2024

Ajou University - Chiba University Joint Symposium

February 21-23th, 2024
Energy Center, Ajou University, South Korea

CHIBA UNIVERSITY

아주대학교 AJOU UNIVERSITY

Symposium Program

[21th Feb.]

Time	Event	Note
~ 16:00	**Registration**	Rm. 311 Energy Center
16:00 ~ 18:00	**Program Committee Meeting** All Committee Members	Rm. 311 Energy Center

[22th Feb.]

Time	Event	Note
09:20 ~ 09:40	**Opening Remark** Prof. Hye-Young Jang and Prof. Takashige Omatsu	Rm. 311 Energy Center
Session 1		Chair Prof. Hyungwoo Lee (Ajou)
09:40 ~ 10:10	• Prof. Jonghee Yoon (Ajou Univ.) *Multimodal optical imaging system for disease diagnosis*	
10:10 ~ 10:40	• Prof. Yasuhiro Yamada (Chiba Univ.) *Anti-Stokes Photoluminescence and Semiconductor Optical Cooling in Dot-in-crystal Perovskites*	
10:40 ~ 10:55	• Young-Chul Kim (Ajou Univ.) *Bacteria-induced modulation in second harmonic generation of molybdenum disulfide for sensing applications*	
10:55 ~ 11:10	• Yuto Yoneda (Chiba Univ.) *Optical skyrmions generation from Pr^{3+}-doped fiber laser*	
11:10 ~ 12:30	**Break and Poster Session**	
12:30 ~ 13:30	**Lunch**	
Session 2		Chair Prof. Takashige Omatsu (Chiba)
13:30 ~ 14:00	• Prof. Hye-Young Jang (Ajou Univ) *Sustainable Catalytic Reactions for Carbon Neutrality*	
14:00 ~ 14:30	• Prof. Nobuyuki Aoki (Chiba Univ.) *Realization of $MoTe_2$ CMOS inverter by contact doping and channel encapsulation*	

14:30 ~ 15:00	• Prof. Jin-Sung Park (Ajou Univ.) *Electrode Design for Achieving High Energy Density All-Solid-State Batteries*	
15:00 ~ 15:15	**Coffee Break**	
Session 3		Chair Prof. Jin-Sung Park (Ajou)
15:15 ~ 15:45	• Prof. Sho Itoh (Chiba Univ) *Laser fusion cutting of flexible glass via Mid-IR laser*	
15:45 ~ 16:00	• Tan Runfa (Ajou Univ.) *Flame Activation of Spinel Zinc Ferrite Photoanode with Enhanced Charge Collection Property for Solar Water Splitting*	
16:00 ~ 16:15	• Miyuka Kono (Chiba Univ.) *In-situ observation of silver precipitation phenomena inside borosilicate glass*	
16:15 ~ 16:45	• Prof. Sunghun Kim (Ajou Univ.) *Strain-controlled quantum physics in quasi-one-dimensional compounds*	
16:45 ~ 17:00	**Group Photo**	
17:00 ~ 17:20	**Closing Remark** Prof. Takashige Omatsu and Prof. Hye-Young Jang	

[23th Nov.]

Time	Event	Note
09:00 ~ 10:00	**Lab Tour**	Rm. 311 Energy Center
10:00 ~ 12:00	**Ajou-Chiba Faculty Meeting** All Faculty Members	Rm. 311 Energy Center

Poster Session

11:10 ~ 12:30, 22th Feb.
Rm 311, Energy Center

- ✓ To presenters, set up your poster at the Rm 311 till 11:10.
- ✓ A poster author is required to stand by the poster during the scheduled poster session to answer questions from attendees.

PS-1
Doyeop Kim (Ajou Univ.)
Strong Random Telegraph Signal Noise at Room Temperature in SrRuO3/LaAlO3/Nb:SrTiO3 Heterojunctions

PS-2
Kaito Sato (Chiba Univ.)
High-precision printing of cyanobacterial suspensions with optical vortex induced transfer

PS-3
Joohyeon Ahn (Ajou Univ.)
Structure-Selective Growth of Symmetry-Broken MoSe2 and Their Broadband Nonlinear Optical Response

PS-4
Sayaka Kai (Chiba Univ.)
Direct print of metallic nanoink with optical vortex induced forward transfer

PS-5
Jun-Hui Choi (Ajou Univ.)
Controlled growth of highly chemical and thermal stable Ge core/ BCN shell nanowire

PS-6
Kosuke Sakamoto (Chiba Univ.)
Diamond slicing at the {100} plane using a picosecond laser beam by developed method restricting crack propagation along the cleaved plane

PS-7
Mukkath Joseph Josline (Ajou Univ.)
Large Area CVD Growth of Bilayer Graphdiyne for Flexible Piezoresistive Applications

PS-8
Ryo Ozaki (Chiba Univ.)
Low energy photoelectron measurement method in practical environment using a Retarding Field Analyzer

PS-9
Jaemin Ryu (Ajou Univ.)
Sunlight-Driven Hydrogen Production from Water

PS-10
Koyo Nomura (Chiba Univ.)
Photoluminescence pattern formation in CH3NH3Pb(BrxI1-x)3 single crystals studied by spatially-resolved Pump-probe spectroscopy

PS-11
Seungjae Lim (Ajou Univ.)
Hyperspectral Investigation of Defects in Monolayer WS_2

[Abstracts, Session 1]

Multimodal optical imaging system for disease diagnosis

Inyoung Park[1], Jonghee Yoon[2]

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Optical imaging techniques, such as microscopy and endoscopy, have been widely used for medical inspections of lesions that can be accessed optically. Disease progression results in changes in tissue morphology and biochemistry that alter tissue optical properties, such as scattering and absorption. This allows the discrimination of abnormal tissue via optical properties. However, early disease diagnosis remains challenging due to subtle differences in optical properties between healthy and abnormal tissue. To address this issue, we propose a multimodal optical system that combines structured illumination and hyperspectral imaging techniques. Structured illumination allows the measurement of quantitative optical properties, such as the reduced scattering coefficient and absorption coefficient, by illuminating a specific pattern (e.g., sinusoidal patterns) onto the target. We have developed an adaptive pattern synthesis method using a digital-micromirror device for accurate structured illumination, which improves the accuracy of the structured illumination method. Additionally, we exploited a liquid-crystal tunable filter placed in front of an imaging sensor for hyperspectral imaging of tissue. Hyperspectral imaging captures both spatial and spectral information, providing rich information for accurate sample classification, which is challenging using conventional color imaging methods. The developed multimodal imaging system captures reduced scattering coefficients and absorption coefficients over multiple wavelengths. We tested the proposed system on gastric tissues obtained from patients and found that lesions could be discriminated from healthy tissue based on the measured optical properties. Thus, the proposed system has the potential to become an early diagnostic tool for diseases in clinical settings.

Anti-Stokes Photoluminescence and Semiconductor Optical Cooling in Dot-in-crystal Perovskites

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The excellent optical properties of halide perovskites have led to their application in various high-performance optoelectronic devices. While early research has focused on solar cells, halide perovskites are now interested in many fields, including light-emitting devices and nanotechnology. The high photoluminescence (PL) quantum efficiency of the halide perovskites is a key characteristic enabling these device applications [1-3]. Furthermore, by combining the strong electron-phonon (e-ph) interactions of halide perovskites, it is expected to lead to unprecedented and unique device applications such as semiconductor optical refrigeration.

Semiconductor optical refrigeration is a technique that cools a semiconductor material by anti-Stokes PL (emission of light at higher energy than the incident light). If the PL efficiency is almost 100%, the material loses energy through anti-Stokes emission, resulting in cooling of the material by optical excitation. While anti-Stokes cooling has already been demonstrated in rare-earth-doped glasses or crystals, achieving it in semiconductors is more challenging due to the difficulty of approaching 100% external PL efficiency. However, if successful, it could lead to the development of revolutionary devices using existing semiconductor fabrication and processing techniques.

To achieve high-efficiency anti-Stokes PL in semiconductors, strong e-ph interactions are necessary. Halide perovskites exhibit strong e-ph interactions compared with conventional semiconductors, making them promising candidates for semiconductor optical refrigeration [4-6]. We recently revealed that $CsPbBr_3$ quantum dots embedded in a Cs_4PbBr_6 host crystal (so-called dot-in-crystal perovskites) exhibit almost 100% external PL efficiency and anti-Stokes PL without PL degradation typically seen in other perovskite materials [6].

In the presentation, we will provide an overview of the e-ph interactions of halide perovskites. We will also discuss the anti-Stokes PL of dot-in-crystal $CsPbBr_3$/$Cs4PbBr_6$ perovskites, highlighting their potential for achieving optical cooling.

Part of this work was supported by JSPS KAKENHI (Grants JP19K03683), the Canon Foundation, the Chiba Iodine Resource Innovation Center, and JST-CREST (Grant JPMJCR21B4).

References

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[2] Y. Yamada et al., J. Am. Chem. Soc. 137, 10456 (2015).
[3] K. Kojima et al., APL Materials 7, 071116 (2021).
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[5] Y. Yamada et al., Phys. Rev. Lett. 126, 237401 (2021).
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[7] Y. Yamada, Y. Kajino, and Y. Kanemitsu, Proc. SPIE 12437, 1243704-1 (2023).

Bacteria-induced modulation in second harmonic generation of molybdenum disulfide for sensing applications

Young Chul Kim, Yeong-Hwan Ahn

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We present the microbial control over second-harmonic generation (SHG) in MoS_2 and the identification of single-cell bacteria. Single-cell bacteria induced an anisotropic enhancement in SHG signals from monolayer MoS_2 flakes. The enhancement factor varied for different orientations of bacteria, relative to the MoS_2 arm-chair direction, which is consistent with the prediction of a tensile stress along the lateral direction of the bacteria. SHG imaging is highly effective in monitoring biomaterial strain effects, even when they are obscure in conventional spectroscopy. By fitting the anisotropic SHG pattern, the bacteria-induced strain was estimated to around 0.1%. In addition, we investigated the UV-induced rupture and ablation processes using the SHG imaging technique for the identification of single bacteria. By monitoring the transient SHG signals, we were able to determine the rupture and ablation times for different bacteria species. To prove the usefulness of our technique, we measured the rupture times for the mixture of bacteria that share habitats and obtained the relative densities of the individual species successfully. The manipulation of nonlinear responses based on the bacteria twist angle offers novel approaches for developing future optical and optoelectronic devices. Furthermore, label-free detection and identification of pathogens at the single-cell level can significantly improve diagnostic tools for a variety of applications.

Optical skyrmions generation from Pr^{3+}-doped fiber laser

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Optical skyrmions [1] carry all polarization states reprenseted on a Poincaré sphere, and they have been currently studied significantly as a quasiparticle of light with topologically protected polarizations in fundamental sciences and advanced applications, such as optical communications [2] and super resolution microscopy [3]. There are no reports on the direct generation of optical skyrmions from the laser system, that is an optical skyrmion laser, while these exotic quasiparticles of light are, in general, produced by employing a holographic technique based on spatial light modulators.

We herein report on the generation of multicolor (green, orange, and red) skyrmions from a Pr-doped fiber laser in combination with a wegde-plate shearing interferometer (WPSI).

A 3000 ppm Pr^{3+} ions doped waterproof fluoro-aluminate glass fiber (Pr:WPFGF) used in this experiment exhibited dimensions of 8 μm (core diameter) x 40 mm (length). The cavity was formed of the input fiber facet with high reflection and the flat output coupler with 94.3-98.6 % reflection for 500-700 nm. Note that an intracavity lens L6 stabilized the laser cavity to produce a Gaussian beam ($LG_{0,0}$ mode) as a cavity mode. Also, the WPSI was formed of the front and rear surface reflections of an intracavity glass slide, and it acted as a vortex output coupler to convert the internal $LG_{0,0}$ mode into a 1st order Laguerre-Gaussian ($LG_{0,1}$) output [4]. The generated $LG_{0,0}$ and $LG_{0,1}$ modes with orthogonal circular polarizations were coherently superposed by employing a polarizing beam splitter (PBS) and a quarter-wave plate (QWP), thereby resulting in the production of the optical skyrmions.

With this system, the generation of multicolor (green, orange, and red) optical skyrmions (Fig. 1(b)) was allowed simply by displacing on-axially the intracavity lens owing to chromatic aberration. Also, Néel-, and anti-type optical skyrmions were selectively produced merely by rotating the QWP towards clockwise or counter-clockwise direction.

Figure 1(a) Experimental setup (b) Experimental results of the generated skyrmions

[Abstracts, Session 2]

Sustainable Catalytic Reactions for Carbon Neutrality

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Due to the global warming induced by increased CO_2 concentration in the air, chemical reactions converting non-fossil fuel-based carbon feedstock to value-added chemicals have received great attention, resulting in the development of sustainable catalysis using renewable resources. Our research group has been interested in sustainable catalytic processes activating CO_2 to industrially valuable polymers. In this presentation, I would like to present recent research results of metal-catalyzed transformations incorporating CO_2 into polycarbonates. There are two major hetereogeneous catalysts converting CO_2 and propylene oxide to polycarbonates; zinc carboxylates and double metal cyanides. Different catalytic activities and polymer porperties formed from these methods will be exhibited in detail.

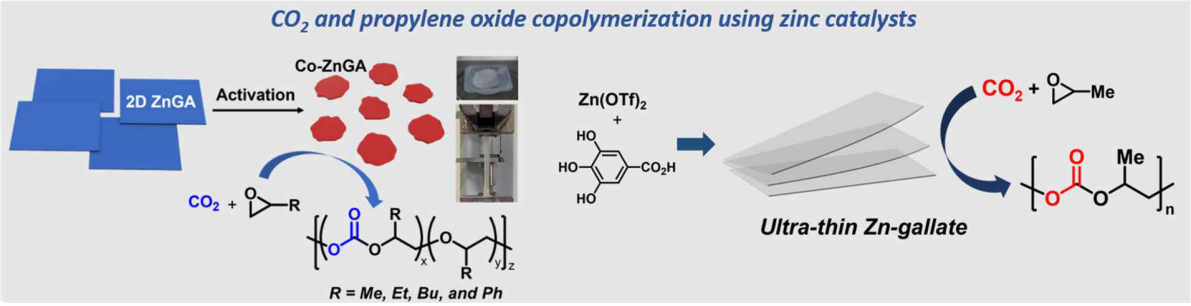

Figure 1 Sustainable Polymerization using CO_2

Realization of $MoTe_2$ CMOS inverter by contact doping and channel encapsulation

Tianshun Xie[1], Mengnan Ke[1], and Nobuyuki Aoki[1]

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Transition metal dichalcogenide (TMDC) materials are expected to replace silicon as the next-generation channel material due to the absence of the short channel effect and their high mobility at sub-1nm thickness in the use for a field effect transistor (FET). $MoTe_2$ is known as an indirect transition semiconductor having a bandgap of about 0.88 eV in the bulk and a direct transition semiconductor having a bandgap of 1.1 eV in the monolayer. Due to the small band gap of multilayer $MoTe_2$, the transmission polarity can be easily controlled by doping, and a combination of p-type and n-type of $MoTe_2$- FET can be made into a complementary metal–oxide–semiconductor (CMOS) inverter. However, the poor contact properties with conventional metals, such as large contact resistance and Fermi level pinning effect, severely weakens the performance of $MoTe_2$-FET. Contact doping is an effective method to reduce contact resistance like Si-MOSFET, but it's still challenging to apply for TMDC-based FET because there are few suitable heavy doping techniques for TMDC materials to date. However, we have recently found a simple, regioselective, porality-controllable, and chemically stable heavy doping method for 2H-$MoTe_2$ crystal via high-density laser irradiation, and the contact properties have been improved by the laser-induced contact doping method [1]. Here, optimized n and p-$MoTe_2$ FET by laser-induced contact doping are combined into a CMOS inverter [2]. Figure 1 shows the optical image at each process of the sample. Graphite/h-BN heterostructure was prepared by the dry transfer process and they were used as a common-globe back gate and gate insulator. Source electrodes were fabricated on h-BN by electron beam (EB) lithography and EB deposition. After that, two h-BN/$MoTe_2$ stacks were placed on the bottom h-BN by dry transfer with contact between $MoTe_2$ and electrodes. It is noted that only the middle part of the $MoTe_2$ sheets was covered by the top h-BN and the two sides were exposed to air for the laser irradiation process and the drain electrodes fabrication. One $MoTe_2$ was irradiated by laser in the air to form a heavily p-doped region, and the other was irradiated in a vacuum to form a heavily n-doped region. The channel of each $MoTe_2$-FET was encapsulated by h-BN to improve carrier mobility and device stability. The fabricated inverter shows a very high gain value of 32 at V_{dd} = 4 V, as shown in Figure 2.

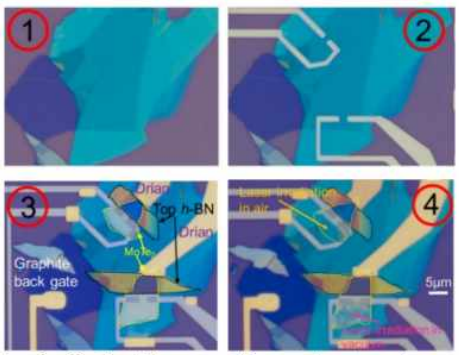

Fig. 1. Optical image of sample at each process.

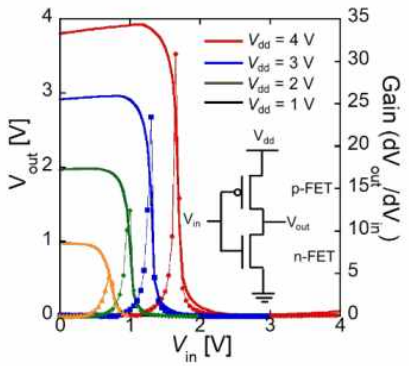

Fig. 2. Transfer characteristics (V_{out}-V_{in}) and DC voltage gain of the CMOS.

References

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Electrode Design for Achieving High Energy Density All-Solid-State Batteries

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All-solid-state batteries (ASSBs) are at the forefront of the next-generation rechageable batteries, offering advantages in terms of safety and energy density. However, the energy density of cathodes in ASSBs is often limited from the low utilization of active materials (AM) with high loading levels (>80%). This is attributed to the low content of solid electrolyte (SE) in the cathode, which frequently results in subpar electrochemical performance due to contact loss and uneven distribution of AM and SE particles. This inhomogeneity often leads to high tortuosity and limitations for lithium and electron transport. In response, we introduce an innovative cathode design capable of reaching a high volumetric energy capacity of 1258 Wh L^{-1} with an AM concentration of 85 wt%, by combining the benefits of AM@SE core-shell composite particles and small-sized SE particles. The core-shell configuration ensures a robust ionic conduction pathway without compromising electronic conduction. Moreover, the small SE particles act as fillers that decrease the void space 1) in the cathode composite electrode and 2) between the cathode and the SE separator layer. A detailed demonstration of this optimization process could offer insights and guidelines for achieving high-density and high-capacity electrodes for ASSBs, ultimately leading to enhanced energy density.

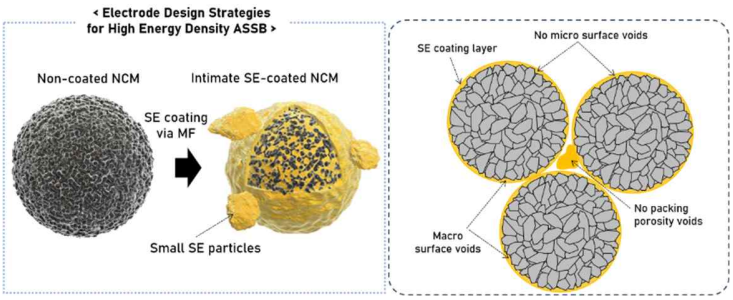

Figure 1 Electrode design strategies for high energy density ASSBs

References

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[Abstracts, Session 3]

Laser fusion cutting of flexible glass via Mid-IR laser

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Ultra-thin glass (UTG) or so-called flexible glass, particularly with a thickness of less than 100 µm, is a material potentially applied for flexible devices but is difficult for processing methods caused by its thinness. Hence, there has been a demand for manufacturable processes, including cutting.

We have focused on the laser fusion cutting approach via CO_2 laser with a wavelength of 10.6 µm, typically applied for metal cutting. We applied this process for glass cutting by resolving the challenge of residual thermal stress by using two laser beams [1,2]. Figure 1 represents a micrograph of successfully cut flexible glass with a thickness of 100 µm. A molten edge is formed along the cutting line (surrounded by a broken line). This presentation also introduces the results via CO laser with a wavelength of 5.5 µm, aiming for faster heating in the depth direction caused by the difference of absorption characteristics and probably shorter processing time.

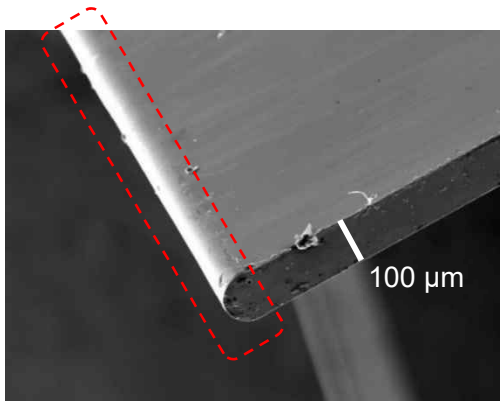

Figure 1 Micrograph of successfully cut flexible glass with a thickness of 100 µm.

References

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Flame Activation of Spinel Zinc Ferrite Photoanode with Enhanced Charge Collection Property for Solar Water Splitting

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Abstract

Spinel zinc ferrite ($ZnFe_2O_4$, ZFO) is a potential photoanode material for photoelectrochemical (PEC) water splitting because of its ideal bandgap (1.9–2.1 eV) and superior chemical stability in aqueous solutions. However, the low charge collection efficiency significantly hinders the improvement in PEC activity. Herein, we report an ultrafast and effective flame activation route to enhance the charge collection properties of ZFO. First, high-temperature flame (> 1300 °C) facilitated surface and grain boundary diffusions, increasing the grain size and connectivity of the ZFO nanoparticles. Second, the reducing atmosphere of the flame enabled the formation of surface defects (oxygen vacancy and Fe^{2+}), thereby increasing the charge carrier density and surface adsorption sites. Significantly, these two factors promoted charge transport and transfer kinetics, resulting in a 10-fold increase in the photocurrent density over the unactivated ZFO. Furthermore, we deposited a thin Al_2O_3 overlayer to passivate the ZFO surface and then the $NiFeO_x$ oxygen evolution catalyst (OEC) to expedite hole injection into the electrolyte. This surface passivation and OEC deposition led to a remarkable photocurrent density of ~1 mA/cm^2 at 1.23 V versus the reversible hydrogen electrode, which is the highest value among all reported ZFO photoanodes. Notably, the $NiFeO_x/Al_2O_3$/F-ZFO photoanode achieved excellent photocurrent stability over 55 h (96% retention) and superior faradaic efficiency (FE > 94%).

Key words: Zinc ferrite, flame activation, grain size, oxygen vacancy, charge collection, photoelectrochemical water splitting

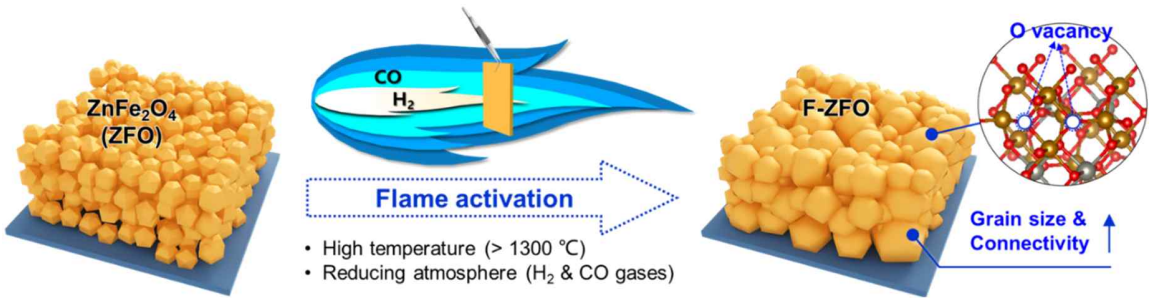

Figure 1. Flame activation of zinc ferrite photoanode.

References

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[2] Nano Lett. 2011, 11, 4978.

In-situ observation of silver precipitation phenomena inside borosilicate glass

Miyuka Kono[1], Souta Matsusaka[1], Sho Itho[1], and Hirofumi Hidai[1]

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When electrons are supplied to the silver ion doped region in a borosilicate glass, the silver precipitates appear inside the glass substrates [1]. This phenomenon would be useful in the industrial applications such as micro-wiring fabrication [2] and micro-hole formation [3]. However, the silver precipitation mechanism needs to be understood more to control their shape arbitrally.

First, a system for dynamic observation of silver precipitation phenomena was devised. By changing the direction of voltage application during the silver precipitation procedure, the size of the precipitates was enlarged, enabling the observation with the experimental setup.

Second, using the observation system, *in-situ* movies of the silver precipitation phenomena were taken, and some snapshots are shown in Fig. 1 (a). The silver precipitation rates were measured and evaluated from the movies. Figure 1 (b) shows the silver precipitation rate, saying that the rate increased with increasing voltage and was accelerated with increasing the area. Figure 1 (c) shows the equivalent electric circuit model for the evaluation of the phenomena [4]. Each un-doped, silver-doped, and silver-precipitated area inside the glass was modeled as an electrical resistance. The value α, which means the normalized precipitation area, was calculated with the model. Furthermore, the approximate curves from the value α drawn in Fig. 1 (b) fit well with the experimental results. This model enables the prediction of the increase in precipitation rate, providing primary data for controlling the precipitation shape. For future work, the model would be developed to predict the growth behavior of the precipitated areas.

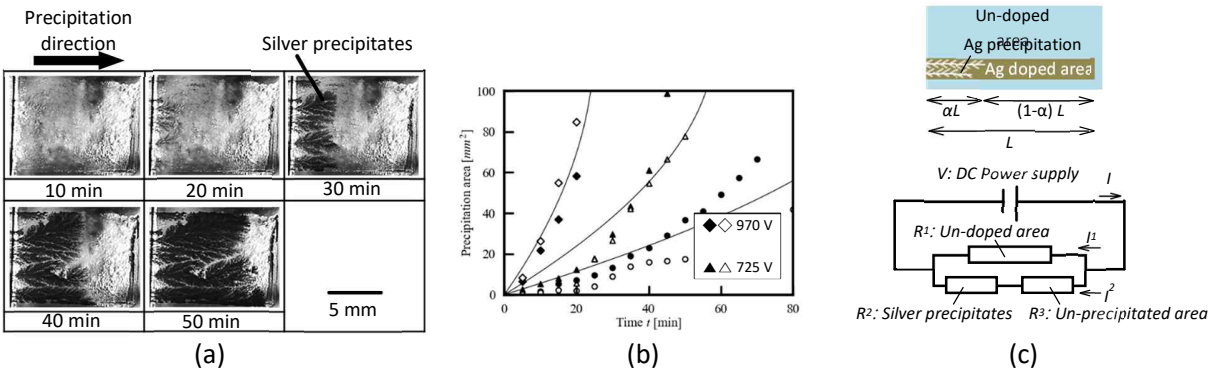

Figure 1 In-situ observation and evaluation of the silver precipitaion phenomena. (a) Snapshots of the precipitation behavior, (b) the silver precipitation rate, and (c) the equivalent electric circuit model.

References

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3. H. Kawamura, R. Okuda, S. Matsusaka et al., Precision Engineering **76**, 141-148 (2022).
4. M. Kono, H. Kawamura, S. Matsusaka et al., Precis Eng **82**, 212-218 (2023).

Strain-controlled quantum physics in quasi-one-dimensional compounds

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Discovery of graphene has greatly boosted intensive and extensive studies on various low-dimensional compounds as a platform for quantum physics based on strong electron correlation and topology. In this regard, various materials with van der Waals stacking have become a central issue of recent research. Among a series of van der Waals materials, quasi-one-dimensional compounds can emerge distinct properties with other two- or three-dimensional materials due to stronger electron correlation compared to them based on its limited interaction channels. Despite the expectation, their simple but unique hairy structures prevent the advanced study to clarify the detailed physics of those materials.

In this talk, I will introduce recent studies of transition-metal trichalcogenides (TMTCs), which would be a novel platform to study quantum properties based on both strong electron correlation[1] and topology[2]. By virtue of the improved angle-resolved photoemission spectroscopy technique with micro-focused light, we succeeded to identify the electronic structure of transition-metal triselenides and revealed the complexed phase diagram of the system. In addition, we directly applied uniaxial strain to the quasi-one-dimensional compounds, which successfully leads to intriguing phenomena of topological phase transition. With our findings, I will further discuss quantum application based on these materials.

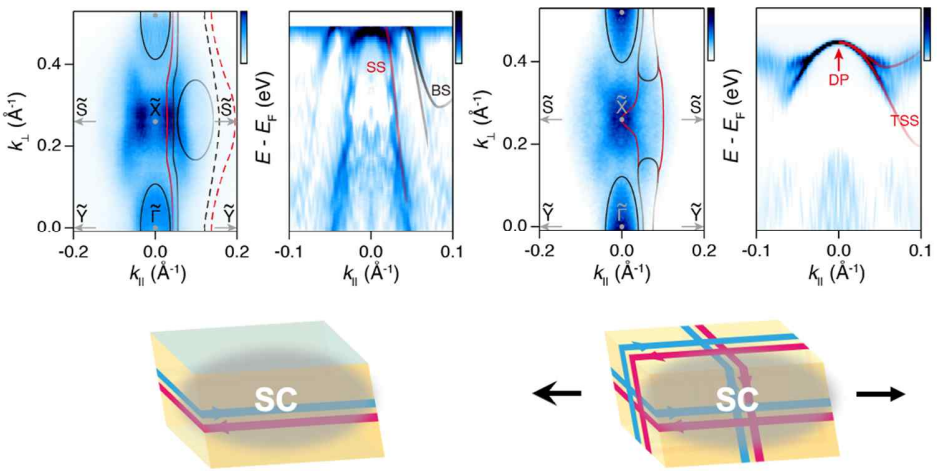

Figure 1 Strain-controlled topological phase transition observed by ARPES.

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[Abstracts, Poster Session]

Strong Random Telegraph Signal Noise at Room Temperature in $SrRuO_3/LaAlO_3/Nb:SrTiO_3$ Heterojunctions

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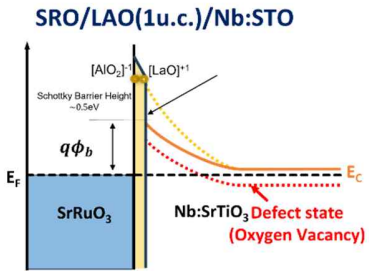
The generation of unbiased random numbers is significant for simulation and cryptography. The random and discrete fluctuation of current signals, also known as the random telegraph signal (RTS) noise, in artificial two-level systems allows for the development of hardware-based random number generators. In this study, we report an electronic two-level system based on $SrRuO_3/LaAlO_3/Nb:SrTiO_3$ (SRO/LAO/Nb:STO) heterostructures. We use two key strategies to realize the two-level system. First, we insert of ultrathin dipole layer of LAO in between the SRO and Nb:STO. Second, we were formed electron hopping sites at the interface. We show that the epitaxially-grown SRO/LAO/Nb:STO heterostructures generate a strong RTS noise at room temperature. This result provides a promising route to develop oxide-based true random number generators.



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High-precision printing of cyanobacterial suspensions with optical vortex induced transfer

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Laser-induced forward transfer (LIFT) technology has been intensively studied as a nozzle-free, cost-saving and resource-saving printing technology. In particular, LIFT bioprinting allows the removal of all nozzle-associated negative effects, such as a narrow bioink viscosity range, low spatial resolution and a fairly low cell viability.

In recent years, a new LIFT technology with optical vortex possessing an orbital angular momentum (OAM) associtaed with a helical wavefront, instead of a conventional Gaussian beam with a planar wavefront, (herein refered OV-LIFT) has been proposed, in which the OAM of the optical vortex pulse twists the irradiated donor material to eject a spinning, picolitre-scale, single donor droplet with a perfectly straight flight path. This technology enables the high-spatial-resolution, direct print of a variety of materials with an long working distance [1,2].

In this study, we demonstrate the OV-LIFT bioprinting, in which a cyanobacter-cells colloidal suspension with a biocompatible materials was directly printed on a glass substrate with a high positional accuracy of < ** μm. This demonstration evndences the possibility to fabricate a free-form biomedical circuits with OV-LIFT.

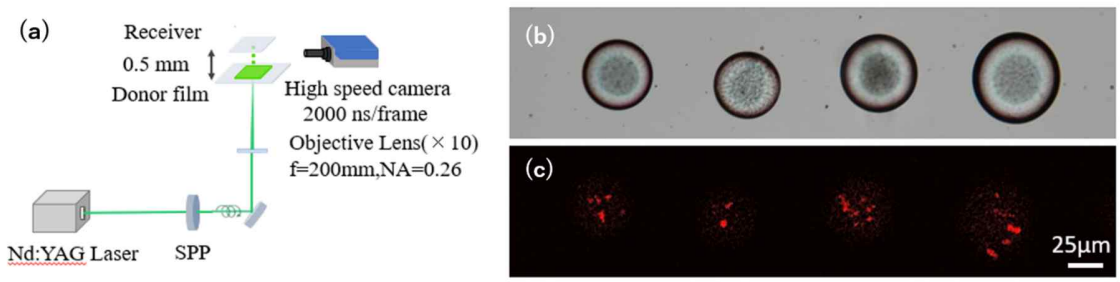

Figure 1 (a) Schematic diagram of experimental setup, (b) Bright and (c) fluorescent (ex. 488 nm) images of printed dot array of cyanobacteria cells suspension by OV-LIFT.

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Structure-Selective Growth of Symmetry-Broken $MoSe_2$ and Their Broadband Nonlinear Optical Response

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Transition metal dichalcogenides (TMDCs) have various electronic and optical properties depending on their structure, so they can be used as a fascinating material in various applications including photonics, electronics, optoelectronics, and valleytronics. In particular, spiral TMDCs grown through the formation of screw dislocations exhibit novel electronic and optical properties different from layer-by-layer TMDCs. However, large-area structure-selective synthesis of TMDCs remains challenging. Here, this work reports for the first time the large-area structure-selective synthesis of monolayer $MoSe_2$ and spiral $MoSe_2$ using a flux-controlled chemical vapor deposition method. Under a low $MoSe_2$ flux condition, monolayer $MoSe_2$ is synthesized, whereas thick spiral $MoSe_2$ is synthesized under a high flux condition. Under a medium flux condition, both monolayer and spiral $MoSe_2$ are synthesized. In addition, through the nonlinear optical (NLO) signal analysis of monolayer $MoSe_2$ and spiral $MoSe_2$, the giant enhancement of NLO signals induced by the combined effect of breaking inversion symmetry and the excitonic resonance effects in the synthesized $MoSe_2$ is confirmed. Monolayer $MoSe_2$ and spiral $MoSe_2$ synthesized using this method are expected to be used as advanced optical materials for novel electronics, optoelectronics, and NLO applications.

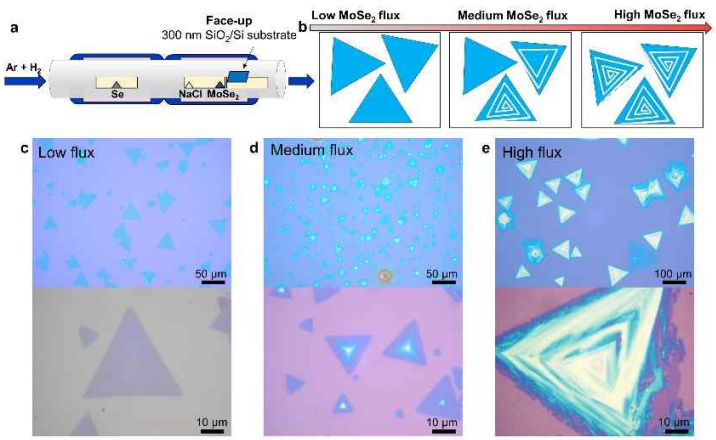

Figure 1. Structure-selective synthesis of monolayer and spiral $MoSe_2$

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Direct print of metallic nanoink with optical vortex induced forward transfer

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A new laser induced forward transfer (LIFT) using an optical vortex with a helical wavefront instead of a conventional LIFT using a Gaussian beam with a planar wavefront, (referred herein OV-LIFT) has been proposed [1-3]. This OV-LIFT also enables the close packing of nanoparticles within the printed dots, thus allowing the development of new generation of printed electronics/photonics devices with ultrahigh spatial resolution.

We herein demonstrate the two-dimensional print of ultrahigh density Au/Ag nanoparticles water/glycol suspensions (viscosity: ~10 mPa-s) (referred to as Au/Ag nanoink) by employing OV-LIFT. The Au/Ag nanoink was dropped onto a glass substrate to form a ~50 μm thick film. A nanosecond green laser (wavelength: 532 nm, pulse duration: ~2 ns, pulse repetition frequency: 50 Hz) was used (Figure 1), and its output was converted to be a circularly polarized vortex with a topological charge $\ell = 1$ using a spiral phase plate and a quarter-wave plate. The output was loosely focused to be a ~20 μm ring-shaped spot on the donor film. With this system, the deposition of a single optical vortex pulse enabled the ejection of a single donor microdroplet. The ejected single donor droplet was printed on a glass substrate 0.5 mm away from the donor film.

Interestingly, optical vortex irradiation produced well-aligned Au circular dots (diameter ~ 45 μm), while the printed Ag dots showed an annular profile (diameter ~ 30 μm) with a central dark core (Figure 2). These manifest that Au/Ag nanoparticles are repelled/trapped in the optical field owing to plasmonic repulsive/collective forces of the irradiating laser. It is also noteworthy that the as-printed dots showed excellent electrical properties (~10^{-7} Ω/m) without any sintering process.

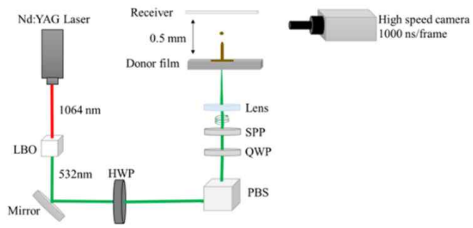

Figure 1 Experimental setup

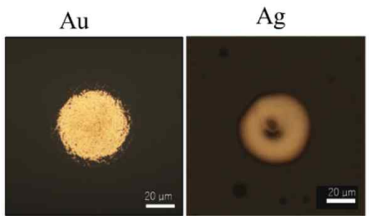

Figure 2 Printed Au/Ag dots

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Controlled growth of highly chemical and thermal stable Ge core/ BCN shell nanowire

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Germanium-based nanomaterials have gained prominence as potential enhancers of energy harvesting efficiency and storage capacity, attributed to their superior electrical conductivity, mobility, and lithium-ion storage aptitude.[1,2] However, their practical application is often hindered by chemical and physical instabilities.[3] In this study, we introduce a facile synthesis method for boron-carbon-nitride (BCN) shell-coated germanium nanowires (Ge@BCN NWs), designed to shield the Ge core from environmental factors while augmenting its electrical conductivity. Through microscopic and spectroscopic analyses, we confirmed that the Ge core is completely encapsulated by a highly crystalline BCN shell. Electron transport measurements on the Ge@BCN NWs field-effect transistor (FET) revealed minimal hysteresis alongside heightened electrical conductivity, suggesting that the BCN shell acts as an efficacious protective barrier, curtailing the degradation of Ge NWs. Our approach presents a reliable method for bolstering the stability of nanomaterials and achieving functional 2D coated NWs.

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Diamond slicing at the {100} plane using a picosecond laser beam by developed method restricting crack propagation along the cleaved plane

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Diamonds are ideal for use in high-power semiconductors [1]. A slicing technique to obtain wafers from an ingot is indispensable to fabricate diamond semiconductors. However, the hardness of diamond makes it challenging to slice a thick diamond crystal into thin wafers using mechanical processing techniques.

Laser slicing is the technology of slicing material by internal laser processing[2]. This method consists of two steps. First, the laser focus is scanned parallel to the slicing plane, and a modified plane is formed. The modified region causes a reduction in density and crack is formed around it. The cracks can connect the modified regions in the modified plane. Second, the sample is separated at the modified plane.

Our purpose of the research is technology development to slice diamonds at the {100}plane by laser slicing. Crystal material, including diamond, has the cleavage plane, which is the most crackable plane. First, We investigate the influence of the {111} plane, the cleavage plane of the diamond, on the laser slicing along the {100} plane. Next, we develop the laser irradiation sequence to restrict the crack propagation along the cleavage plane and demonstrated the {100} surface diamond wafer.

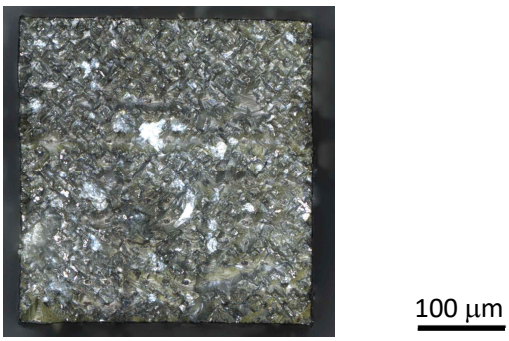

Figure 1 The confocal microscope image of the sliced diamond

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Large Area CVD Growth of Bilayer Graphdiyne for Flexible Piezoresistive Applications

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Graphdiyne (GDY) has garnered significant attention as a cutting-edge 2D material owing to its distinctive electronic, optoelectronic, and mechanical properties, including high mobility, direct bandgap, and remarkable flexibility.[1,2] One of the key challenges hindering the implementation of this material in flexible applications is its large area and uniform synthesis.[3] The facile growth of centimeter-scale bilayer hydrogen substituted graphdiyne (Bi-HsGDY) on germanium (Ge) substrate is achieved using a low-temperature chemical vapor deposition (CVD) method. This material's field effect transistors (FET) showcase a high carrier mobility of 52.6 $cm^2V^{-1}s^{-1}$ and an exceptionally low contact resistance of 10 Ω.μm. By transferring the as-grown Bi-HsGDY onto a flexible substrate, a long-distance piezoresistive strain sensor is demonstrated, which exhibits a remarkable gauge factor of 43.34 with a fast response time of ~275 ms. As a proof of concept, communication by means of Morse code is implemented using a Bi-HsGDY strain sensor. These results are anticipated to open new horizons in realizing Bi-HsGDY for innovative flexible device applications.

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Low energy photoelectron measurement method in practical environment using a Retarding Field Analyzer

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Observation of the electronic structure of organic materials under actual conditions such as air is important for the development of organic electronics. This is because most organic materials are exposed to atmospheric conditions during their manufacture and operation. Then, their electric properties are affected by moisture and oxygen.[1] Therefore, it is necessary to observe the electronic structure of organic materials both in vacuum and in air. Ionization energy and density of states (DOS) of the valence state are important parameters for studying the electrical properties of materials. Photoelectron yield spectroscopy (PYS) is a technique that can determine ionization energy in both air and vacuum.[2] However, this technique cannot directly observe DOS. On the other hand, ultraviolet photoelectron spectroscopy (UPS) and constant final-state photoelectron yield spectroscopy (CFSYS) are methods to measure DOS. However, the commonly used analyzer can only operate in high vacuum, and photoelectrons are quickly scattered in air. Therefore, the purpose of this study is to propose a method for evaluating DOS under vacuum using a PYS measurement system. UPS and CFSYS measurements under near ambient pressure are also examined.

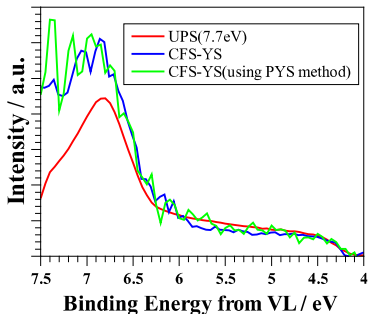

Figure 1 UPS(7.7eV) and CFSYS and CFSYS (using PYS method) for Au film

CFSYS is a method to observe DOS by obtaining the yield of photoelectrons with a specific kinetic energy as a function of irradiation light energy.[3] We propose that this measurement can be performed using PYS system: Differential PYS spectra measured under two different retarding bias voltages gives CFS-YS for photoelectrons with kinetic energy corresponding to the bias region. Figure 1 shows the results of the measurement for gold film deposited by vacuum evaporation. The obtained differential spectrum is almost identical to the CFSYS spectrum.

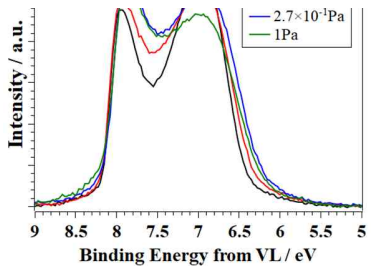

Figure 2 UPS spectra at each pressure

Next, in this experimental system, a hemispherical retarding field analyzer (HRFA) was used to analyze photoelectrons; unlike conventional kinetic energy analyzers, the HRFA does not require a high vacuum for operation. UPS measurements for C60 film on Cu substrate were performed as a function of vacuum pressure from high vacuum to 1Pa. As shown in Figure 2, spectral changes due to residual gas were observed. This is thought to be an observation of the effect of water adsorption on the C60 surface.

The above results suggest the usefulness of retarding field analyzer-based photoelectron measurement method in practical environment.

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Sunlight-Driven Hydrogen Production from Water

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Photocatalytic water splitting stands out as a sustainable avenue for hydrogen production by generating photoexcited charge carriers that catalyze water decomposition. While this method often relies on sacrificial electron donors to scavenge holes, their use presents challenges in net energy storage. Addressing this, our study introduces a novel additive designed to boost hydrogen production under 1 sun illumination without relying on sacrificial reagents. This additive plays a key role in enhancing water dissociation and reducing the energy barrier needed for the half-oxidation reaction, thereby facilitating the efficient harnessing of photoexcited charge carriers. Furthermore, our experiments have confirmed the stability of the system under prolonged exposure to harsh reaction conditions.

Photoluminescence pattern formation in $CH_3NH_3Pb(Br_xI_{1-x})_3$ single crystals studied by spatially-resolved Pump-probe spectroscopy

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Lead halide perovskite semiconductor $CH_3NH_3PbX_3$ (X = I, Br, Cl) is expected to be used as a next-generation semiconductor device material due to its high photoluminescence (PL) efficiency and excellent defect tolerance. Furthermore, the bandgap energy can be changed continuously over the entire visible range by changing the halogen ratio. However, when the lead halide perovskite mixed crystal $CH_3NH_3Pb(Br_xI_{1-x})_3$ is continuously illuminated with excitation light, a phenomenon called photo-induced phase separation occurs [1][2], which causes a change in the absorption wavelength, resulting in device degradation. This is a critical problem in terms of device application. Although much research has been performed on photo-induced phase segregation, the physical mechanism is still under discussion. Furthermore, recently, when mixed crystals are illuminated with light, macroscopic spatial PL patterns over tens μm have been observed in addition to the nano-scale photo-induced phase segregation, which is due to long-distance ion migration. However, since previous reports target a thin film [3], it is affected by grain boundaries and unsuitable for observing ion migration on the μm scale. Therefore, this study aims to visualize the distribution of halogen ions through PL imaging in high-quality $CH_3NH_3Pb(Br_xI_{1-x})_3$ bulk single crystals, thereby detecting the behavior of ion migration without the influence of grain boundaries.

$CH_3NH_3Pb(Br_xI_{1-x})_3$ bulk single crystals were prepared by anti-solvent crystal growth. In this study, the pump beam that causes photo-induced phase segregation was focused on a spot of several tens μm, and the resulting changes in the spatial distribution of halogen ions were detected by a probe beam that illuminated a wider area. As a result, we found that a spatial PL pattern was formed. We believe that this spatial PL pattern is due to changes in the spatial distribution of halogen ions. In the presentation, we will discuss the spatial pattern of halogen ions and their formation mechanism, along with the results of numerical simulations and spectroscopic measurements.

Part of this work is supported by Casio Science Promotion Foundation and the Chiba Iodine Resource Innovation Center.

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Hyperspectral Investigation of Defects in Monolayer WS_2

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Transition metal dichalcogenides(TMDCs) monolayers exhibit remarkable electronic and optical properties.[1] For practical applications of TMDCs, there are several challenges such as scalable growth and controlled defect formation. Recently, scalable growth of monolayer TMDs has been successfully demonstrated using the metalorganic chemical vapor deposition (MOCVD) growth method,[2] however, a large-scale characterization tool is still missing, which is necessary due to its heterogeneous defect formation.[3]

In this research, we used hyperspectral line imaging methods to statistically analyze photoluminesence (PL) and reflectance contrast (RC) spectra of WS_2 monolayer flakes grown under different tungsten and sulfur precursor ratio. We systematically investigated correlations of spectral features, such as exciton peak position, peak width, trion-exciton intensity ratio, and Stokes shift. Furthermore, we compared the effects of the environment (vacuum and ambient) and bis(trifluoromethane)sulfonimide (TFSI) treatment. We found contrasting optical responses from the samples grown under tungsten-rich and sulfur-rich conditions. Comparing with the defect formation energies obtained from density functional theory (DFT) calculations, we conclude that these different responses originate from different types of defects such as chalcogen vacancy (V_s) and chalcogen antisite defects (S_w). Using 1× objective lens, we demonstrated large-area characterization, around mm scale, of defect formation in WS_2 monolayer film.

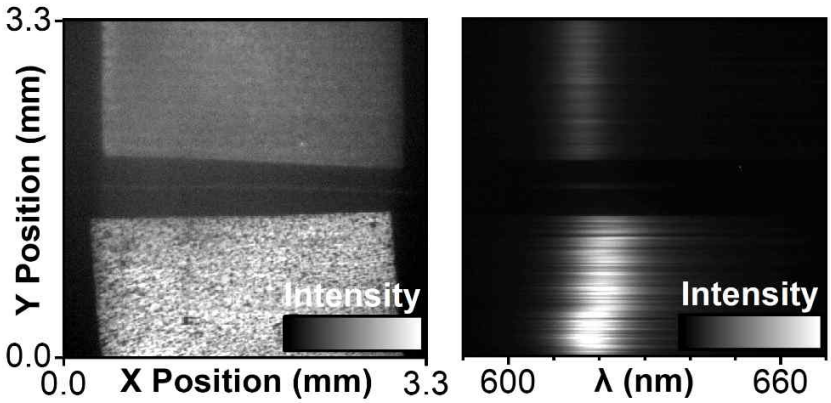

Figure 1 PL image of WS_2 monolayer film and correlated HSLI spectrum.

References

[1] Manzeli, D. Ovchinnikov, D. Pasquier, O. V Yazyev, A. Kis, Nat Rev Mater 2017, 2, 17033.

[2] K. Kang, S. Xie, L. Huang, Y. Han, P. Y. Huang, K. F. Mak, C. J. Kim, D. Muller, J. Park, Nature 2015, 520, 656.

[3] P. V. Kolesnichenko, Q. Zhang, T. Yun, C. Zheng, M. S. Fuhrer, J. A. Davis, 2d Mater **2020**, 7

Map

[Campus Map]

Symposium Venue: #311, Energy Center
Lunch Restaurant: 11F, Yeonam Hall

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