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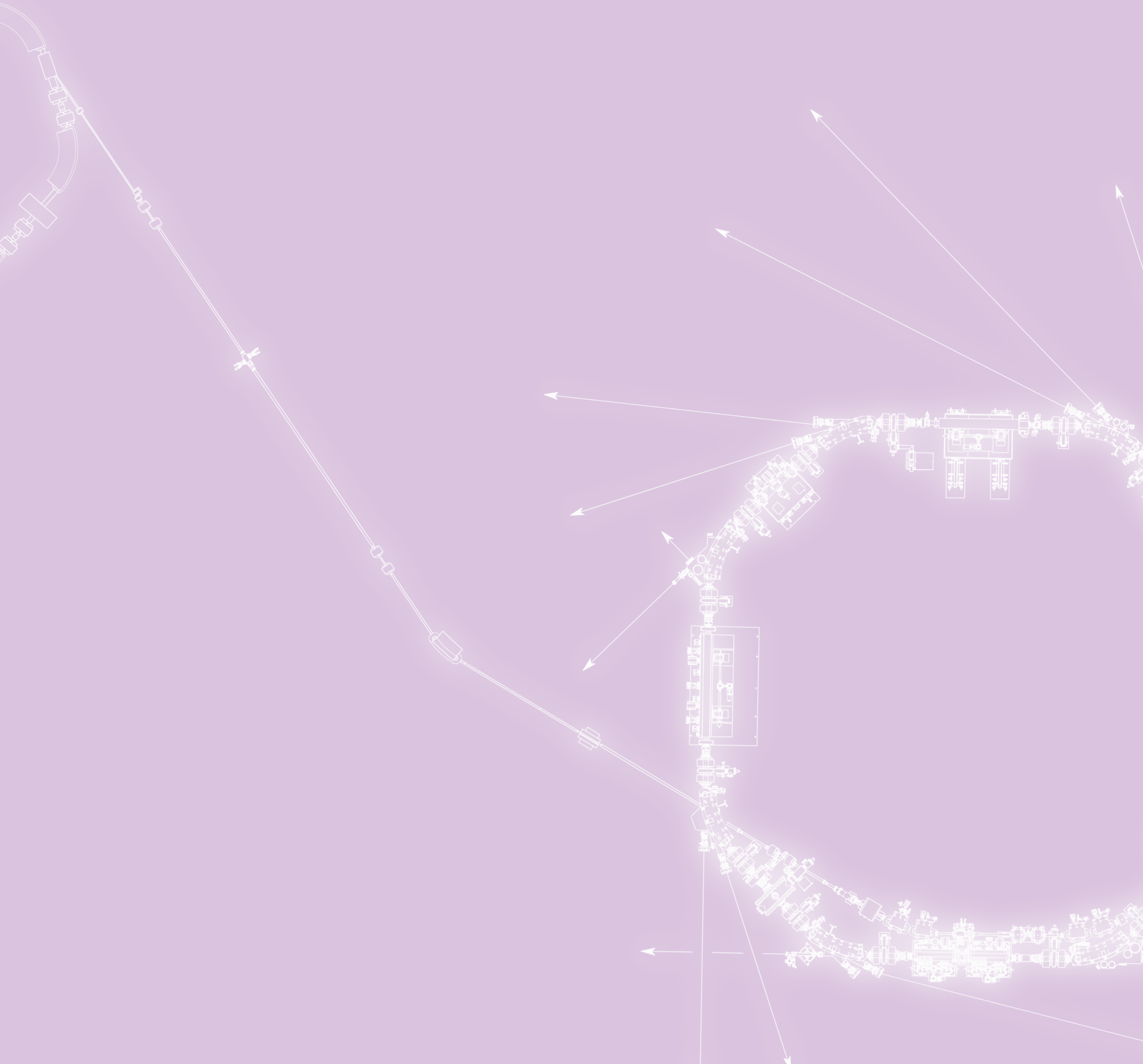
Life, Earth and Planetary Sciences



BL4U

Hayabusa2 Returned Samples: Unique and Pristine Record of Solar System Materials from Asteroid Ryugu

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The Hayabusa2 spacecraft successfully returned surface materials from the C-type asteroid Ryugu to Earth on December 6th, 2020. The sample capsule contained a large number of small grains, collected from touchdown (TD) sites 1 and 2 on Ryugu, with a total mass of ~5.4 g [1]. After initial characterization of the grains by JAXA curation [1,2], eight Ryugu particles (~60 mg in total), four from Chamber A and four from Chamber C, were allocated to the Phase2 curation Kochi team (Ph2K). The principal goals of the research are to elucidate the nature, origin, and evolutionary history of asteroid Ryugu, and to document the similarities to and/or differences from other known extraterrestrial samples, such as chondritic meteorites, interplanetary dust particles and returned cometary samples collected by the NASA Stardust mission.

The coordinated micro-analysis work involved the use of a wide range of multi-beam instruments to acquire detailed micro-textural and chemical information about the samples at a sub-micrometer scale using a combination of FIB, STXM-NEXAFS, NanoSIMS and TEM [4,5]. In parallel, we conducted bulk systematic analysis of the samples using SEM-EDS, EPMA, XRD, large geometry type SIMS, high precision O isotopic analysis by laser fluorination and INAA [4-8].

Using a combination of STXM-NEXAFS – NanoSIMS – TEM techniques, we have been able to establish the spatial distribution of organics with an aliphatic-rich carbon structure that are associated with phyllosilicates at sub-micrometer scale in the C0068-25 FIB section (Fig. 1).

C-NEXAFS spectra in the C0068-25 section show a variety of functional groups of aromatic (or C=C), C=O, C-H or aliphatic, and C(=O)O, without 1s-σ^* exciton of graphene structures (Fig. 1(A)). Figure 1(B) shows the spatial distribution of carbon in the section. In Fig. 1(C), three representative areas of aromatic (or C=C)-rich organics can be seen in red, aliphatic-rich carbon is shown in green and matrix in blue. Areas with an intense aliphatic-rich carbon structure (green area in Fig. 1(C)) are present locally in coarse-grained phyllosilicates in the section (Fig. 1(D)), as well as areas with a poorly aromatic (C=C) carbon structure. The distribution of organics with an aliphatic carbon structure may vary significantly depending on the existence of coarse-grained phyllosilicates. The C-NEXAFS revealed that the organics in the Ryugu particles are chemically distinct from the previously studied IOM of the Murchison CM chondrite [8]and show greater similarity to IDPs [9] and cometary particles obtained by the Stardust mission [10].

A question that arises is whether the unique nature of the aliphatic carbon-rich organics associated with coarse-grained phyllosilicates observed in this study is a unique feature, only found in the Ryugu asteroid. This question requires additional work. Further study is needed to fully define the nature of the organics and their relationship with the surrounding hydrous mineral phases.

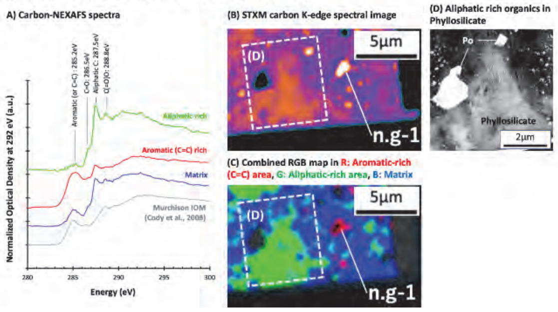
Fig. 1. STXM analysis of FIB section (C0068-25)

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BL1U

Study of Pygmy Dipole Resonance using Linearly Polarized Photon Beam

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The emergence of low energy dipole strength so called Pygmy Dipole Resonance (PDR) has motivated many experimental and theoretical efforts [1]. The PDR has been observed as a concentration of electromagnetic strength near the low-energy tail of the Giant Dipole Resonance (GDR). It provides useful information on fundamental properties such as the neutron-skin thickness of medium to heavy nuclei, the nuclear symmetry energy, and the properties of neutron stars. The stable lead isotopes, including ^{206}Pb, are suitable for these studies since they exhibit an appreciable amount of low-energy dipole strength.

In a previous nuclear resonance fluorescence (NRF) measurement for ^{206}Pb using unpolarized bremsstrahlung [2], extra strengths were observed at the energy region ranging from 5 to 8 MeV which could be related to the PDR. The photo-absorption cross sections in ^{208}Pb in average amount to about 60% of that in ^{206}Pb. This behavior differs from that found in the series of xenon isotopes, in which the summed dipole strength in the energy region from 6 to 9 MeV increases with the neutron numbers [3]. Possible reasons are that the strength in the quasi-continuum may not be neglected in ^{208}Pb either or that there are structural differences that interfere the effect of the neutron excess [3].

To study the PDR nature in ^{206}Pb we measured NRF γ rays using linearly polarized photon beam. The laser Compton scattering (LCS) γ rays with a maximum energy of 7.54 MeV were generated by collision of 746-MeV electrons with linearly polarized laser photons with a wavelength of 800 nm at a collision angle of 82 degrees. A lead collimator with a 18-cm thickness and 3-mm aperture was used to form a quasi-monochromatic LCS photon beam. The photon flux was measured during the NRF measurement by a large volume $LaBr_3$ scintillation detector. The target consisted of a metallic cylinder (8 mm in diameter) of enriched ^{206}Pb. Four high-purity germanium (HPGe) detectors were used to measure scattered photons from the target. Two of these detectors were placed in the horizontal plane at a scattering angle of 90 degrees and the others were placed in the vertical plane. The experimental setup is shown in Fig. 1. A part of the photon scattering spectra observed at a polar angle of 90 degree relative to the polarization plane of the incident photon beam is represented in Fig. 2. The measured spectra are used to determine the parities of the resonant states by extracting the intensity asymmetry of resonantly scattered γ-rays with respect to the polarization plane of the incident photon beam.

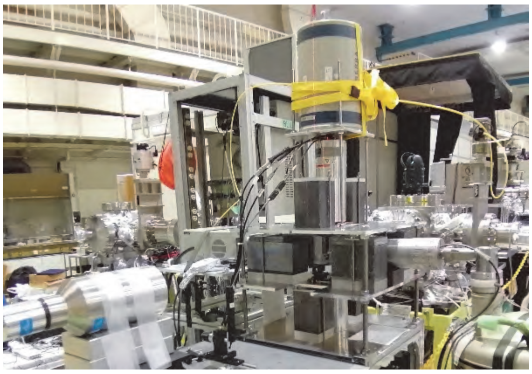

Fig. 1. Photo of the experimental setup used for NRF measurements at BL1U.

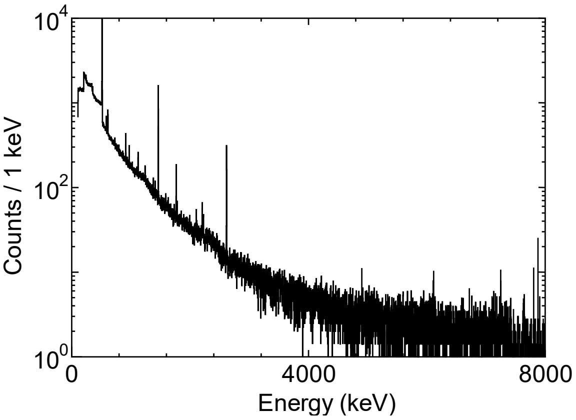

Fig. 2. Typical γ-ray spectrum observed at a polar angle of 90 degrees relative to the polarization plane of the incident photon beam.

[1] D. Savran *et al.*, Prog. Part. Nucl. Phys. **70** (2013) 210.
[2] T. Shizuma *et al.*, Phys. Rev. C **98** (2018) 064317.
[3] R. Massarczyk *et al.*, Phys. Rev. Lett. **112** (2014) 072501.

BL3U

X-ray Absorption Spectra of Lipid Bilayer Membranes in Aqueous Solutions

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The lipid bilayer is a self-assembled structure of amphiphilic lipid molecules and is the fundamental structure of biomembranes such as cell membranes. Internal structures of lipid bilayers, such as two-dimensional domains and hydrophobic thickness, and physical properties affect the transportation of materials, information, and energy through the biomembranes. All these physiological reactions proceed in the presence of ions. Ions in the aqueous solution significantly influence to these structures and properties of lipid bilayers. Phosphatidylcholine (PC) is the most abundant lipid of eukaryotic cell membranes. Cations bind to the phosphate and carbonyl groups of PC. However, affinity of cations to PC and effects of cations to molecular orientation are still controversy especially in the fields of theoretical simulations [1]. We aim to determine the binding affinity of cations to lipids in aqueous solutions experimentally, by means of X-ray absorption spectroscopy (XAS) [2,3].

Supported lipid bilayers (SLBs) of dioleoyl-PC (DOPC) were formed on the Si$_3$N$_4$ membranes of the XAS flow cell [2] by the vesicle fusion method. We prepared DOPC-SLBs with few residual vesicles as shown in Fig. 1. Fluorescence recovery after photobleaching observation showed that fluid and continuous SLB covered the whole Si$_3$N$_4$ membrane surface. O-K edge XAS spectra of the Si$_3$N$_4$ membrane before and after formation of SLB were obtained in a buffer solution (NaCl 100 mM, HEPES 25 mM/ pH 7.4 NaOH) which thickness was controlled to be less than 100 nm. The XAS spectrum of the Si$_3$N$_4$ membrane without SLB was subtracted from that with SLB.

The O-K-edge spectrum of DOPC appeared at 531 - 533 eV (Fig. 2). It is attributed to three components due to the phosphate and carbonyl groups on the PC headgroup: $1s \rightarrow \pi^*$ transitions of P=O, P-O-Na, and C=O at 531.5 eV, 532.3 eV, 532.0 eV, respectively [3]. We measured XAS spectra at different incident angle to obtain the orientation of these groups in the lipid bilayer [4]. The relative intensity of the three components varied with the incident angle (Fig. 2). The result indicates that XAS in the aqueous sotion is capable to obtain information about the molecular orientation of lipids in bilayer membranes.

In conclusion, we obtained O-K edge XAS spectra of SLBs in an aqueous solution at various incident angles. We will investigate the effects of the cation concentration and species on the XAS components and their relative intensities.

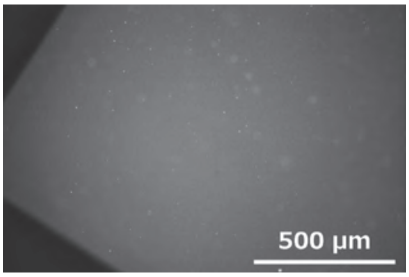

Fig. 1. Fluorescence image of DOPC-SLB on the the Si$_3$N$_4$ membranes of the XAS flow cell.

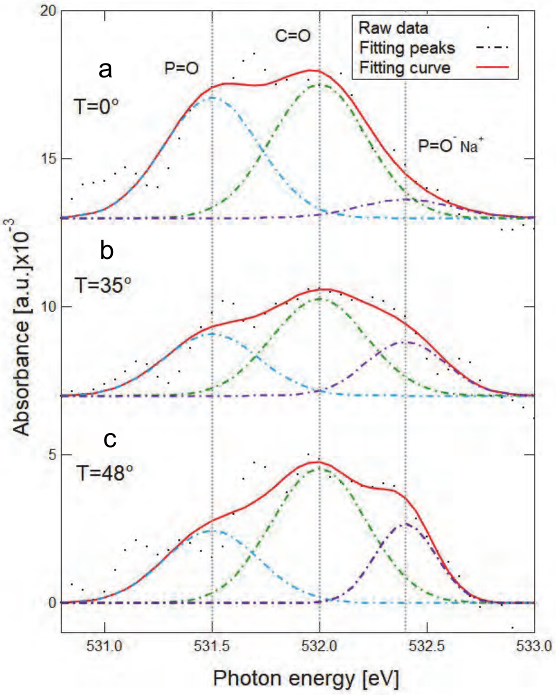

Fig. 2. O K-edge XAS spectra of DOPC-SLB obtained at various incident angle: (a) 0°, (b) 35°, and (c) 48°. Black dotted curves represent raw data. Dashed curves and red solid curves show deconvoluted components and their summation, respectively.

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BL4U

Evaluation of Exposure-Effects on Biomolecules for the Molecular Mapping of Biological Specimens Using STXM

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It is well recognized that spectromicroscopy using a scanning transmission X-ray microscope (STXM) in the soft X-ray region is a powerful tool for the molecular mapping of biological specimens. We have been working on a quantitative mapping of nucleic acids (DNA and RNA) and proteins (histone and bovine serum albumin abbreviated as BSA) in chromosomes, cultured mammalian cells, and isolated apoptotic nuclei using combined NEXAFS spectra at the C, N and O-K absorption edges [1-3].

In the quantitative analysis, precise absorption spectra of constituent molecules are definitely required. However exposure of X-rays for the observation itself could induce molecular changes resulting in the spectral changes of them. Actually, we have calculated the exposure and absorption doses for biological specimens in a hydrated condition to achieve a defined spatial resolution based on the method by Sayre et al. [4], and estimated the number of DNA strand breaks generated [5]. For example to obtain 100 nm spatial resolution, the absorption dose in the order of 10^4 Gy is required, which induces about 10^5 DNA double strand breaks per cell. In the present study, we evaluated the exposure-effects on the spectra of major biological molecules such as DNA, RNA, histone and BSA as a trial.

We prepared dry thin films of DNA, RNA, histone, and BSA on SiN membrane. Each one micrometer square area in the specimens was scanned with 10 x 10 pixels at the energy of C, N and O-K absorption edge regions in this order with a dwell time of 6, 12 and 20 msec in addition to 2 msec for DNA. For each dwell time the scanned area was shifted to the different area.

Figure 1 shows NEXAFS of DNA at the C, N and O-K absorption edges with four kinds of dwell times. A slight but significant change was observed in the profiles of the spectra, though it was not clear whether or not that was depending on the level of exposures.

In the case of RNA and histone, similar tendency was observed. However for BSA, a clear change in the profiles was observed in a dwell time dependent manner.

At this stage of the results, we decided that spectra of the molecules observed at the same exposure condition should be chosen as the reference data for analysis, though the repeated measurement and confirmation of the results remained.

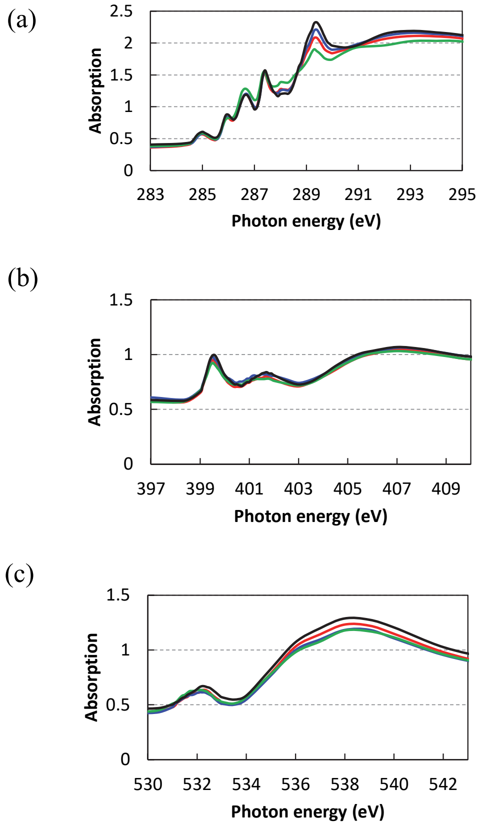

Fig. 1. NEXAFS of DNA at the C-K (a), N-K (b), and O-K (c) edges. Dwell time: 2 (black), 6 (red), 12 (blue), and 20 (green) msec.

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BL4U

Physicochemically Characterization of Dust/Salt Mixtures Originating from the Source of East Asian Dust Storms

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Mineral dust aerosols are a primary component in the atmosphere, accounting for almost half of tropospheric aerosol masses, and they can deteriorate human living conditions, endanger human health, and affect ecosystems. In the context of global climate change, the trend of warming and drying that is intensifying desertification in northern China is clear. The dominant regional geophysical feature, the neighboring Third Pole, that is the elevated region represented by the Himalayas and the Tibetan Plateau, impacts the entire planet's climate directly and via global teleconnections [1]. In this study, dust, salts and mixed samples were collected from important source regions of East Asian Dust Storms, including the Badain Jaran Desert, the Tengger Desert and the Ulan Buh Desert in northwestern China.

Scanning transmission X-ray microscopy (STXM) measurements were performed at the BL4U UVSOR-III beamline. For STXM measurements sample particles were deposited on filmed TEM grids, and data was analyzed with the aXis2000 program. Example optical images are presented in Fig. 1, where Fig. 1(a) is an image captured at 348 eV photon energy, corresponding to calcium absorption. Potassium-containing particles in the same sample are highlighted in Fig. 1(b) (297 eV) as the dark more cubic particles.

Individual particles were chemically mapped using the STXM technique. Particle images are shown in Fig. 2 and a zoomed-in view in Fig. 2(a). Figure 2(a) shows the two typically observed particle morphologies, needle-like and more cubic or polygonal. We observe distinct chemical characteristics of the two morphologies, as illustrated in Figs. 2(b)–2(d), which include the carbon K-edge and potassium L-edge spectra, the calcium L-edge spectra and the oxygen K-edge spectra.

The carbon K-edge includes the presence of a carbonate peak (at 290.2 eV) for needle particles that is minimally present for the polygonal particles [2]. Given the region around 284–290 eV is flat, these particles cannot include significant black or organic carbon components. At the potassium L-edge, a doublet at 297.2 and 299.8 eV indicates the presence of potassium in the polygonal particle [3]. In Fig. 2(c), the calcium L-edge shows the presence of calcium (at 348.8 and 352.1 eV) in the needle, suggesting the needle is likely $CaCO_3$ [2]. At the oxygen K-edge (Fig. 2(d)), one sharp peak is observed at 533.6 eV in the needle, which likely corresponds to the oxygen in the carbonate ions, which further supports the supposition that the needle-like particles are dominated by CO_3 and Ca. The broad components in the oxygen K-edge spectra are associated with other oxygen species. These results show the mixing state of the $CaCO_3$ and K/O salts in sand samples, and these two components most likely have different solubilities, *i.e.*, $CaCO_3$ has low solubility in water, but the K/O salts may be highly dissolvable. The STXM results here provide unique information that cannot be accessed by other conventional methods.

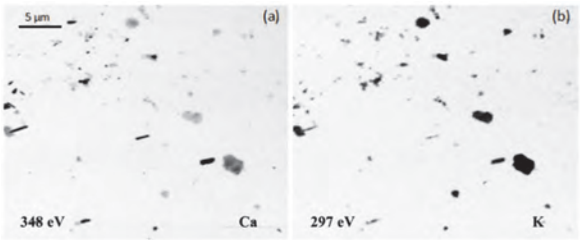

Fig. 1. STXM images shows the morphology of dust/salt mixture particles. (a,b) Snapshots measured at 348 eV and 297 eV.

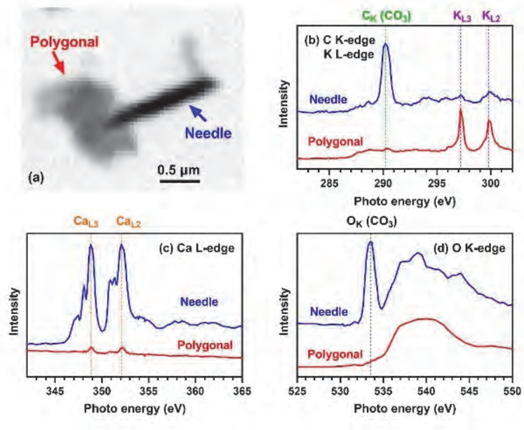

Fig. 2. STXM image and spectra of representative particles. (a) Optical image, (b) spectra scanned at C K-edge and K L-edge, (c) Ca L-edge spectra, (d) O K-edge spectra. Blue lines and red lines represent the mean spectra for needle-like particles and polygonal particles, respectively.

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BL5B

Development of Multilayer-coated Mirrors for the Next Generation of the Inner Magnetospheric Imaging

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Inner magnetospheric imaging at 30.4 nm, which is a resonantly scattered emission line by singly-ionized helium, contributed to our present understandings of plasmasphere formation, emerges of fine structures and solar wind interaction. RemFigote-sensing technique in this spectral region has become known as a promising tool in geophysics.

We have still strong motive in extension of the inner magnetospheric imaging since instrument developments on Kaguya, Nozomi, International Space Station. A multilayer coated mirror reflecting the EUV radiation at the normal incidence has been providing solutions to overcome the technical difficulties, i.e., existing optics has less effective collection of EUV photons. Therefore, multilayer coated mirrors have been employed for solar physics and astrophysics as well. The multilayer coating consisting of alternating layers of typically molybdenum and silicon (Mo/Si) achieved the highest and stable reflectivity (approximately 20 %) at 30.4 nm, and therefore it has been most often employed in the space missions. The thickness of each layer should be determined by the trade-off as follows: it maximizes the constructive interference of the incidence reflected at each interface and it minimizes the total absorption to enable more interfaces to contribute to the absolute reflectance increase.

Recently, we have shown the performance of the new multilayer coated mirror, consisting of 40 pairs of Mg and SiC. Its peak reflectivity achieved 30 % or higher. However, we had to realize that the Mg/SiC multilayer mirror has decisive disadvantage. The degradation of the reflectivity occurred under the condition of high temperature and/or high humidity. The interface between two materials became unstable, the thickness of the layer changes due to interfacial tension, and then the reflectance decreased dramatically (diffusion problem). As a result, we were forced to use a conventional multilayer mirror.

Space mission payloads have to survive hot and/or humidity environments before the launch as well as very cold condition in space. The development of robust instruments against environmental changes is mandatory for us.

More recently, we have designed a new multilayer coating, (B4C/MgSi). We use the metal alloys of MgSi instead of using bulk of Mg to solve diffusion problems. Figure 1 shows the reflectivity of the coating for S- and P- polarizations. For both polarizations, the measured reflectivities are relatively ~ 25 % lower than those of the expectations by calculations (We have an ordinary way using optical constants [1] to calculate the reflectivity). We will have some modification on the manufacturing process (e.g., Mg/Si ratio) to increase up to the expectations.

On the other hand, for non-polarization radiation (that is our target in planetary science), we expect that we have achieved higher reflectivity (average over S- and P- polarizations, about 30 %) than that of a conventional Mo/Si coating. The development will be progress next year.

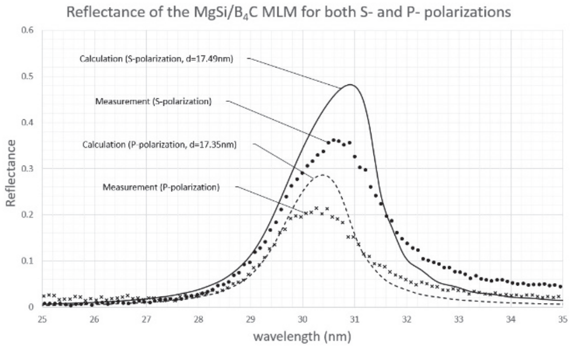

Fig. 1. Reflectivity of the multilayer coating of B_4C/MgSi. We have measured the reflectivity for both S and P polarizations. Predictions by the calculations are also shown.

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BL5B

Performance Evaluation of an Optical Filter Aiming for Observation of Atmosphere of Comets

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Investigating the hydrogen isotope (D/H) ratio of emitted gases from comets is important to understand the water-related history of the solar system. Here, we are developing a Lyman-alpha line absorption cell that can distinguish the emission line of D and H, by utilizing the resonance absorption of the hydrogen atoms. To evaluate its performance, accurate calibration of the wavelength for the monochromator is required. However, the BL5B facility is known to have a drift-like tendency. Therefore, we examined the temporal shift of the wavelength using the known absorption line of the Krypton (Kr) .

We evaluated the wavelength shift by irradiating the EUV light to the absorption cell filled with Kr gas (Fig. 1). The measurements were conducted three times. For all measurements, the scanned wavelength was from 122.6 nm to 124.6 nm, and the scan step was 0.01nm. The slit width was 0.01 mm. The pin hole diameter was 1 mm, and the grating and the mirror were set as “G3M5”. The gas pressure of the Kr gas was 1000 Pa.

The result is shown in Fig. 2. The absorption wavelength by Kr is 123.58 nm in literature [1]. However, the figure shows two primary absorptions, 123.50 nm and 123.80 nm. We have two hypotheses for this result.

The one is that the absorption near the wavelength of 123.50 nm might be the absorption by Kr, since its wavelength is near that of Kr in literature [1]. Based on this hypothesis, the other absorption, which is around 123.80 nm, should be an effect of other substances. A possible substance is water molecules. They absorb light near the wavelength of 122.00nm, 123.85 nm, and 124.10 nm. It is difficult to completely prevent water molecules from entering the cell, so some water molecules remaining in the cell might absorb the light near 123.80 nm. However, if this hypothesis is correct, an absorption near 124.10 nm also should appear. As the future work, we plan to dry the Kr cell completely by baking enough and confirm whether the absorption around 123.80 nm is derived from water molecules.

The other hypothesis is that both two absorption lines are caused by water molecules. It means that the wavelength adjustment by approximately +0.30 nm is needed. Based on this hypothesis, we have to consider the possibility that the absorption by Kr is too faint to observe. The future work for this case is the same as mentioned above, since if both absorptions are effects of water molecules, both absorptions would disappear by drying the cell. Moreover, we also should find out appropriate Kr gas pressure.

As a supplementary experiment, we also evaluated the upper limit of absorption rate by hydrogen by filling the cell with hydrogen gas. It can be derived by calculating the ratio of the standard deviation to the average direct count, using the hydrogen-filled cell. We call it “relative error”.

The measurement was conducted 10 sets. Each measurement set has three trials. The scanned wavelength was from 119.6 nm to 123.6 nm, and the scan step was 0.02 nm. The slit width was 0.01 mm. The pin hole diameter was 1 mm, and the grating and the mirror were set as “G3M5”. The hydrogen gas pressure was 200 Pa. Electric energy applied to the filament in the cell was changed from (1.05 W, 2002 K) to (2.60 W, 2740K).

As a result, the average “relative error” was 2.31 %. This means that if the absorption for hydrogen Lyman-alpha is less than 2.31%, we cannot find it out. Therefore, we have to adjust the power for the filament so that the absorption exceeds the ratio.

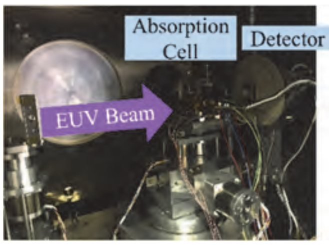

Fig. 1. The setup of experimental instruments.

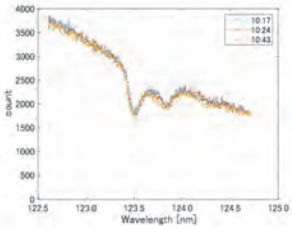

Fig. 2. The absorption spectrum of Kr. It shows primary absorptions at 123.50 nm and 123.80 nm.

[1] National Institute of Standards and Technology, *NIST Atomic Spectra Database Lines Data*, https://physics.nist.gov/PhysRefData/ASD/lines_form. html. Accessed March 2, 2022.

BL5B

Performance Evaluation of UV Absorption Filter Onboard Spacecraft

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In the planetary science, deuterium-hydrogen (D/H) isotope ratio of comets is emphasized to know the origin of water on Earth. We develop an imager onboard the Comet Interceptor spacecraft to observe this. However, small spectrometers have too low wavelength resolution to distinguish emission lines of H and D, whose wavelength are different only by 33 pm. To overcome this difficulty, we use gas filters named Hydrogen Absorption Cell. This is a small glass cell filled with hydrogen molecules, in which filaments are set. By applying voltage to this filament, hydrogen molecules dissociate into atoms resulting in absorption of Ly-α. It is noted that Ly-α of deuterium is not absorbed. Therefore, we can evaluate D/H ratio from the difference of the brightness of the observation target when the voltage is applied (called "on") and not applied (called "off") to the filament.

Our experiments aim to understand appropriate pressure of filled hydrogen for the future comet exploration. We obtained transmittance spectra with several pressure conditions through the comparison of "on" and "off" data. Then, absorption width and depth are evaluated using Gaussian fitting. Wavelength scanning was performed using the G3M4 grating system with the range of 121.5-122.5 nm, 0.02 nm steps and summing 20 times. The higher hydrogen pressure is, the more difficultly the filament temperature rises, since hydrogen molecules take away the heat of the filament. Thus, experiments were conducted under three conditions –temperature of the filament is fixed, power applied to the filament is fixed, and applied voltage is fixed.

The results are shown in Fig. 1. When power or voltage are fixed, the temperature of the filament decreases and absorption gets shallower with higher pressure. On the other hand, when filament's temperature is fixed to 1800 K, absorption gets deeper. However, power consumption also increases. Although it seems that intermediate pressure (from 200 to 400 Pa) is the best so far, we need to precisely discuss it in terms of lifetime of filaments and available power onboard the spacecraft.

When voltage is applied, filaments are expected to glow like light bulbs, which causes the contamination of observation data. To verify this fact, we measured the brightness with shutters closed. As we expected, the filament gets brighter as its temperature rises. Besides, at constant temperature, higher hydrogen pressure is found to suppress the brightness. Utilizing this knowledge, we will soon estimate the expected S/N ratio of the instrument mounted on the spacecraft.

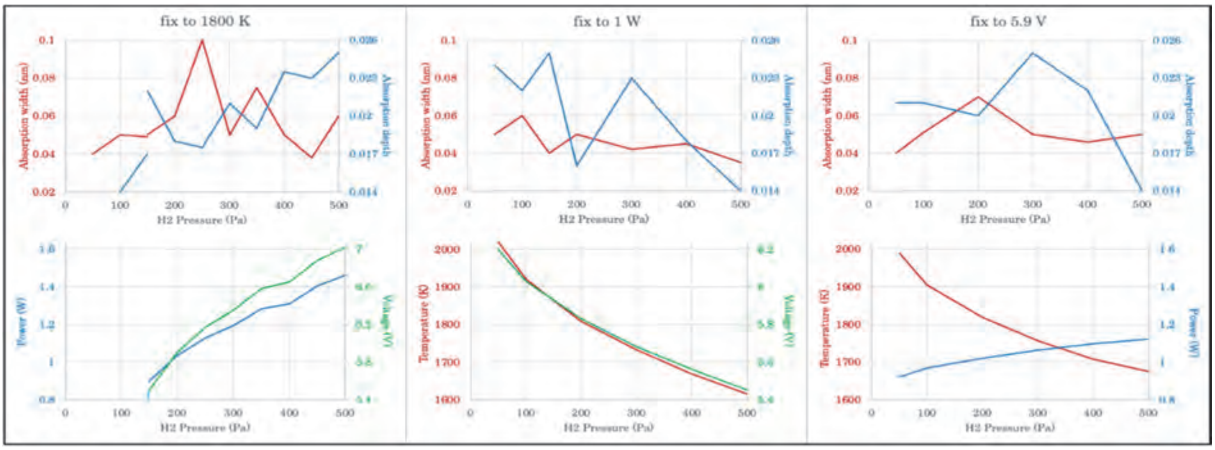

Fig. 1. Dependence of absorption width and depth on the pressure of filled hydrogen in the cell.

BL7B

The Effect of Space Weathering on The PAH Wavelength of Interstellar Dust Organic Matter

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In astronomy, extinction is the absorption and scattering of electromagnetic radiation by dust and gas between the emitting astronomical object and the observer. Interstellar extinction was first recorded in 1930 by Robert Julius Trumpler. However, its effects were already noticed by Friedrich Georg Wilhelm von Struwe in 1847, and its influence on stellar colors was observed by many, but they did not link it to the prevalence of galactic dust.

Polycyclic aromatic hydrocarbons (PAH) are a prevalent component of space organics and are present in interstellar dust. They play an important role in a variety of astronomical observations in the ultraviolet and far-infrared ranges, covering a wide range of objects and environments from meteorites and interplanetary dust particles to the outer solar system [1].

A prominent feature in the measured extinction curves of many objects in the Milky Way is a broad "bulge" at about 2175 Å, right into the ultraviolet region of the electromagnetic spectrum. This feature was first observed in the 1960s, but its origin remains unclear. Several models have been proposed to explain the bulge, including graphite particles containing a mixture of PAH molecules. Studies of embedded interplanetary dust particles (IDPs) have observed this feature and identified the presence of carriers of organic carbon and amorphous silicates in the particles.

The PAH present on Earth have an absorption band with a wavelength of about 210 nm. And due to the weathering of the universe, PAH may increase the wavelength range of the UV absorption band in the universe.

Therefore, it is assumed that the reflection band of PAH on Earth has a wavelength of about 210 nm, which may correspond to the absorption band of 217.5 nm that appears in the interstellar darkening curve (the curve describing the absorption spectrum of interstellar dust).

This experiment was conducted to observe and analyze the effect of space weathering on the light absorption properties of PAH. We prepared PAH samples Fig. 1) synthesized in the laboratory for comparison experiments with PAH samples exposed on the International Space Station (ISS) (exposed samples) and similar samples synthesized and stored in the laboratory (unexposed samples), both exposed and unexposed samples were made of PAH only and not mixtures. We divided the reflectance properties of these samples into three parts with the non-exposed samples in the wavelength range of 100-300 nm for the experiments and compared the reflectance properties.

The reflectance properties of the Coronene samples showed a significant decrease near 270 nm wavelengths and a trend in the 210-280 nm wavelength range where the attenuation of reflected light was more pronounced in the longer wavelength range (Fig. 2).

This trend suggests that the wavelength corresponding to the bottom of the depression may shift to longer wavelengths due to space weathering.

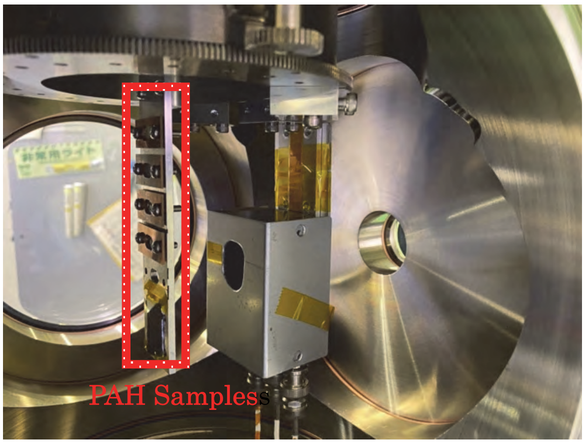

Fig. 1. PAH samples installation diagram.

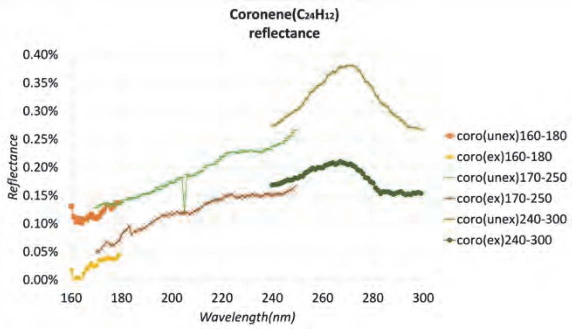

Fig. 2. The reflection characteristics of coronene samples in the wavelength range of 160-300 nm.

[1] Salama, Farid. (2008). PAHs in astronomy - A review. Proceedings of The International Astronomical Union. 251. 10.1017/S1743921308021960.

BL7B

A study on Space weathering of Carbonaceous Meteorites by Far-ultraviolet Spectroscopy

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We study space weathering in Carbon-complex asteroids by measuring the spectral shifts of carbonaceous meteorites due to weathering, focusing on the far-ultraviolet (FUV; 50-200 nm). The feature of the meteorite materials on this spectral area has not been much examined well.

Asteroids are believed to be well preserved in primitive state since they have been left out of the planetary formation process. Accordingly, they have been the focus of much attention as a clue to the nature of the early solar system. However, to analogize the past state from the present observations, it is necessary to understand the process of transformation such as space weathering.

Space weathering is the dominant transformation process on the surface of celestial bodies with thin atmospheres, such as asteroids. This process is caused by solar photons, charged particles like energetic electrons, and impacts by micrometeorites. The physical properties of such asteroid surfaces have been understood mainly through spectroscopic observations in the visible and infrared regions. However, the spectra in these regions of Carbon-complex asteroids are generally flat and have little characteristic shape [1]. On the other hand, the UV spectra of organic compounds vary remarkably with the degree of carbonization, suggesting that the UV region may be suitable for evaluating space weathering effects on Carbon-complex asteroids.

In this study, four types of carbonaceous chondrites included in the meteorites were irradiated with FUV light from the UVSOR BL7B, and the FUV spectra before and after the irradiation were compared (Fig. 1). To compare reflectance before and after UV irradiation, relative reflectance with respect to a specific wavelength was used.

As a result, bluing of the spectrum was observed in the wavelength range of 50~200 nm (Fig. 2). This change was the opposite of that observed for hydrocarbons using polystyrene, and like that observed for bodies with little or no organic matter, such as the lunar surface [2]. Since carbonaceous chondrites contain about 20 wt% of Fe, it is possible that a process of coating with Fe of several hundred nm in size occurred by the UV-irradiated surface, like that in the lunar surface.

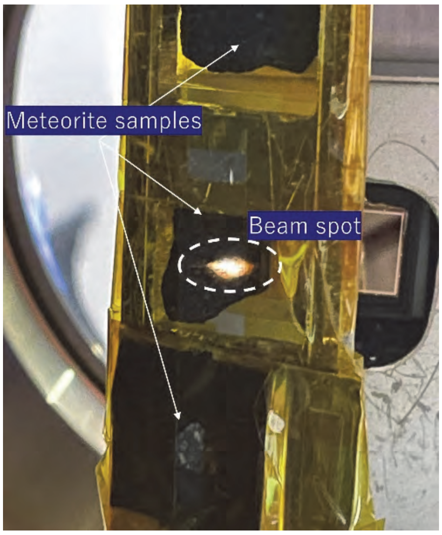

Fig. 1. Light irradiation of a meteorite sample.

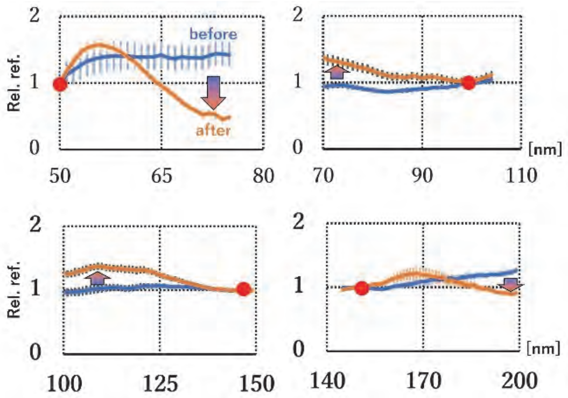

Fig. 2. Relative reflectance variation in a certain carbonaceous meteorite (“Aguas Zarcas”). (The horizontal axis is wavelength [nm] and the vertical axis is relative reflectance (normalized at red spots). Blue and orange lines correspond to before and after irradiation, respectively.)

[1] S.J. Bus& R.P. Binzel, Icarus, **158** (2002) 146.
[2] A.Hendrix *et al.*, Journal of Geophysical Research, **117** (2012) E12