RD-024

Mn Atomic Spatial Distribution in Ferromagnetic (Zn, Sn, Mn)As_2 Thin Films Using the Image Reconstruction of 3DAPT

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Ternary $ZnSnAs_2$ is a semiconductor spintronic material that exhibits ferromagnetism at room temperature by Mn-doping, and lattice matching with InP substrate[1]. The distribution of Mn atoms in the $ZnSnAs_2$:Mn crystal was studied using three dimensional atom probe tomography (3DAPT). As a result, the $ZnSnAs_2$:Mn has a inhomogeneous Mn distribution due to the spinodal decomposition. In ferromagnetic semiconductors, clustering of magnetic elements strongly affects magnetic properties[2]. Therefore, in order to investigate the relation between the inhomogeneous Mn distribution and the magnetic characteristics, the purpose of analyzing 3DAPT data in the $ZnSnAs_2$:Mn epitaxial thin film, reconstructing the Mn atomic spatial distribution, and confirmed Mn clustering.

Coordinate information of 4 unit cells (cube with one side of 11.76Å) is extracted from the three-dimensional atomic image and the coordinates of the Mn atoms are superimposed on the $ZnSnAs_2$ of the ideal lattice. Crystal reconstruction was attempted by measuring the distance between the cation site and Mn atom and replacing Mn to the nearest cation site (Zn, Sn). All the Mn atoms were replaced to cation sites within 2.5Å which are shorter than the closest atomic distance (2.56Å) of the ideal lattice. Crystal reconstruction was carried out for each sample with Mn concentration of 3.6 at.% and 2.1 at.%.

Fig.1 shows the three-dimensional atomic image after reconstruction in the sample with Mn concentration of 3.6 at.%. Each atom is composed of Zn (light blue), Sn (yellow green), As (pink) and Mn (yellow). Fig.2 shows only Mn and As in the reconstruction result. We confirmed Mn-As clustering, two Mn monomer, two Mn dimer and one Mn trimer. Table1 shows the number of Mn-As clustering at each location. Many Mn monomer is observed in both Mn concentrations of 2.1 at.% and 3.6 at.%. In conclusion, it is considered that the distance between the Mn atoms is apart from each other to some extent and the correlation between the Mn atoms is related to magnetism.

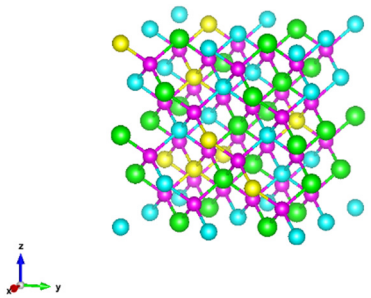

Fig.1 Reconstruction result

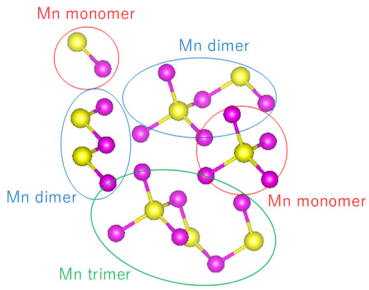

Fig.2 Mn-As clustering

Table.1 Types of Mn-As clustering

	2.1at.%			3.6at.%			合計
	No.1	No.2	No.3	No.1	No.2	No.3	
monomer	2	3	2	4	5	2	18
dimer	0	0	0	0	0	2	2
trimer	0	0	0	0	0	1	1
Tetramer	1	0	0	0	0	0	1
Mn 7個	-	-	1	-	-	-	1
Mn 19個	-	-	-	1	-	-	1

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RD-025

Epitaxial Growth and Electrical Characteristics of Cr-doped $ZnSnAs_2$ Thin Films

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II-IV-V_2 ternary compound semiconductor $ZnSnAs_2$ is lattice-matched with InP (with lattice mismatch ~ 0.3%), and we have obtained high T_c (~333K) by Mn-doping[1,2]. In recently, the first-principles calculation about transition-metal-doped $ZnSnAs_2$ has been reported[3]. It is suggested that ferromagnetic behavior above room temperature is expressed by Cr-doping not just Mn-doping. This is first report about Cr-doping. In this work, we report the growth and electrical characteristics of Cr-doped $ZnSnAs_2$ thin film.

Cr-doped $ZnSnAs_2$ thin films were grown on semi-insulating epi-ready InP(001) substrates by using solid source molecular beam epitaxy (MBE). First, ~20 nm $ZnSnAs_2$ buffer layer was grown on InP(001) substrate. Cr-doped layer was subsequently grown that while heating the Cr source at 1200℃, and Zn, Sn, As were supplied at different equivalent pressure ratio of 20 : x : 50 (x = 1.0, 0.9, 0.6). Figure 1 (a) shows the composition as a function of different beam equivalent pressure ratio of Cr/Sn used for 3 samples.

Hall effect measurements were performed for 4 samples of non-doped and Cr-doped $ZnSnAs_2$ thin films, showing p-type for all samples. Figure 1 (b) shows the Cr concentration dependence of carrier concentration and mobility at 300K, where Cr cat.% = Cr / (Zn+Sn+Cr)×100%. The carrier concentration decreases toward the Cr concentration, and carrier concentration of non-doped sample is 1.82×10^{19} cm^{-3}, whereas that of the sample of 8.07 cat.% is 1.24×10^{17} cm^{-3}. This is contrary to the tendency of Mn-doped $ZnSnAs_2$. The mobility also increases toward the Cr concentration, contrary to the tendency of Mn-doping.

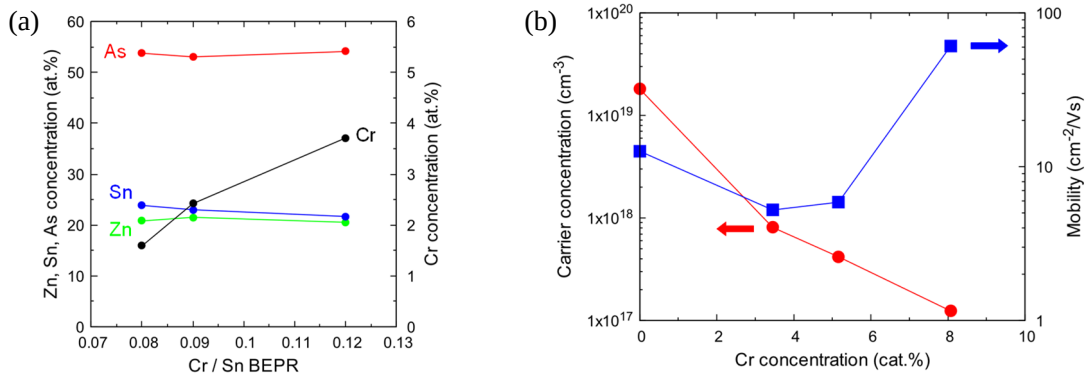

Fig. 1 (a) Composition of Cr-doped $ZnSnAs_2$ thin films , (b) Carrier concentration and Mobility at 300K

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RD-026

Bayesian Inference and Data Extraction on Comfortable Condition and Power Consumption of Air Conditioner Using Environmental and EEG Data

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In this study, we construct techniques both for extracting large-scale data from observed data on environmental variables, power consumption of air conditioner and the EEG and for predicting model variables approximating optimal values of the thermal comfort via the temperature-humidity index (THI) via the expected a posterior (EAP) estimation utilizing those information, i.e. the environmental variables, the power consumption of air conditioner and the EEG.

In this method, we first extract valuable information by using several models, i.e. the neural network or the PCA [1] from the set of the environmental variables in Fig. 1, the power consumption of the air conditioner and the EEG data of the subjects. Then, by making use of the Bayesian inference via the EAP estimation [2]-[4], we predict appropriate variables which approximates the optimal condition providing comfortable condition with effective use of power due to air conditioner.

Here, we show results of the Bayesian inference via the EAP estimation using information extracted by the PCA from data, i.e. a typical time-series of temperature, relative humidity at a sampling point of small-scale environment. At the conference, we show our results using the EEG data in addition to that of the environmental data and power consumption of air conditioner.

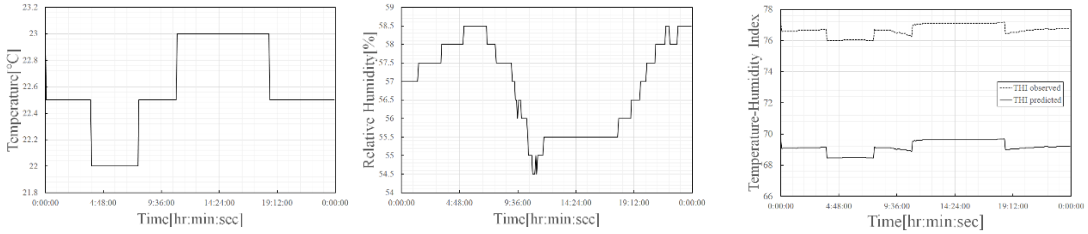

Fig. 1 Temperature, relative humidity(original) and THI(original, predicted) at a sampling point.

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RD-027

Nitrogen Doping of ZnO Films Using NO Gas Excited on Heated Ir Wire

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The blue light emitting diode (LED) made of gallium nitride (GaN) has been put to practical use. However, there are some disadvantage for the fabrication of the LEDs, such as consumption of harmful source gases and expensive rare metal element. Zinc oxide (ZnO) is a direct-transition type semiconductor with a wide bandgap of 3.37eV and an exciton binding energy of 60meV at room temperature [1]. Since the ZnO is grown from abundant and harmless resource such as zinc and oxygen, the ZnO is noted as an alternative material to GaN. We previously developed a new chemical vapor deposition (CVD) method for ZnO film growth using a catalytic reaction over Pt-nanoparticles between dimethylzinc and high-temperature H_2O. N-type ZnO films grown on a-plane (11-20) sapphire (a-Al_2O_3) substrates exhibited excellent optical and electronic properties [2]. The growth of p-type ZnO films is required for the fabrication of the optoelectronic devices.

In the present study, we attempted nitrogen doping of ZnO films by decomposition of NO gas using a heated Ir wire during film growth. The CVD apparatus and basic growth procedure have been previously reported [2], but without the use of the Ir wire. Epitaxial ZnO films were grown directly on a-Al_2O_3 substrates at a substrate temperature of 773 K for 60 min without a buffer layer. The NO gas pressure was varied in the range 1.0×10^{-3} to 3.0×10^{-1} Pa. By the addition of NO gas, the crystallinity and crystal orientation along c-axis were found to be deteriorated from X-ray diffraction measurement. In the observation of electrical characterization of the ZnO films using Hall effect, residual carrier concentration in the films decreased with increasing NO gas pressure. This is probably attributed to the increase of accepter concentration in the ZnO films. In X-ray photoelectron spectra, multiple overlapping N-1s peaks were observed from 390 to 410 eV. By deconvolution of the spectra, components such as Zn-N, N-N, N-O, and NO_x were identified. The relative intensity of the Zn-N peak at 392.5-400.0 eV increased when the heated Ir wire was used to decompose the NO gas.

Acknowledgement
This work was supported in part by a Grant-in-Aid for Scientific Research (B) (No. 16H03869) from the Japan Society for the Promotion of Science.

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RD-028

Naturalness Preserving Image Stitching Based on Optimal Seam Estimation

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Image stitching with large parallax is still a challenging task in computer vision. Conventional methods achieved global and local alignment of images with small parallax successfully. However, undesirable artifacts such as ghosting are introduced in overlapping region when input images have a large parallax and occlusions. Images which are taken casually by users have large parallax, image stitching aims to stitch even such images. In existing method, the pixel values of overlapping region are the mean of overlapping pixel values. Therefore, artifacts occur in mutual occlusions which have no matching point in input images. To avoid occurring ghosting artifacts, it is effective that estimating the optimal seam of input images instead of taking the average of pixel values in overlapping region. In this report, we propose a naturalness preserving image stitching method based on optimal seam estimation. We estimate the optimal seam using the result of feature points matching. The seam consists matching points which have high matching score in overlapping region. Experimental results show that our method can stitch images more natural than other existing methods without ghosting artifacts.

RD-030

Study on Amplification of Optical Emission from Ge Quantum Dots by Photonic Crystal Resonator

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Semiconductor quantum dots formed with nanometer sizes can confine the carriers three dimensionally and exhibit different characteristics from the bulk semiconductor. Although Ge, which is an indirect transition type semiconductor, originally has low optical emission efficiency, Ge quantum dots exhibit strong emission in the infrared region due to their discrete quantum levels [1]. In our previous study, high-density (10^{12} cm^{-2}) Ge dots with an average diameter of 6 nm were formed on Si substrates by gas-source molecular beam epitaxy, using monomethylgermane as the Ge source [2]. Despite the high density, however, the emission intensity for the Ge dots was low compared to that for direct transition-type semiconductors such as GaAs and related compound semiconductors. Utilization of a photonic crystal resonator in a Si substrate has been reported as an effective means of enhancing the emission intensity [3].

In this study, in order to increase the optical emission from the Ge dots, we introduced photonic crystal resonator in Si-on-insulator (SOI) substrate. The lattice constant of the photonic crystal was designed to be 380 nm and the diameter of the air holes was varied from 200 nm to 240 nm. After the fabrication of the photonic crystal resonator, oleic acid coated PbS core-type quantum dots were placed inside the photonic crystal cavities, and the photoluminescence spectra were measured. From the PbS dots coated on Si without the photonic crystal cavity, emission peak derived from PbS dots at 0.89eV was observed. From PbS dots coated on SOI substrate, on the other hand, photoluminescence at 0.75-0.90 eV was observed. In particular, sharp emission peak at 0.81eV was observed at cavities with air hole diameter of 220 nm.

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RD-031

Object Tracking for Large Displacement Based on Optical Flow and Context Model

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In this report, we propose an object tracking method based on optical flow and a context model. Object tracking is a technique for estimating a location of target objects in videos. Since most normal videos are taken at about 30 fps or fewer, a displacement of objects between two consecutive frames is small. Therefore, many object tracking methods adopt a center bias which gives additional weight to previous target center. However, there is a problem that the center bias does not function properly. It is because a target center deviates from object area in case of large displacement such as fast motions or close to the camera. To solve this problem, the proposed method calculates displacement of target object using an optical flow method, and corrects the target center based on the calculated displacement. Thereby, the target center is located on the object area in case of large displacement. In experiments, we show that the proposed method performs favorably against state-of-the-art methods in terms of accuracy and robustness.

RD-032

3D Shape Measurement Method for Metal Object

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In this research, we propose a robust 3D shape measurement method for metal object using grating projection method, hue and multiple exposure images. 3D shape measurement method is a technique which can measure materials with high accuracy and is important for factory automation. In recent years, many 3D shape measurement methods have been proposed and a grating projection method can measure with pixel level accuracy. However, the methods cannot measure the metal object. Grayscale fringe patterns are projected onto the object and read pixel intensity in the methods. Therefore, measurement errors are caused by specular reflection. We proposed a 3D shape measurement method using grating projection, hue and measuring at multiple exposures. Color fringe patterns are projected onto the measured object and read a hue in our method. The measured object is taken some times with various exposures. These techniques reduced the effects of specular reflection. Experimental results are indicated that proposed method is better than latest grating projection method on metal object.

RD-033

Effect of N_2 annealing on Electrical Characteristics of $Ca_2AlMnO_{5+\delta}$ Ceramics.

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Oxygen storage materials[1] absorb and desorb oxygen according to changes in temperature and atmosphere. Especially, $Ca_2AlMnO_{5+\delta}$ with Brownmillerite (BM) type crystal structure[2] can absorb and desorb a large amount of excess oxygen (3.3 wt %) in response to variations in temperature and the surrounding atmosphere in a highly reversible manner[3,4]. To obtain high absorption / desorption amount of oxygen, N_2 annealing of the material is needed. However the effect of N_2 annealing on the electrical properties of this material are not well known. In this work, we prepared $Ca_2AlMnO_{5+\delta}$ ceramics by solid-state reaction combined with N_2 annealing and investigated the electrical characteristics.

The powders of $CaCO_3$, Mn_2O_3 and Al_2O_3 were used as starting materials. These materials were mixed in the molar ratio of Ca : Al : Mn = 2 : 1 : 1 in 2 - propanol using an alumina mortar and pestle. The mixture was calcined at 1100℃ for 2 h in air and ground into powder. The powder was pressed into pellets under a uniaxial pressure of 20 MPa, sintered at 1240℃ for 5 h in air followed by annealing at 800 ~ 1240℃ for 2.5 h in N_2. All the samples were annealed again at 700℃ followed by furnace cooling in air.

The resistivities at room temperature were 0.6×10^6 and 2.0×10^3 Ω·cm for samples without and with N_2 annealing at 1240℃ for 2.5 h, respectively. The samples showed the weight loss of 0.80 and 2.76 wt% with increasing temperature between 500 and 700℃, which reflected the desorption of oxygen from the sample. Comparison between the temperature dependences of resistivity and weight loss revealed that the charge carrier is hole in this material. The remarkable decrease in resistivity at room temperature is considered to be related to the effect of N_2 annealing which increase the amount of absorption of oxygen into the sample during cooling in air.

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RD-034

TiO_2-$BaSnO_3$ Composite Film Prepared by Sol-gel Method and Its Application to Si Solar Cell

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$BaSnO_3$ as a material showing strong near-infrared emission by irradiation with ultraviolet light is expected as a wavelength conversion material to improve the power generation efficiency of Si solar cells.[1-3] However, there is few reports demonstrating the improvement of the efficiency because the translucency of films made of the material is poor since the refractive index is as high as 2.26. In this study, TiO_2 having a refractive index close to that of $BaSnO_3$ was exploited as a matrix to improve the transmittance of a composite film containing $BaSnO_3$ and its optical properties were evaluated.

To obtain TiO_2 sol, 3 ml of Ti $[OCH(CH_3)_2]_4$ was hydrolyzed with 2 ml of purified water peptized using 2 ml of nitric acid, and then dried at room temperature for 24 h. $BaSnO_3$ powder was synthesized by a solid-state reaction. Raw powders of $BaCO_3$ and SnO_2 were mixed in a molar ratio of Ba : Sn = 1 : 1.1, sintered in air at 1350°C for 3 h, and then ground into powder. TiO_2 Sol and $BaSnO_3$ powder were mixed in a mass ratio of 1: 0.25 and spin-coated on Eagle XG substrate followed by annealing at 200 - 600°C for 1 h in air. The film was placed above a Si solar cell and a current-voltage characteristic of the cell was measured under the irradiation from a solar simulator.

XRD peaks attributed to $BaSnO_3$ were confirmed in all the films. A near-infrared light emission peak at 840 nm was measured from the films excited by UV light at 380 nm in wavelength. The films had 65 - 75% of transmittance in visible and near infrared region. The film annealed at 600℃ showed the highest absorbance. The conversion efficiency of the Si solar cell combined with the film containing $BaSnO_3$ was successfully improved by 10% compared with that not containing $BaSnO_3$.

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RD-035

Electrical Conductivity of Carbon Fiber Sheet Made from Silk

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Carbon fibers having high electric conductivity and chemical stability collects much attention for the application to the electrodes of capacitors, fuel cells and so on[1-3]. However, it is a problem that the production method of carbon fiber is complicated and takes a high cost. A simple and cost effective process is needed to use the sheets widely. In the present study, to obtain carbon fiber sheet, silk fabric was simply heat-treated in carbon powder. The relation between the synthesis condition and conductivity of the carbon fiber sheet was investigated.

Silk was cut to 2 x 2 cm^2, embedded in the carbon powder in the crucible, and then heat-treated at 200 ~ 1400°C for 30 min. Also the silk was immersed in an aqueous solution of $Fe(NO_3)_3$ and subjected to heat treatment. Four points on the resultant sheet were electroded using Silver paste and current-voltage characteristic was measured by 4-terminal method.

SEM observation revealed that the fabric structure remained after the heat treatment. The XRD peaks of Fe_3O_4 were measured from the sheets prepared with $Fe(NO_3)_3$. The peak of graphite was detected from the sheets treated at temperatures of 1000°C and above. The sheets heated at 700 ~ 1400℃ had electrical conductivity. The resistivity decreased with increasing treatment temperature. The resistivity of the sheet with Fe_3O_4 was lower than that without it, which implied that the Fe_3O_4 accelerated the carbonization and graphitization of the silk.

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RD-036

The Effects of Transition Metals Doping on Optical Properties of β-Ga_2O_3 by DV-Xα Method

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Gallium oxide (β-Ga_2O_3) is emerging as a viable candidate for certain classes of power electronics, solar blind UV photodetectors, solar cells, and sensors with capabilities beyond existing technologies due to its large band gap [1]. In the development of transition metals (Cr) activated persistent luminescence materials, β-Ga_2O_3 as an excellent host because Cr^{3+} ions can easily substitute Ga^{3+} ions and the suitable host lattices crystal field strength around Cr^{3+} ions. There are now a lot of studies on the effect of transition metals(Cr) on doping with β-Ga_2O_3 on properties such as optical, persistent luminescence and photocatalytic [2]. When β-Ga_2O_3:Cr^{3+} was co-doped with Zn^{2+}, the persistent luminescence were obviously improved, which is due to the formation of new traps by oxygen vacancy in the energy levels [2].

There are some issues as why use Cr or Zn to doping with β-Ga_2O_3 rather than other transition metals. It is difficult to appreciate the use of transition metals as suitable and desirable in the study of properties with β-Ga_2O_3 without experiment. So instead of experimenting with a lot of different transition metals, the calculation and simulation of β-Ga_2O_3 properties with transition and typical metals such as Cr, Mn, Zn doped with β-Ga_2O_3 properties is one of a new method for research and contribute to the development of later studies with β-Ga_2O_3.

In this Research, the effects on the persistent luminescence and optical properties of transition and typical metals such as Cr, Mn, Zn doped β-Ga_2O_3 are investigated with DV-Xα method [3], which is one of the first principle molecular orbital calculation methods, and was used for the calculation of the energy levels and density of states of the transition metals doped β-Ga_2O_3 crystal. In this method, Slater's exchange potential and the numerical basis functions were used [3]. The conduction and valence bands primary come from Ga-4s and O-2p states, respectively. The origin of emission is assigned to transition metals ions in the β-Ga_2O_3 host, and values for the energy level of the emission are explained by calculated results. With the energy levels and density of states results by DV-Xα method, we will present the effect of persistent luminescence properties resulting from the new energy levels of dopants or defects when transition or typical metals doping in the β-Ga_2O_3.

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RD-037

High-Speed Photographing for the Restoration of the Minute Light Emission

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We propose high-speed photographing for the restoration of the minute light emission. High-speed photographing is a technique for the purpose of photographing high speed phenomenon such as discharge plasma. In conventional method, high-speed photographing is realized by using streak camera and image compression method. This method captures observed image using streak camera. This image includes all of light emission phenomena at the respective time. After captured the image, image compression method restores phenomena at the respective time using observed image. After the restoration, this method estimates the shape of plasmas using binarization so that it reduces artifacts in the restoration. Finally, a more precisely photographing is realized by the re-restoration using the estimated results. However, when this method restores the minute light emission, shapes of restoration target can't be estimated. The conventional method fails estimating shapes because shapes are lost by binarization. The proposed method estimates the shape information using active contour model. This model can detect the minute light emission because of using a gradient and a region. Then, the re-restoration realizes high-speed photographing for minute light emission. Through simulations, we show that the proposed method objectively and perceptually outperforms previous methods.

RD-038

Compact Pulsed Power Generator Operated with Low Voltage Using Power SIC-MOSFETS

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In recent years, much attention has been paid to high voltage pulsed power generators. Among them, compact high voltage pulsed power generators using solid-state devices are expected to be used for many applications in various fields such as environment, medical, agriculture, defense-related, and so on. Conventional pulsed power generators consist of pulsed power circuits and high-power supplies. They are huge and heavy when we consider usage for general household applications.

In this study, we developed a compact pulsed power generator capable of obtaining 1kV output from 5V input. By selecting 5V as the input voltage, it is possible to operate by battery. The developed pulsed power generator consists of two-stage boosting circuits and a pulse generating circuit. The generator measures 12cm long and 10cm wide. As the switching element, silicon carbide metal-oxide-semiconductor field-effect transistors (SiC-MOSFETs) were used. Comparing with Si-MOSFETs, SiC-MOSFETs have many advantages such as high withstand voltage and low on-resistance, the fast turn-on and turn-off are the attractive advantages. As a result, a maximum voltage of 1.3kV, and 1kV was obtained the output had a repetitive rate up to 100 pulses per second at 100-ohm resistive load.

RD-039

First Principles Study on Magnetic Properties in Chalcopyrite Cr-doped $ZnSnAs_2$ Semiconductor

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Recently, many studies have been conducted into ferromagnetic semiconductors because of their potential applications in spin-based electronic devices (spintronics). The first principles calculation of magnetic properties in chalcopyrite Mn-doped $ZnSnAs_2$, which is one of the potential candidate for spintronics material, have been performed by several groups [1,2]. Meanwhile there are a few reports on II-IV-V_2 compound doped with Cr from experimental and theoretical aspects. In this work, we employed density functional theory (DFT) implementation: exact full-potential augmented plane-wave (LAPW) method (WIEN2k) to determine whether the ferromagnetic state is stable depending on the distance between two Cr atoms in 64–128 atoms supercells of Cr-doped $ZnSnAs_2$. Fig.1 shows the dependence of $\Delta E = E_{AFM} - E_{FM}$ on the distance between substitutional Cr atoms, where we consider three scenarios: (1) both Cr atoms occupy Zn sites (2Cr→2Zn), (2) both Cr atoms occupy Sn sites (2Cr→2Sn), and (3) one Cr atom occupies a Sn site and the other occupies a Zn site (2Cr→1Zn1Sn). In the case that Mn atoms substitute Sn sites, ferromagnetic state is stable [2]. In contrast, 2Cr→2Sn structure is found to be energetically stable in the AFM state. On the other hand, 2Cr→2Zn and 2Cr→1Zn1Sn structures are stable in the FM state. Density of states of these structures indicated half metallic behavior. These results predict that the growth condition of Cr-doped $ZnSnAs_2$ thin film in which Cr atoms preferentially substitute with Zn site leads to half metallic ferromagnetism.

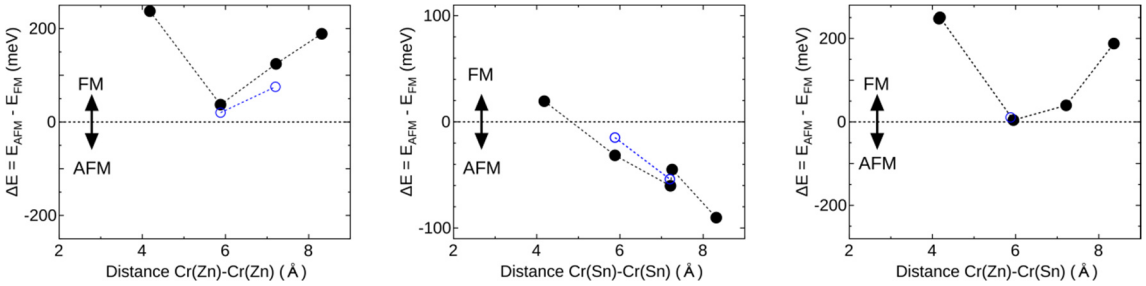

Fig.1 The dependence of ΔE of 2Cr→2Zn, 2Cr→2Sn and 2Cr→1Zn1Sn structures on Cr-Cr distance.

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RD-040

Fabrication of MOS Transistor Array Pattern on i-line Photoresist Film by the Hyblid Lithography

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Electron beam(EB) lithography can draw high-resolution pattern with sub-10nm applying to fabricate nano-scaled devices. EB lithography is performed by using photoresists such as epoxy-based, diazonaphthoquinone (DNQ) / novolak resin and chemically amplified resists. The DNQ / novolak resin positive photoresist(i-line photoresist) is also used for i-line photoresists which consist of DNQ and novolac resin. The dissolution rate of i-line photoresist increases upon exposure to i-line. On the other hand, it has been reported that the rate decrease upon to electron-beam[1]. In this work, we have focused on the fabrication of transistor array pattern on i – line photoresist using by EB and i-line lithography.

The design of MOS transistor array pattern is shown in Fig.1. Transistors are located within a 200μm square region. The gate length were 200nm and 400nm respectively. Drain-Source region pattern and fabrication process are shown Fig.2. In order to optimize the process, the dose coefficient (the exposure time calculated from the sensitivity of the resist) was adjusted. As the coefficient increase, the gate length is closer to the design value with increasing the dose coefficient. This results suggest that the photoresist swelling depends on the dose coefficient.

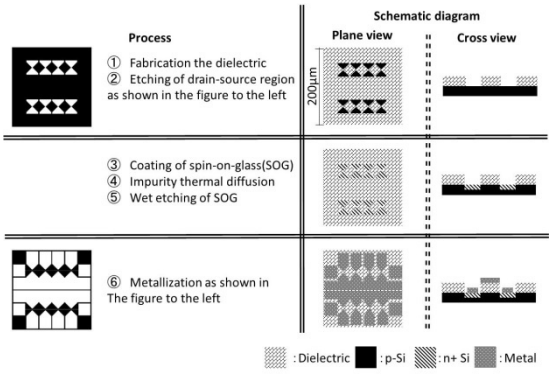

Fig.1 Design of MOS transistor

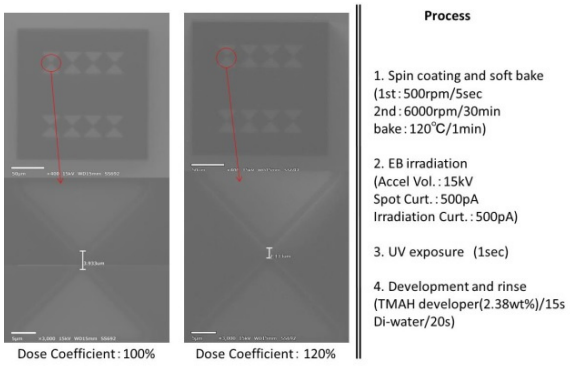

Fig.2 Photoresist pattern of drain-source

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RD-041

Noise Bias Compensation for Tone Mapped Noisy Image Using Prior Knowledge

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Most studies of noise reduction are focused on utilizing correlation between pixels. In regression filters, a convolution kernel was determined based on the spatial distance or the photometric distance. Recently, interests in non-local mean (NLM) filters that replaces pixel-wise calculation of the distance with patch-wise one has been growing. Later on, NLM filters have been developed to be adaptive to the local statistics of an image with introduction of the prior knowledge in a Bayesian framework.

From an astronomical image to a night scene image photographed by general purpose digital cameras installed at places of daily life such as schools, roads and commercial facilities, study of the reduction of noise included in the image after TM is necessary. Most of literatures usually assume the noise to be i.i.d. additive white noise, and the zero-mean assumption has been widely imposed on the filter design. However, in tone mapping (TM) processing, the noise that included in an image after TM has a non-zero average (= noise bias). This noise bias (NB) is due to the non-linearity of TM such as the power function, the logarithmic function and the Hill function, etc. However, little attention has been given to NB.

We propose a new noise reduction method for noise included in the image after TM. The proposed method recovers the ideal output image from the observed output image by compensating NB. The NB is a different notion from the ensemble average of the noise over `all' pixels. In the proposed method, pixels in the noisy image before TM are classified into several subsets according to the pixel value after TM, and compensates the pixel value in each subset with a preliminarily determined compensation value. This procedure is the noise bias compensation (NBC). The NB is the mean of the noise in the subset corresponding to the pixel value after TM and it is compensated. By subtracting the compensation value from the pixel value after TM, NB becomes to zero value. The compensation value is determined from prior knowledge based on the Bayesian inference theory. The effectiveness of the proposed method over the existing method was experimentally confirmed for tone mapped noisy images.