To enhance the efficiency, two excitation dressed states are necessary.

Two excitation dressed states:




## 4. Control method for the Optimal Conditions of the entangled photon generation

Effects of the Cavity quantum electrodynamics (Cavity QED) are significant.

•The frequency $\omega_1$ of a right (left) circularly polarized laser field is tuned to a frequency of a cavity polariton.

•The frequency $\omega_2$ of a left (right) circularly polarized field is tuned to the transition frequency from the cavity polariton to the two-excitation dressed states.

## 5. Application

Quantum Information / Communication Technology

Quantum Lithography

## Patent Licensing Available

Patent No. : JP 4863105, 3649408

US 7649679, 7683361

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# Quantum dot manipulating method and quantum dot production/manipulation apparatus

Optical Manipulation

Prof. Tadashi ITOH ,Prof. Masaaki ASHIDA (Osaka Univ.), Prof. Hajime ISHIHARA ,Prof. Takuya IIDA (Osaka Prefecture Univ.)

## 1. Optical manipulation in nanoscale regime

| Laser Tweezers *in μm regime* | *Nanoscale regime* | Atom trapping *in atomic regime* |
| --- | --- | --- |
| μm | nm | Atomic scale |
| non resonance classical treatment | *new frontier* | resonance quantum mechanical |

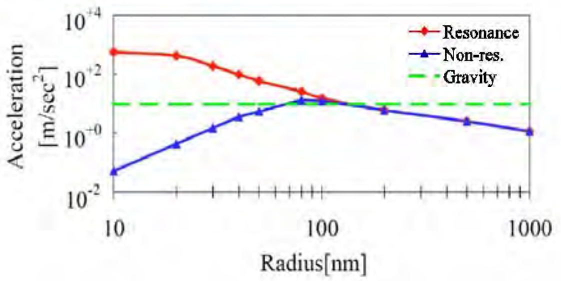
Degrees of freedom of the spatial structure of the electronic wave functions

New possibilities of optical manipulation !

## 2. Theoretical Analysis

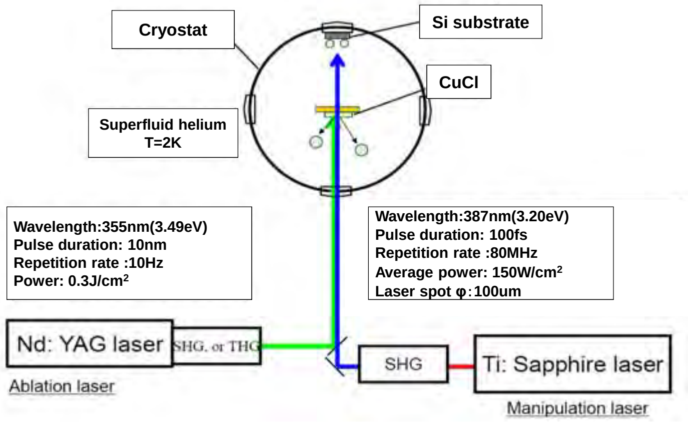
For a CuCl nano-particle (50μW/100μm² Γ=0.06 meV)

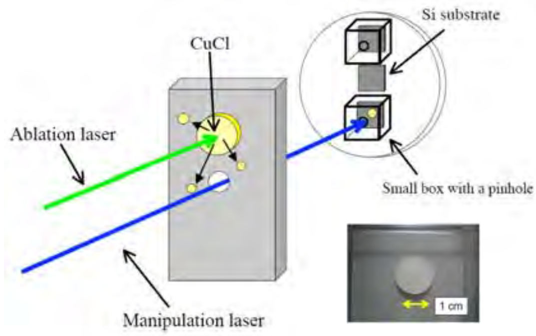
**Numerical Calculation** T. Iida & H.Ishihara, Phys.Rev.Lett.90,057403(2003)




**For particles @ 10nm, resonance effect works more than 100 times bigger than for ones @ 100nm**

## 3. Experimental setup for particle transport

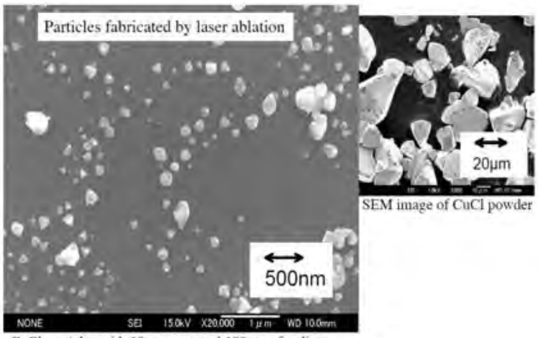



Pelletized target from CuCl powder

## 4. Experimental Results:

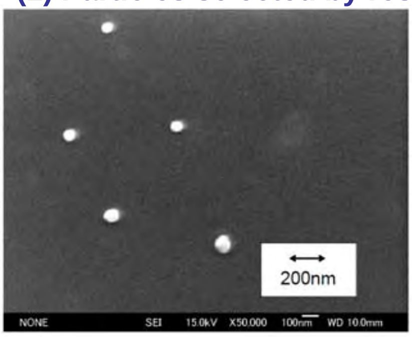
### (0) Particles fabricated by laser ablation

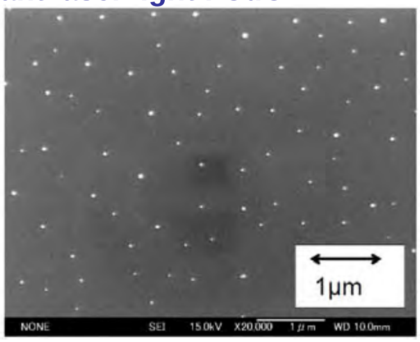



SEM image of CuCl powder

CuCl particles with 10nm～several 100nm of radius

### (1) Particles selected by resonant laser light : CuCl



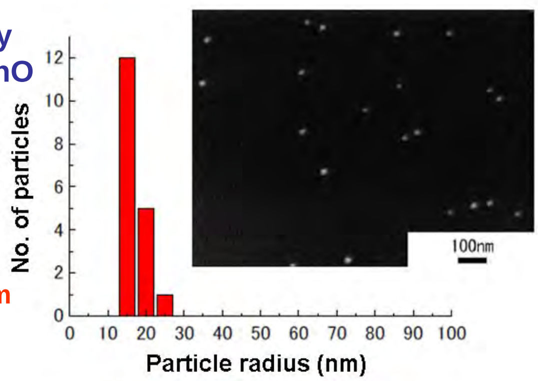

**The particles adhered only to the substrate irradiated with resonant light.**

**Many particles with 10 ~50nmφ**

**Number of particles in this picture:83**
**Density of particles: 3.05/um2**
**Average radius: 22nm**
**Particle number in spot: About 24000**

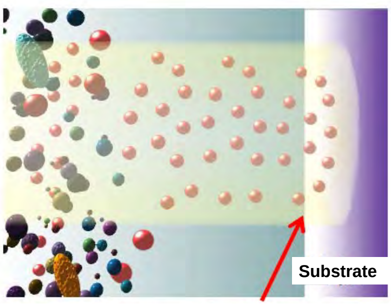
### (2) Particles selected by resonant laser light : ZnO

**Average size: 19nm**




## 4. Potential Applications

**Nanoscale optical chromatography**




Selection of nano materials by the correspondent resonant waves

## Patent Licensing Available

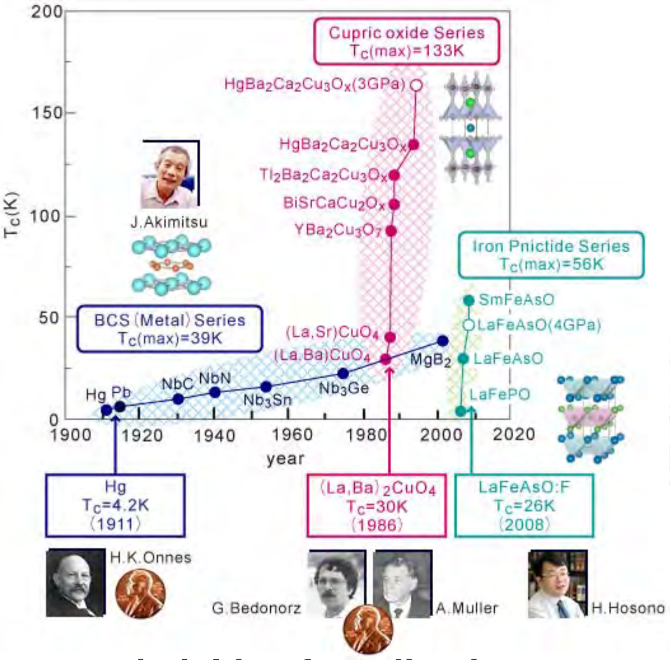
**JP 4878550, US 7662731, 8357272**

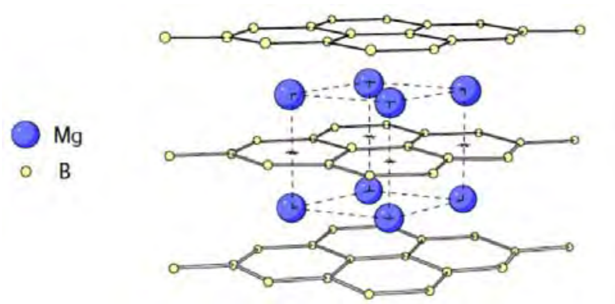
Super-conductor

# Magnesium Diboride ($MgB_2$) as superconducting Materials

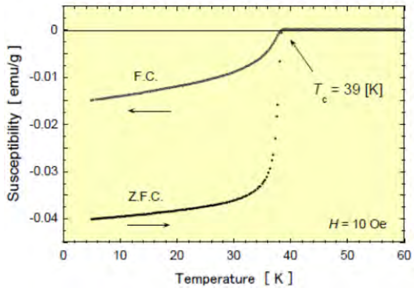
Prof. Jun AKIMITSU (Aoyama-Gakuin University)

## 1. Introduction: Superconducting $MgB_2$

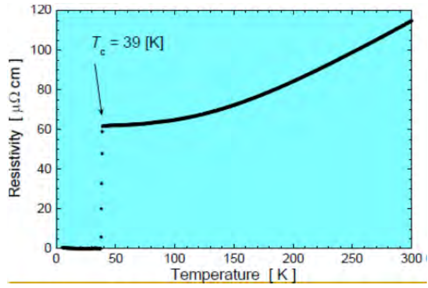



Crystal Structure (Honeycomb Lattice)

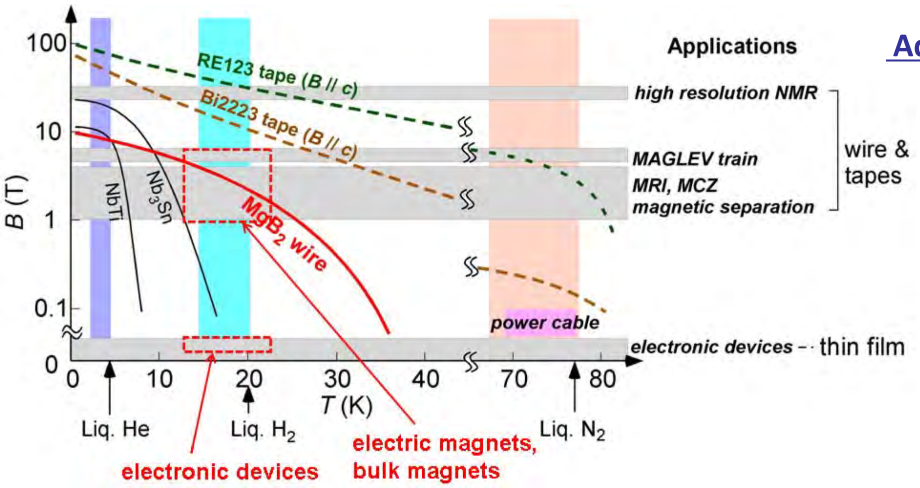



Meissner Effect
(Perfect Diamagnetism)




Zero Electrical Resistivity

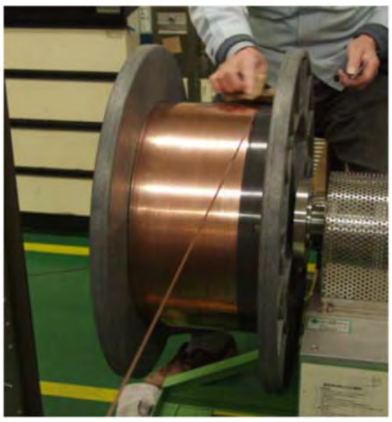
## 2. Expected Fields of Applications

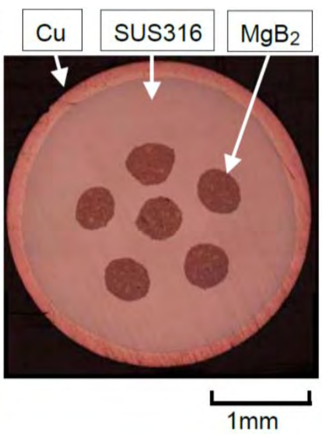



### Advantages of $MgB_2$

①Highest-*Tc in the intermetallic superconductors*
②Starting materials are light and not expensive
③Its *Tc is a sweet spot for refrigerator*
④No-weak-link between grains
⑤Using cheap sheath-material is feasible
⑥Heat treatment is unnecessary. or treatment at low temperature and short time is feasible
⑦Good performance for bending

## 3. Application Examples






100m class wire and its cross section with 6 filaments
(courtesy of Central Japan Railway Company, Hitachi, Ltd. and National Institute for Materials Science (NIMS))

Small solenoid coil
(courtesy of NIMS)

MRI (Magnetic Resonance Imaging)
(excerpt from Paramed website Open MRI)

## Patent Licensing Available

Patent No.: WO2002/055435 (JP, US, EP, KR, CN, CA)

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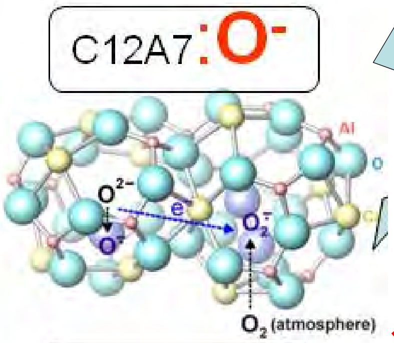
Super-conductor

# Electro-conductive & Transparent Nano-porous Compound C12A7

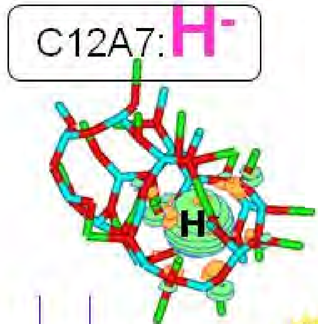
Prof. Hideo HOSONO (Tokyo Institute of Technology)

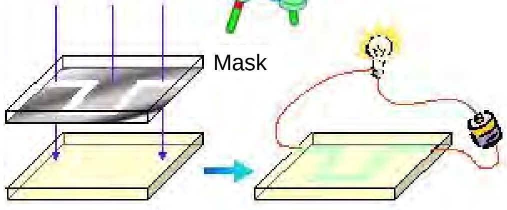
## 1. Novel Compound $12CaO \cdot 7Al_2O_3$ (i.e.C12A7)

- C12A7 is composed of materials of alumina cements, and has 6 cages with an inner free space of 0.4nm of which only one cage is filled by $O^{2-}$. These 80% cages are free spaces.
- The oxide ions can be replaced by various anions such as $O^-$, $H^-$, $OH^-$, $e^-$ etc and show very interesting functions.

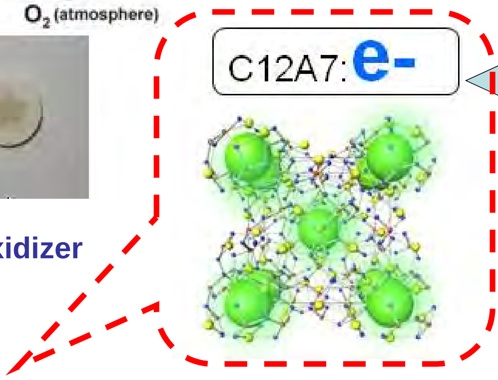




・Strong oxidizer



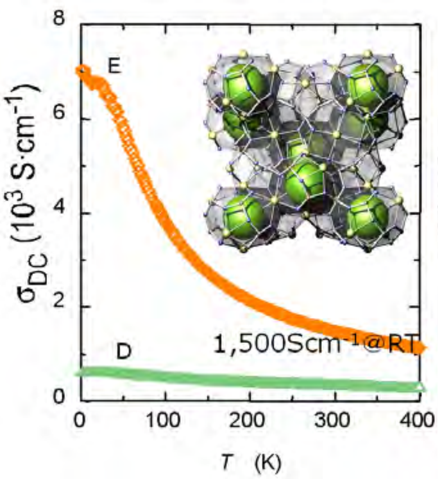

・Electro-conductive by photo-irradiation
・Reducer



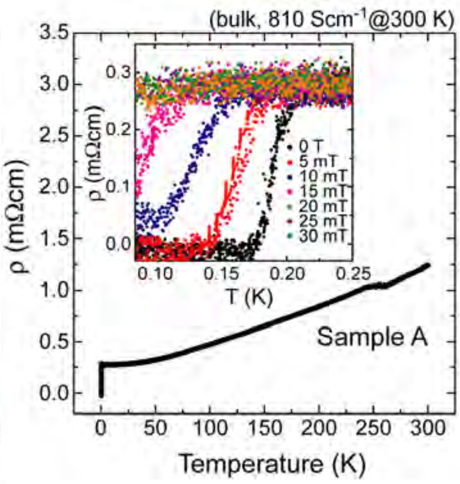

*・Highly electro-conductive*
*・Strong reducer*

## 2. Electride C12A7: e-

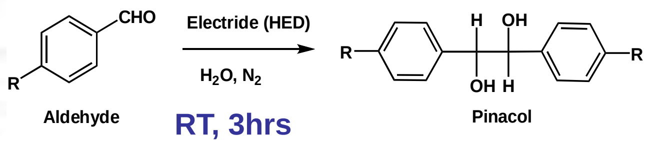
- Conductivity of C12A7: e-



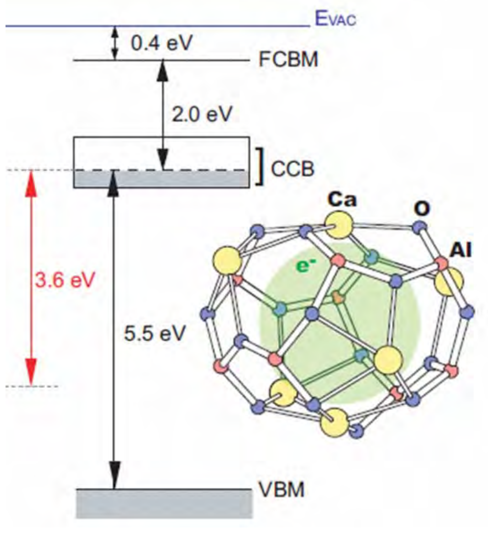

- Superconductor of C12A7: e-




- Reduction reaction using C12A7: e-




## 3. Small work function of C12A7: e-




## Patent Licensing Available

Patent No. :US6818192,7462334.7235225,7507289,7465433, EP1717217, JP4147324,4219821,4245608, TW283234 etc

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# Iron-Based New Superconductors

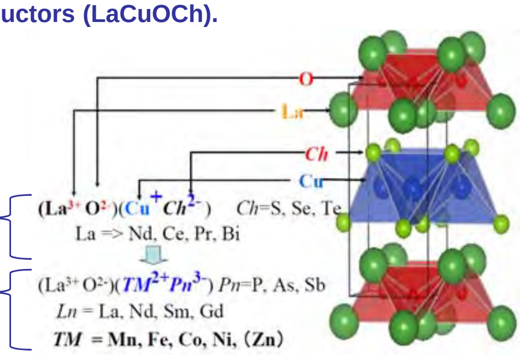
Super-conductor

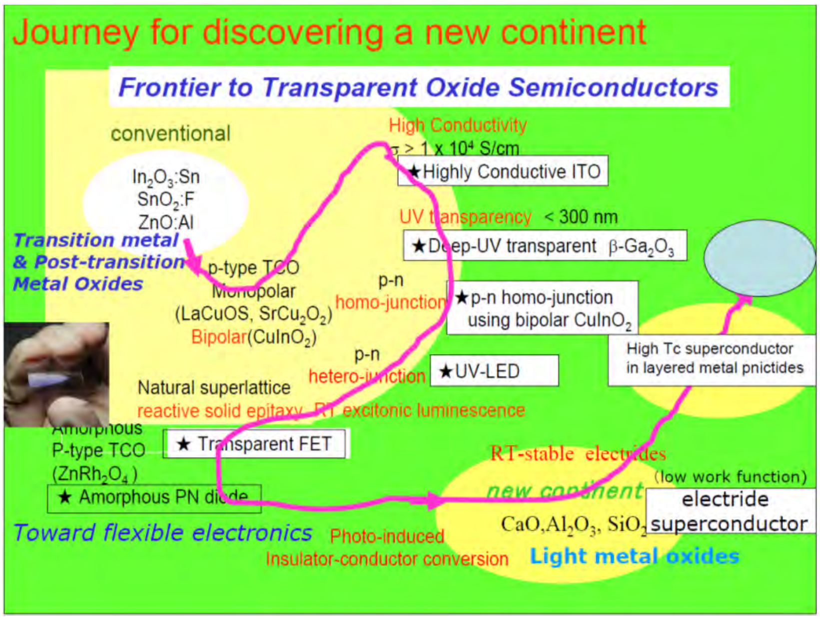
Prof. Hideo HOSONO (Tokyo Institute of Technology)

## 1. Long Journey to Iron-Based Superconductors

- Iron has been supposed to be hard to be superconductive, because of the common sense that **ferromagnetism is incompatible with superconductivity.**

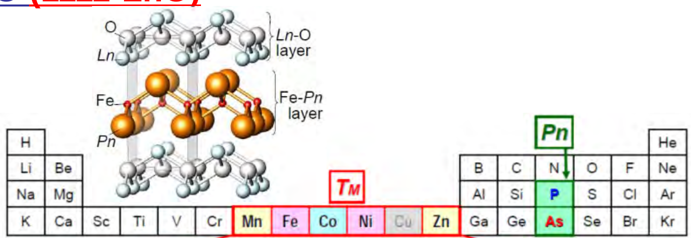
- In 2008, Iron-Pnictides superconductor (LaFePO) was discovered, during the course of finding magnetic semiconductors (LaTMOPn) from p-type transparent semiconductors (LaCuOCh).




## 2. Two types of Iron-Based Superconductors

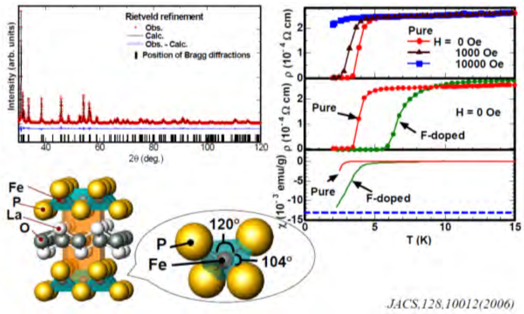
### 1) LaTMPnO (1111-LnO)




| $TM^{2+}$ | Mn(3d⁵) | | Fe(3d⁶) | | Co(3d⁷) | | Ni(3d⁸) | | (Cu) | Zn(3d¹⁰) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Pn | P | As | P | As | P | As | P | As | | P | As |
| Elect. Prop. | Semiconductor | | Super-conductor | | Metal | | Super-conductor | | — | Semiconductor | |
| Magnetism | AFM | | | | FM | | | | — | nonmagnetic | |
| $E_g$ | ~1 eV | | — | | — | | — | | — | ~1.5 eV | |
| $T_C$ / $T_N$ | > 400 K | | Undoped: 5 K | Undoped: X F-doped: 26 K | 43 K | 66 K | Undoped: 3 K | Undoped: 2.4 K | | — | |
| Ref. | Yanagi et al. JAP submitted | | Kamihara *et al.* JACS(2006), Kamihara *et al.* JACS (2008) | | Yanagi et al. PRB (2008) | | Watanabe *et al.* IC (2007), Watanabe *et al.* JSSC (in press) | | — | Kayanuma *et al.* PRB (2007), Kayanuma *et al.* TSF (2008) | |

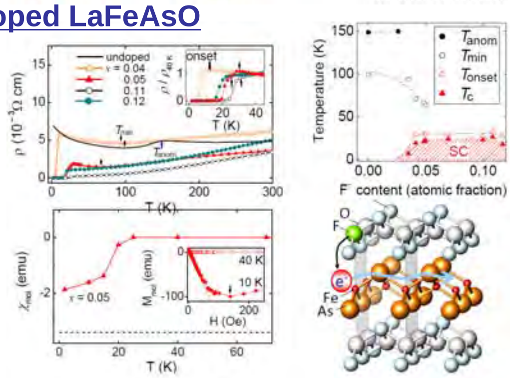
Related Patent: WO 2009/104611 (JP, US)

**▪LaFePO**




JACS,128,10012(2006)

**▪F-doped LaFeAsO**




### 2) AeFeAsF (Ae=Ca & Sr) (1111-AeF)

***Substitution of blocking layer***

$[Ln^{3+}O^{2-}]$ layer — *Ln*: rare-earth element ex. La, Ce, Sm … etc

$[Ae^{2+}F^{-}]$ layer — *Ae*: alkali-earth element ex. Ca, Sr

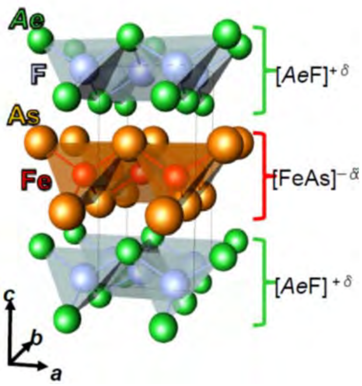
***Doping method***

① Doping to AeF layer: *Ae*, F → ? ✗

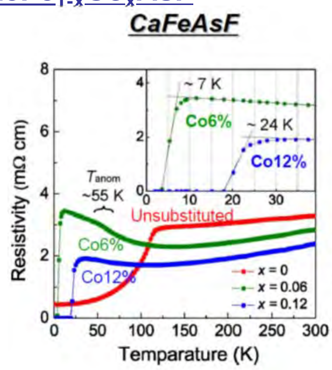
② Doping to FeAs layer: Fe → Co, Ni ○

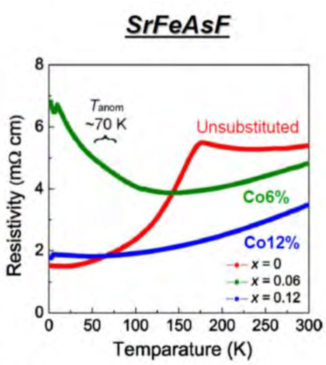
$CaFe_{1-x}Co_xAsF$ *Tc* = ~22 K

$SrFe_{1-x}Co_xAsF$ *Tc* = ~4 K




**▪$AeFe_{1-x}Co_xAsF$**




$Fe^{2+}$ 3d⁶ $Co^{2+}$ 3d⁷

Related Patent: WO2009/119216 (JP, US)

## Patent Licensing Available

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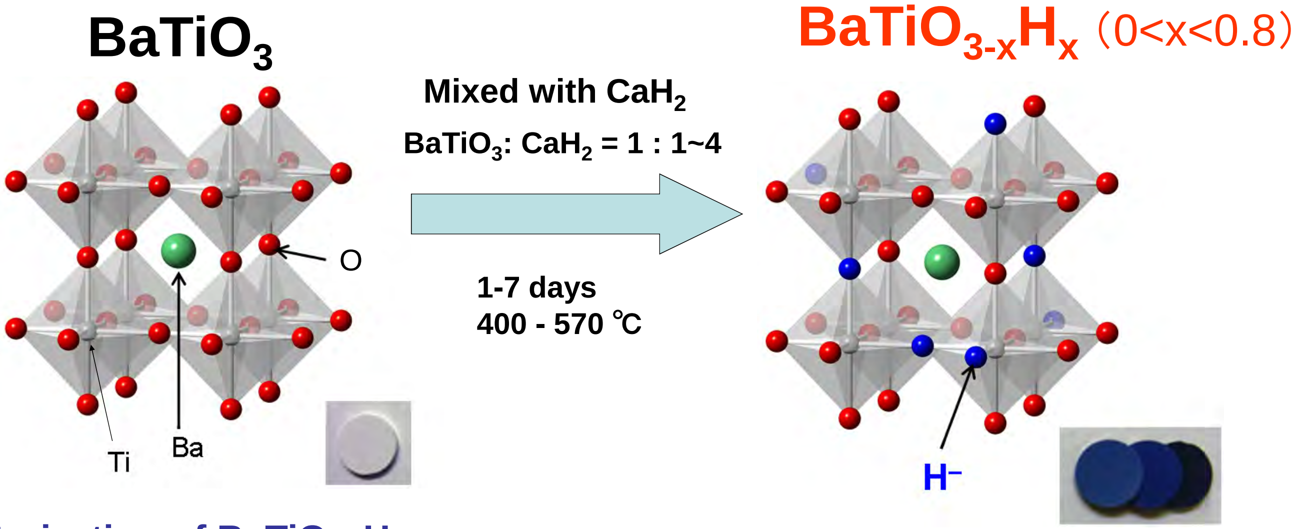
# Novel Materials ; $BaTiO_{3-x}H_x$ (0<x<0.8)

Prof. Hiroshi KAGEYAMA (Kyoto University)

## 1. Preparation of $BaTiO_{3-x}H_x$

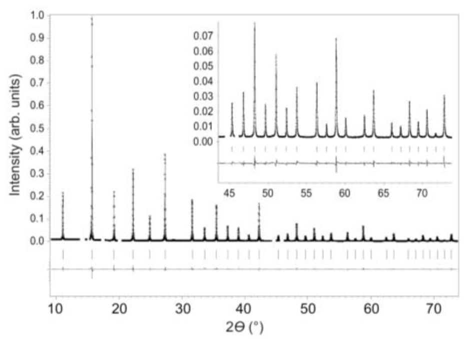
- The oxyhydrides $BaTiO_{3-x}H_x$ are prepared by a novel low temperature reaction of a well-known ferroelectric compound $BaTiO_3$. The reducing reaction with $CaH_2$ results in color change of powder specimen from white to light blue, dark blue, black compound, depending on the severity of the reduction. Despite the presence of $H^-$ ions, the oxyhydrides are stable in air, boiling water and aqueous alkali solutions.



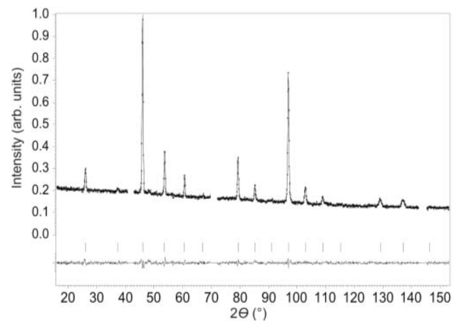

## 2. Characterization of $BaTiO_{3-x}H_x$

- Synchrotron X-ray/neutron diffractions combined refinement reveal that $BaTiO_{3-x}H_x$ adopts cubic perovskite with $H^-$ ions located randomly at the oxygen site.

Synchrotron XRD

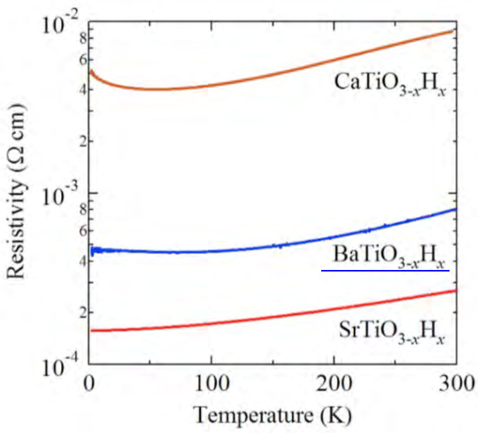



Neutron Diffraction



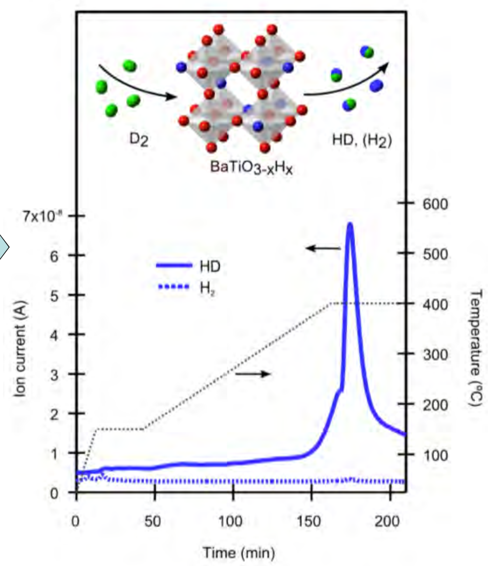

## 3. Metallic Conductivity & Deuteride Exchange of $BaTiO_{3-x}H_x$

- $BaTiO_{3-x}H_x$ is intrinsically metallic with $10^2$-$10^4$ S/cm.




- $BaTiO_{3-x}H_x$ is exchangeable with $D_2$ to give $BaTiO_{3-x}H_yD_z$.

Mass spectrometry




## Patent Licensing Available

Patent No. : WO2013/008705

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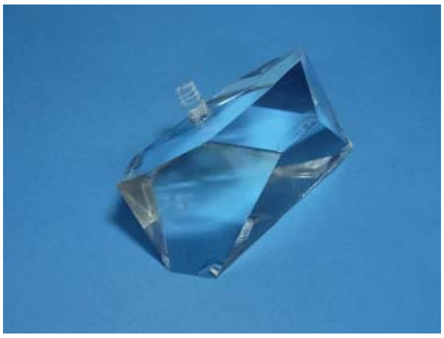
Oxides

# Cesium Lithium Borate ($CsLiB_6O_{10}$: CLBO) Single Crystals for Ultraviolet Light Generation

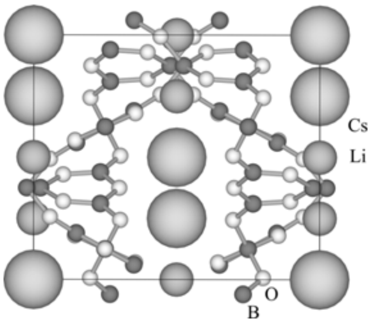
Prof. Yusuke MORI (Osaka University)

## 1. CLBO single crystals

**CLBO was discovered by Osaka University in 1993 as a new material.**



High-Quality CLBO
(85×53×46mm)



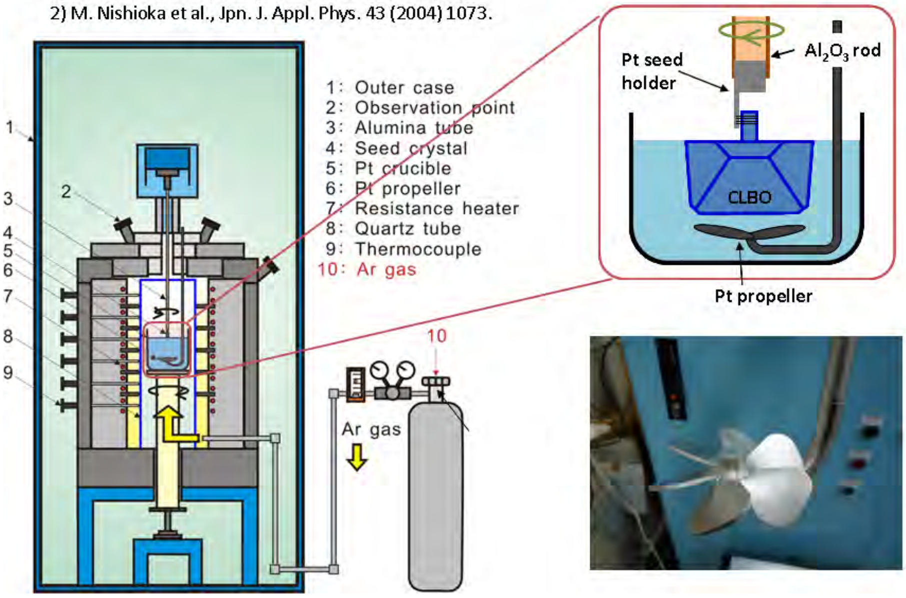

**Tetragonal, Point group -42m**
**$d_{36}$=0.76pm/V**
**$\Delta$n=0.052**
**4HG, 5HG of Nd:YAG laser**

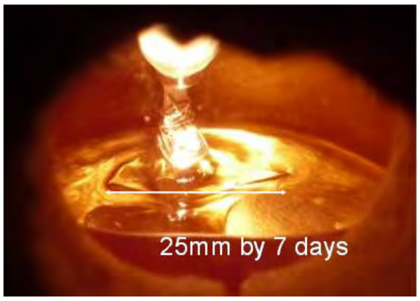
***See details on CLBO in an authorized vender catalog!***

## 2. CLBO single crystals growth method

Solution-Stirring Top-Seeded Solution Growth (SS-TSSG) method[1,2)]

1) M. Nishioka et al., J. Cryst. Growth 279 (2005) 76.
2) M. Nishioka et al., Jpn. J. Appl. Phys. 43 (2004) 1073.

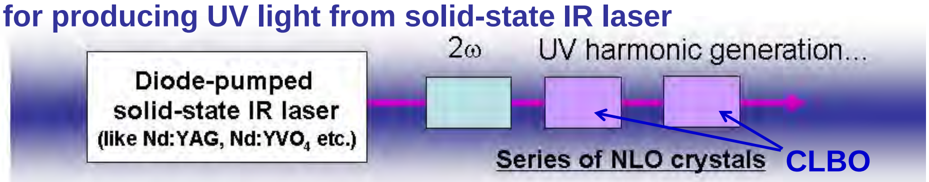


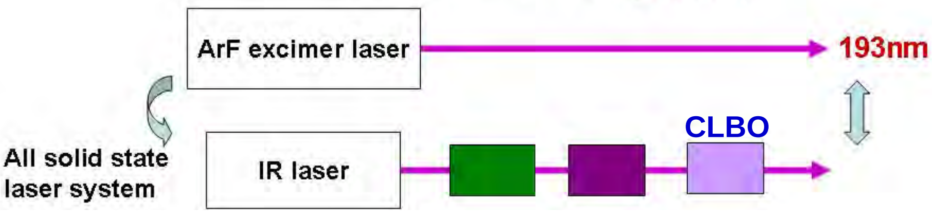

Stirring effect of normal growth method is inadequate for CLBO solutions with high viscosity. New effective solution stirring technique is based on a forced solution-stirring technique combining propeller and crucible rotation. Rotating the crucible with a static propeller effectively induces forced convection despite the high viscosity of the solution.

## 3. Some applications

**Sum-frequency generation by NLO crystals is an effective way for producing UV light from solid-state IR laser**




ω + 2ω → 3ω (355 nm)
2ω + 2ω → 4ω (266 nm)
ω + 4ω → 5ω (213 nm)




**CLBO advantages:**

- **large nonlinearity**
- **small walk-off angle**
- **broad angular, spectral and temperature acceptance bandwidths**
- **high-conversion efficiency**
- **long life time**

**⇒suitable for high-power UV light generation (266nm, 213nm and 193nm UV light generation is already achieved).**

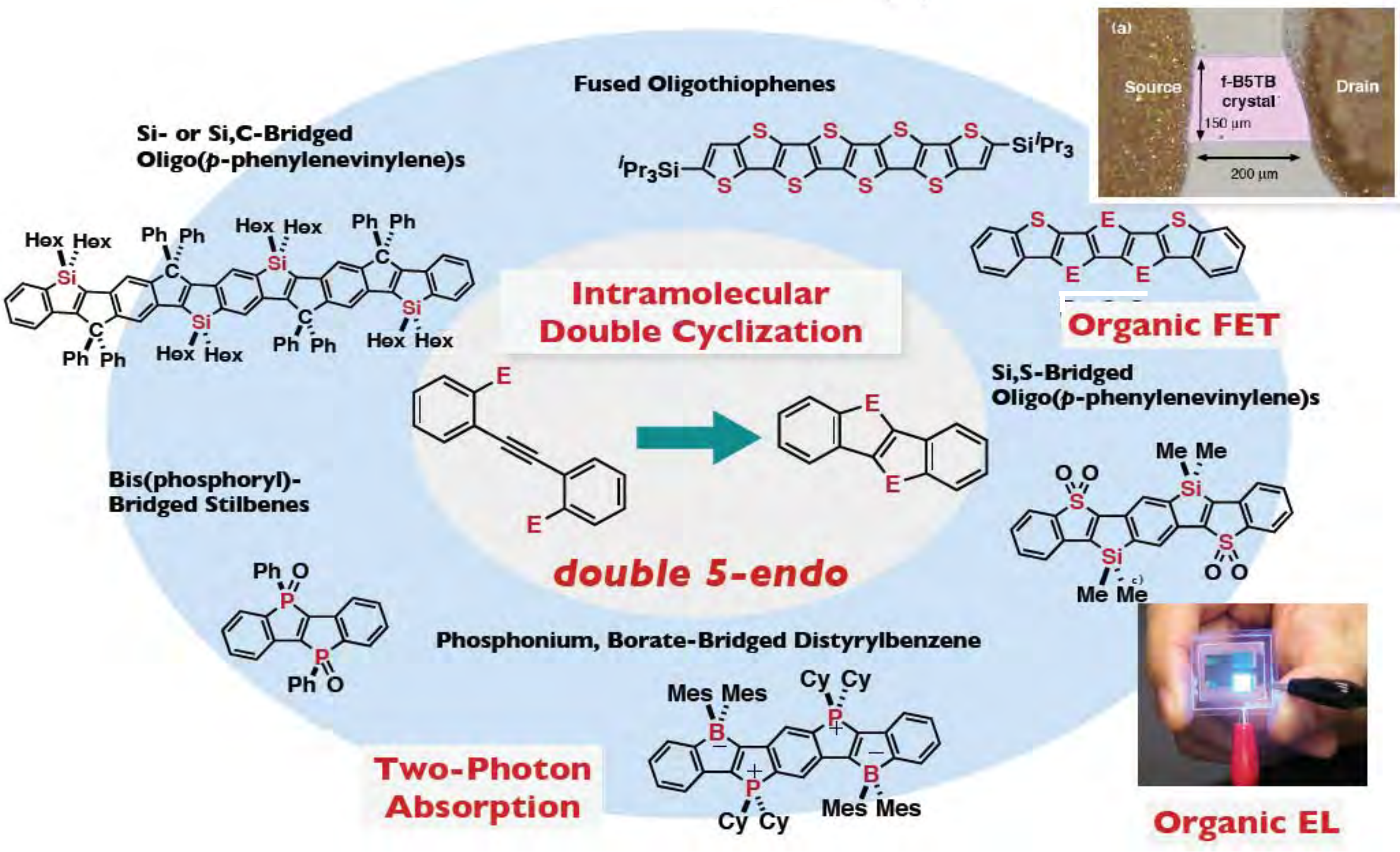
**For further information**
Center for Intellectual Property Strategies
Japan Science and Technology Agency (JST)
Phone: +81-3-5214-8486, Fax: +81-3-5214-8417
e-mail: license@jst.go.jp

Organic Materials

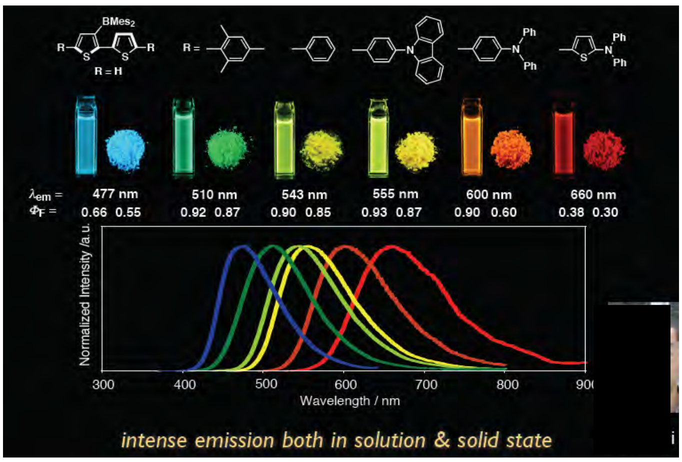
# Ladder π-Conjugated Materials for OLED

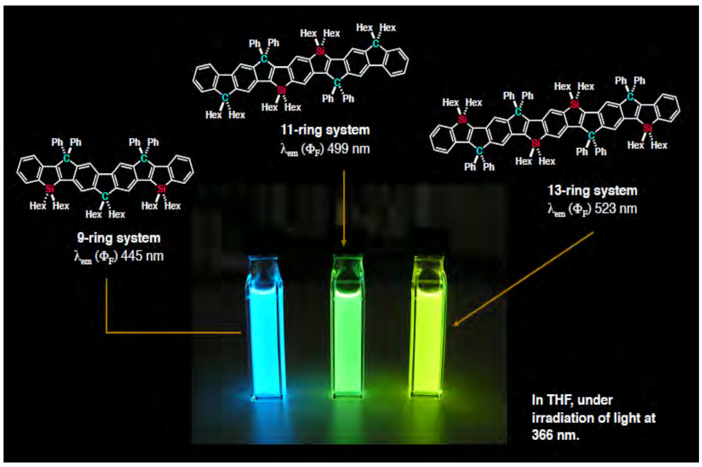
Prof. Shigehiro YAMAGUCHI ( Nagoya University )

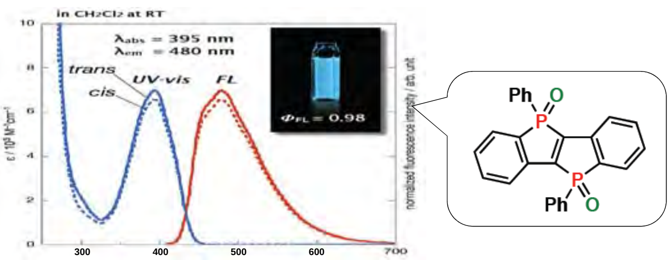
- **Incorporation of main group elements, such as B, Si, P, S into the ladder π conjugated framework gives rise to attractive photophysical and electronic properties such as intense luminescence, electron/hole transport etc. for organic light-emitting diode (OLED).**

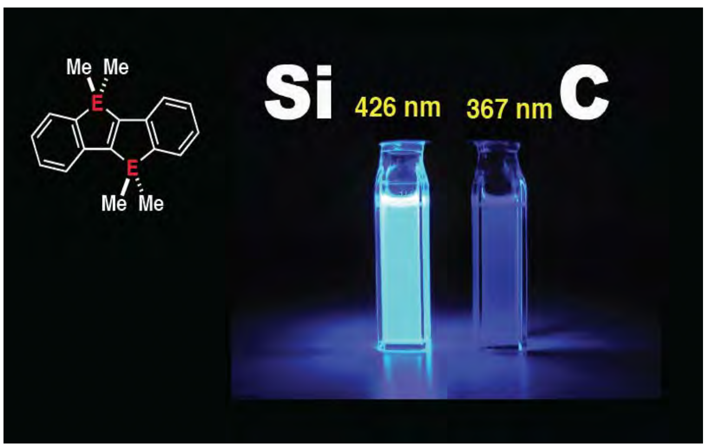



## Ex. Intense Luminescence for OLED Application




## Patent Licensing Available

Patent No. : WO2005/044826,087780 etc.

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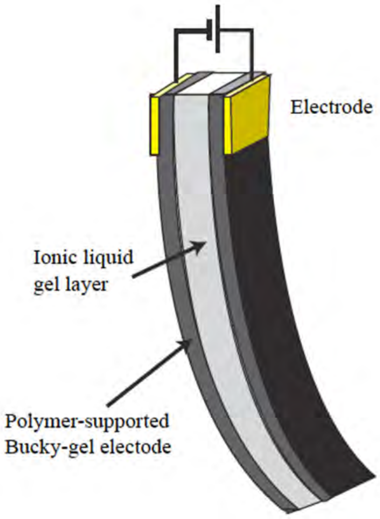
Organic Materials

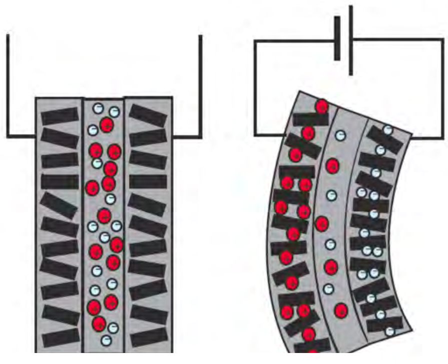
# Bucky Gel Actuator

Dr. Kinji ASAKA (National Institute of Advanced Industrial Science and Technology)

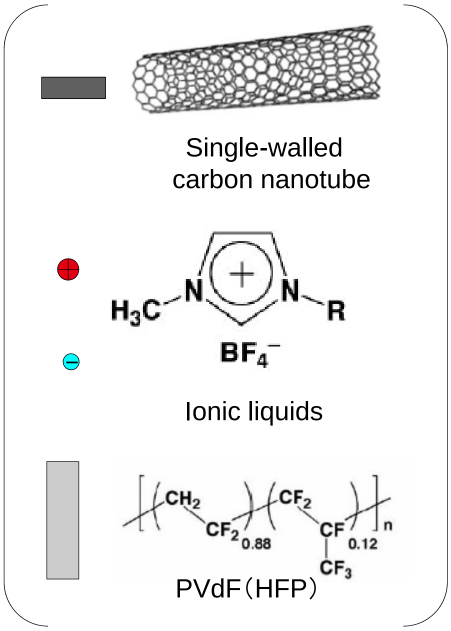
## 1. Bucky Gel Actuator

- Bucky gel actuator has a triple-layered configuration with an ionic-gel electrolyte layer sandwiched by nano-carbon dispersed ionic-liquid gel electrode layers.
- It is operable in air at voltages lower than 3V.



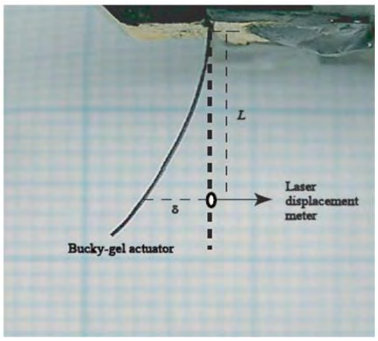



ionic liquid Nano-carbon PVdF (HFP)



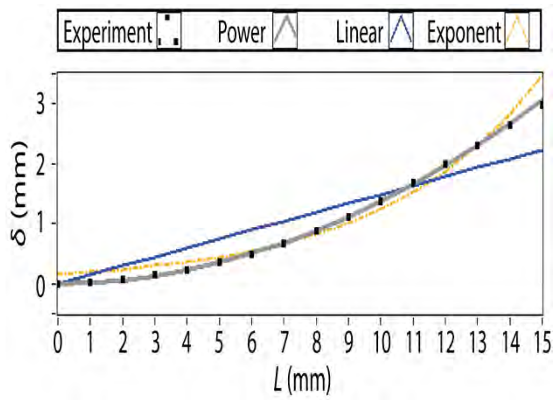

## 2. Displacement Measurement

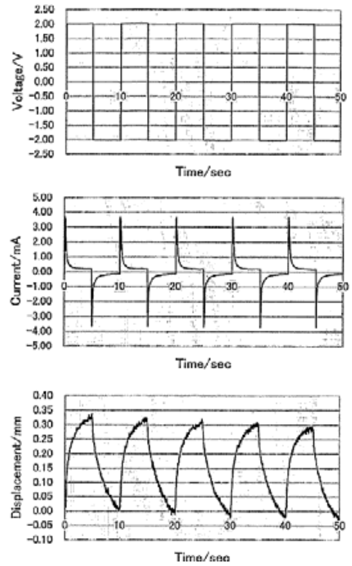
- Cantilever bending of bucky-gel actuator




**L**: Free length **δ**: Displacement

- Actuator's curvature at large deflection




## 3. Applications

### Tactile Devices

- Tactile device for portable equipments
- Wearable tactile devices
- Large-area tactile display
- Film-like tactile display

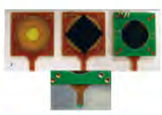
Etc.

### Robotics

- Artificial muscle for wearable robot
  - Prosthetic application
  - Rehabilitation
- Artificial muscle for personal robot
- Tactile sensor for these robots

Etc.

### Biomedical Devices



- Micro-active catheter
- Micro-active endoscope
- Micro noiseless pump for biomedical applications

Etc.

## Patent Licensing Available

Patent No. : WO 2005/057772 （Co-applicant; JST/AIST）

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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.

http://www.jst.go.jp/EN/about/index.html


# Japan Science and Technology Agency
## Center for Intellectual Property Strategies

**5-3, Yonbancho, Chiyoda-ku, Tokyo, 102-8666 JAPAN**
**phone : +81-3-5214-8486**
**fax : +81-3-5214-8417**
**e-mail : license@jst.go.jp**
**URL : http://www.jst.go.jp/tt/EN/**
**http://www.jst.go.jp/tt/EN/mrs2013.html**