

Life, Earth and Planetary Sciences



BL3U

Measurement and Assignment of 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 twodimensional 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 also other lipids, 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 dioctadecenyl-PC (DOPC), (dietherPC), and digalactosyldiacylglycerol (DGDG) were formed on the Si₃N₄ membranes of the XAS flow cell [2] by the vesicle fusion method. We prepared SLBs with few residual vesicles as shown in Fig. 1. Fluorescence recovery after photobleaching observation showed that fluid and continuous SLB covered the whole Si₃N₄ membrane surface. O-K edge XAS spectra of the Si₃N₄ 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 ~100 nm. The XAS spectrum of the Si₃N₄ membrane without SLB was subtracted from that with SLB.

The O-K-edge spectrum of DOPC, which has phosphate and carbonyl groups on its headgroup, appeared at 531 - 533 eV (Fig. 2a, black dotted line). Removing residual vesicles from SLBs drastically improved the S/N ratio [2]. Figure 2b shows the XAS spectrum of dietherPC, which have only the phosphate group. We attributed the components of the dietherPC spectrum to $1s \rightarrow \pi^*$ transitions of P=O and P-O-Na at 531.5 eV and 532.3 eV, respectively, based on the inner shell calculation. We assigned the single component at 532.0 eV in the DGDG spectrum (Fig. 2c) to C=O. Based on these assignments, we deconvoluted the DOPC spectrum to P=O, C=O, and P-O-Na (Fig. 2a, dashed lines).

In conclusion, we obtained O-K edge XAS spectra of SLBs in an aqueous solution with a sufficient S/N ratio to identify the components in the spectra. We will investigate the effects of the cation concentration and species on the XAS components in SLBs.



Fig. 1. Fluorescence image of DOPC-SLB on the the Si_3N_4 membranes of the XAS flow cell.



Fig. 2. O K-edge spectra of (a) DOPC-, (b) dietherPC-, and (c) DGDG-SLBs. Black dotted curves show raw data. Dashed curves and red solid curves show deconvoluted components and their summation, respectively.

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Improvement of Molecular Mapping for Thin Sections of Isolated Mammalian Nuclei Embedded in Resin Using STXM

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Spectromicroscopy using a scanning transmission X-ray microscope (STXM) has been widely accepted as a useful tool to visualize molecular distribution in specimens. Using STXM installed at BL4U, we have been developing an image processing procedure for the quantitative mapping of biomolecules, and successfully applied to the distribution of nucleic acids (DNA and RNA) and proteins such as histone and bovine serum albumin (BSA) in biological specimens using combined NEXAFS at the C, N and O-K absorption edges [1-3].

In continuing effort to obtain molecular distribution of thick biological specimen, we used thin-sectioned specimen to ensure sufficient transmitted X-ray photons [4]. However, the morphology of the specimen was not properly imaged to identify the inner structure of the nucleus. In the present study, we tried the following issues to explore a proper analysis procedure for molecular distributions in isolated mammalian nuclei embedded in agarose and resin: 1) the sectioning method to attain thinner specimen with high quality and 2) analytical procedure to obtain maps of biological molecules in the presence of agarose and organic resin.

Isolated nuclei from human HeLa S3 cells were fixed with glutaraldehyde followed by mixing with agarose to confine to limited volume, and then embedded in Quetol-812 epoxy resin with curing agents and a curing promoter as described previously [4]. The resin section of 0.2 μ m thickness was made by a microtome with a diamond knife in place of a glass knife used before. The section was attached directly on an address mesh (HF-15, Nissin EM) without any supporting membrane such as collodion to avoid the complexity of analytical procedure by the additional organic compound.

We applied our method to calculate the distributions of nucleic acids and proteins [3] with some modifications for the resin-embedded section specimens. In order to estimate the stack files of agarose and resin, we adopted an iteration procedure: First, the tentative stack files of agarose and resin were obtained with the SVD (Singular Value Decomposition) method applied to the observed data with the spectra for nucleic acids, proteins, agarose and resin. After subtracting stack files of agarose and resin, residual stack files including nucleic acids and proteins were calculated by our method [3]. The stack files of these biomolecules were used to obtain the secondly approximated stack files of agarose and resin. By using thus obtained stack files of agarose and resin, the improved stack files of biomolecules were calculated. The above procedure was repeated.

Figure 1 shows the X-ray image of the isolated nucleus at 398 eV (panel a), where the dense area in the center of nucleus is probably assigned as a nucleolus. The quality of the image was much better than the previous one [4]. Molecular images of DNA, RNA, and histone were shown in the panel b, c and d, respectively. DNA and histone seem to be preferentially co-localized in the nucleolus, while RNA had significant distribution all over the nucleus.



Fig. 1. Isolated nucleus of human HeLa S3 cell. (a) X-ray image at 398 eV, (b-d) Molecular distribution of DNA, RNA and histone.

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Nano-Structural and Chemical Analysis of Structural Color on an Elytron of a Jewel Beetle

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Structural color is not a real color but an optical phenomenon such as reflection, diffraction and interference. Some kinds of animals, birds, clam shells, squids and insects, have the structural color caused by fine periodic structures, whose size is nearly wavelength of visible light. The structural color often shows shiny and metallic color and is different from pigment color. Therefore, the animals with the structural color are sometimes treated as jewelry. A jewel beetle, Chrysochroa fulgidissima (Fig. 1), shows structural color, green with a red line, on its elytron and is used as ornaments on Tamamushi no zushi as a national treasure in Japan (made in 7th c.). On the other hand, the structural color is attracting the attention in industries as an ecological painting method because the structural color does not use pigments. In this research, the fine structures of the elytron of the jewel beetle are analyzed to understand origin of the structural color. Then, scanning transmission X-ray microscopy (STXM) is a powerful tool to analyze chemical and morphological information of the sample with high spatial resolution.

As a sample preparation, the elytron of the jewel beetle, which was captured in Ishikawa prefecture, is embedded in NER-814 epoxy resin (Nisshin EM Co. Ltd.) without chemical fixation and staining. Thin sections of thickness of 150 nm were cut by using ultra-microtome and set on a TEM grid with a support membrane. An energy stack of surface of the elytron with the embedded resin, was acquired with C 1s regime ($280 \sim 300 \text{ eV}$). Then, dwell time was 3 ms and scanning pitch was 30 nm step for each pixel, respectively. A STXM images (transferred as optical density) at 282, 286, 288 and 300 eV in X-ray energy and localized X-ray absorption spectra (XAS) are shown in Fig. 2. Positions of the XAS spectra are indicated in Fig. 2(b) as corresponded colors. The multilayers can be clearly distinguished only in a small energy region, from 285 to 287 eV and is probably 14 layers. A top layer, which decides color of the elvtron (orange in Fig. 2(b)), shows the lowest optical density in the observed region [1]. XAS of the darker layer (pink) is almost coincident with a substrate of the elytron (green). Therefore, the brighter layers (blue) with different chemical state are considered to be formed on the substrate layer during metamorphosis. From comparison of optical density for the excitation to continuum level between the two layers, difference of density is $\sim 6\%$. Even though this difference is small, the pair of the layers works as a multilayer to form structural color. For the next step, polarization of molecules of the elytron will be studied [2].



Fig. 1. Photo of a jewel beetle, Chrysochroa fulgidissima



Fig. 2. Optical density images at X-ray energies of (a) 282, (b) 286, (c) 288 and (d) 300 eV and (e) localized X-ray absorption spectra of the elytron of the jewel beetle.

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Analysis of 3D Structure of Extraterrestrial Organic Materials Using Combination of STXM-NEXAFS and SR Nano-tomography

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Unique structure of organic compounds in extraterrestrial materials, spherical in sub-µm radius and sometime accompanying with hollow structure, is considered to be informative about their origin and evolutional history [1,2]. In previous studies, most of such globules, called hollow organic nano-globules, were found in insoluble organic matter (IOM), which was extracted as residual of acid treatment of meteorites, to remove rocky materials. Content of organic matter in meteorites is up to 2 % for carbonaceous chondrite, and it is difficult to determine the organic globules in rocky meteorites by in situ analysis in previous studies. Thus, analyzing organic matters in IOM seems to be reasonable for previous studies.

However, organic materials were damaged and averaged, and their nature was lost by acid treatment of meteorites. For example, origin of hollow structure is uncertain, because materials inside the globule would lost during the acid treatment. Molecular structure is also changed due to averaging.

Recently, we obtained the distribution of organic component by in situ observation of ultrathin sections of meteorites, using scanning transmission x-ray microscopy and near edge x-ray absorption fine structure (STXM-NEXAFS) analysis, equipped at BL4U of UVSOR in previous studies [3]. The organic globules distribute widely in meteorites, and their number density was much higher than expected before, and reduced due to aqueous alteration.

In this experiment, we aim to obtain 3D shape and structure of the organic globules, using in situ observation with combination of the high resolution (HR) nano tomography developed at SPring-8, and STXM-NEXAFS. Pixel size of HR-nano tomography at SPring-8 is around 10 nm, and is enough to resolve the organic globules, although it is difficult to observe carbonaceous materials inside the rocky material due to large difference of linear attenuation coefficient (rocky material: 200 - 500 cm⁻¹, carbonaceous materials: 10 -20 cm⁻¹). In this study, we determined position of spherical holes in meteoritic samples using in HR-nano tomography at first. Then an ultrathin section around the largest hole was extracted by Focused ion beam (FIB). Figure shows mapping of C-NEXAFS of the ultrathin section extracted from A 12169 (CM) meteorite. It shows multiple small object, which shows organic

globules. Unfortunately, the globules were very small, less than 100 nm, and could not resolve even by HR nano tomography. Although we tried to make an ultrathin section of the largest globules observed in HRnano tomography, FIB fabrication with accuracy less than a micron meter was failed in this case.

In future work, we plan to improve accuracy of the FIB work. By putting marks on the surface of sample using FIB, we can determine the position of the largest globule in the sample with higher accuracy. In addition, The thin section was deformed and tilted slightly during thinning of the sample. Then objective organic globule could not be included in the thin section. We can fix the problem by holding both sides of the section by FIB grid.



Fig. 1. (a) mapping of intensity of carbon absorption (b) mapping with 3 phases blue: matrix, red: organic globules, green: carbonate. Some of tiny spots of high carbon absorption in (a) are coupled with red area of (b), suggesting that they are organic globules. However, their size is less than 100 nm and could not resolve by HR-nano tomography, in this time.

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Assessing the Debris Generated by the Small Carry-on Impactor Operated from the Hayabusa2 Mission

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The JAXA planetary exploration mission Hayabusa2 (to the near-Earth C-type asteroid (162173) Ryugu) is a combination of an asteroidal sample-return mission and detailed spectroscopic observations designed to improve our understanding of Solar System evolution from the point of view of organics and water (as hydrous minerals). The Hayabusa2 spacecraft is to have obtained Ryugu samples successfully (with a total amount of ~ 5.4 g) from surface and subsurface regions [1]. To obtain fresh subsurface samples from the Ryugu asteroid, a small carry-on impactor (SCI) was used to generate an artificial crater on the surface (e.g., [2,3]). Since very-high-explosive energy was required for the cratering operation of the Hayabusa2 mission, the SCI system contained HMX (the high-melting-point explosive cyclotetramethylenetetranitramine, C₄H₈N₈O₈) and other combustion chemicals. HMX is a typical high explosive that is used to produce a momentary driving force (e.g., [4]).

Because these materials may be possible contaminants in the subsurface samples, they must be investigated prior to analysis of the Ryugu samples. They may have been scattered around the surface of the Ryugu asteroid, including at the second touchdown site, and then have been collected into the sample container together with the asteroidal subsurface samples during touchdown sampling. We therefore set up an engineering model of the SCI experiment using an HMX mixture containing HTPB, IDP, and IPDI in an Ar atmosphere at ambient temperature and pressure in a closed system.

In this work, we report chemical and isotopic studies of the carbonaceous-based explosion products in addition to those presented by [5]. We used both nondestructive and destructive analytical techniques to identify the chemical nature of the materials. From SEM–EDS, we found the materials to be composed mainly of carbon, nitrogen, and oxygen, with a detectable amount of metals. Suitable parameters for identifying these materials are a FTIR peak at 1520 cm⁻¹, low reflectance and gentle red slope of FTIR spectrum compared with a Murchison CM2 chondrite, the Raman D and G bands, and the H, C, and N isotopic compositions and their spatial distributions. The STXM–XANES results (Fig. 1) provided the molecular nature of these highly aromatic materials, which was supported by results from TD–GC/MS. These results suggest that it is possible to distinguish either Ryugu samples or SCI materials as potential contaminants in a sample container by using proper combinations of analytical techniques. This assessment provides information useful for the analysis of the Ryugu asteroidal samples.



Fig. 1. Carbon-XANES of carbonaceous grains. Solid line is average of measured spectra together with spectrum of Murchison IOM (dotted line [6]). Grey area is a range of maximum and minimum absorptions observed among all spectra of each measurement.

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Penetration of Redox-Sensitive Nanocarriers in Human Skin Ex Vivo

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Redox-sensitive nanocarriers transporting drugs into human skin have been investigated. The goal of this research is to use local changes in the redox state of inflamed skin for controlled drug release. This requires redox-sensitive nanocarriers transporting the drugs over the skin barrier, which have recently been characterized by in vitro and ex vivo studies [1]. These core-multishell nanocarriers (CMS) contain dendritic architectures with sizes below 20 nm. Key is redoxsensitive sites that can lead upon oxidation to changes in local polarity of the sulfur sites (osCMS) or upon reduction to the cleavage of disulfides (rsCMS). In a first step skin penetration of these redox-sensitive nanocarriers has been investigated by scanning transmission X-ray microscopy (STXM). The challenge of these studies was the selective probing of the nanocarriers, since there is no distinct chemical shift compared to the majority species contained in the EPON fixed human skin samples. This required the use of a recently developed procedure of data reduction by singular value decomposition [2].

The present studies on human skin ex vivo consider changes induced by the topically applied oxidizer dibenzoyl peroxide (DBPO, 40 mg/mL dissolved in a 1:1 mixture of acetone/propyl myristate), which was applied to one half of the samples for 16 h prior to topical application of rapamycin-loaded nanocarriers (rapamycin: C51H79NO13, M = 914.13 g/mol). The nanocarrier samples (rsCMS (5 mg/mL, rapamycin loading: 2.7 %); osCMS (5 mg/mL) 0.5 % rapamycin loading) were formulated in HEC gel and 40 µL of this formulation were topically applied for 10, 100, and 1000 min to the skin samples, respectively. The final drug concentrations were 1 µg/cm² (osCMS) and 5.4 $\mu g/cm^2$ (rsCMS), respectively. The experiments were performed at the BL4U beamline of UVSOR III. They mostly rely on scanning of the photon energy in the O 1s regime (520 - 565 eV), allowing for the acquisition of stacks of images by concentrating on the stratum corneum, the top horny layer of skin. Selected results are shown in Fig. 1, where a comparison is made between a skin sample initially not exposed to DBPO (A) and another one with pretreatment (B). The skin samples were subsequently exposed for 1000 min to drug-loaded rsCMS. The top of each plot shows (a) an X-ray micrograph recorded at 532.04 eV. The skin surface is located at the right hand side of each micrograph. Clearly, the stratum corneum (SC) with its layered structure is visible besides the viable epidermis (VE). The spatial distribution of rsCMS is shown in (b). Less nanocarriers are found in the nonpretreated skin sample (A), which indicates that DBPO enhances the skin penetration of the nanocarriers. This becomes clearly visible from the integrated rsCMS signals as a function of depth. In the case of the not pre-treated skin sample only weak intensity is observed, whereas for the DBPO-treated sample (B) shows an enhanced rsCMS concentration. Integrations also show that the maxima of the local rsCMS concentration are correlated with narrow regions that are assigned to the lipid regions between the corneocytes. This is similar to earlier work on CMS nanocarriers that were not redox-sensitive [3]. Note that the present results could only be derived by singular value decomposition derived from data stacks containing the full spectral information in each pixel of the micrographs, whereas the previously used pairs of photon energies for probing the nanocarriers (cf. [3]) did not yield reliable results. Furthermore, the local rapamycin concentration was too low in the present samples to be detected. Subsequent work is required with enhanced drug loading to probe the redox-triggered drug release.



Fig. 1. Results from STXM of the top skin layers of fixed human skin without (A) and with (B) primary treatment with DBPO for 16 h followed by 1000 min exposure to reduction-sensitive nanocarriers (rsCMS): (a) X-ray scanning micrograph recorded at 532.04 eV; (b) spatial distribution of rsCMS; (c) integrated concentration of rsCMS.

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Chemical Mapping of Particulate Matter from a Marine Test-bed Engine with Varying Sulfur Content Fuels and a Laboratory Wet-Scrubber

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The marine shipping sector remains a large source of anthropogenic particle emissions [1]. In order to reduce particle emissions from ships, the international maritime organization (IMO) has implemented regulations that offer ship operators two primary options for compliance. They can either use marine low sulfur content fuels or high sulfur content fuels in conjunction with wet scrubbers as exhaust abatement system [2]. It is of large interest to investigate how both compliance measures affect physicochemical properties of exhaust particles and thus their potential role(s) within the climate system.

In June 2019 laboratory measurements investigating the effects of fuel sulfur content (FSC) and wet scrubbing on the droplet forming potential of exhaust particles from a marine diesel engine were performed using a cloud condensation nuclei counter (CCNC, DMT Inc.). Three different marine distillate fuels including a high sulfur content fuel, heavy gas oil (HGO), with a FSC of 0.86 wt % and two IMO compliant fuels with a FSC of < 0.003 wt %, marine gas oil (MGO) and hydrotreated vegetable oil (HVO), were used in a four-stroke marine test-bed engine. HGO was also used in conjunction with a laboratory wet scrubber which itself was operated using both fresh as well as seawater. While a reduction in FSC decreased the ability of the exhaust particles to act as CCN, wet scrubbing facilitated droplet formation significantly. Figure 1 shows the critical supersaturations, *i.e.*, the supersaturations needed to activate particles into cloud droplets, of exhaust particles for different mobility diameters.

STXM measurements of exhaust particles collected during a second campaign in 2020 helped to identify chemical information (*e.g.*, functional groups) of the particles, which indicates the mechanism causing the differences observed in CCN activity. The STXM results presented in this study were obtained at the BL4U beamline at UVSOR.

Figure 2 shows C K-edge NEXAFS spectra of 4 cases, *i.e.*, HGO (2 samples), MGO, seawater and freshwater scrubbing cases. Interestingly, the two HGO and seawater scrubbing cases show almost identical spectra, and the MGO and freshwater scrubbing cases are similar in line shapes. This indicates the different organic species and abundance of these 4 cases. In addition to the carbon edge, we also acquired N K-edge, S L-edge, O K-edge and Cl L-edge spectra. Further

analysis of this STXM dataset and comparison with gas (e.g., SO_2) and particle emission results is currently ongoing. A manuscript is in preparation.



Fig. 1. Critical supersaturations measured for exhaust particles of three different mobility diameters. The colors represent the different fuel types, "Fresh" and "Sea" designate wet scrubbed exhaust particles using fresh and seawater, respectively.



Fig. 2. Carbon K-edge NEXAFS spectra of sampled particles from HGO, MGO, seawater scrubber and freshwater scrubber cases.

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Study on Reflectance Characteristics of Mirror-polished Meteorite Fragments in the EUV Region

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We study the transition of the reflection spectrum in the UV region when the meteorites are exposed to solar UV for a long time. In preparation for the measurement of meteorites, we, in this time, measured the reflectance of mirrors with higher reflectance, since it is easier to be measured. The principle of reflectance measurement, such as decreasing higherorder rays and the design of jigs, is the same for meteorites and mirrors. These mirrors are also to be used for the Hydrogen Imager (HI) onboard Comet Interceptor (CI) mission launched in 2028. In this experiment, the transmittance of filters used for the same mission was also measured. Evaluation of the wavelength dependence and the incidence angle dependence of the mirrors' reflectance and the filters' transmittance is also important in estimating the radiance expected in CI/HI observations.

We estimated the mirror's reflectance (or the filter's transmittance) by calculating the ratio of the radiance when a mirror was placed on the main stage (or a filter was placed on the filter stage) to it when nothing was placed on the optical path (Fig. 1). Wavelength scan was performed from 110 nm to 140 nm in 0.2 nm step with summing 5 using G3M4 grating. A photo-diode was used as a detector. The slit width and the pinhole diameter were set to 0.5 mm and 1 mm, respectively. Two types of filters are used: named (f1) and (f2) here, whose transmission peak are around 122 nm and 120 nm, respectively. We also used two kinds of mirrors: (m1) and (m2), an aluminum mirror and a multilayer dielectric-coated mirror, respectively. Measurements repeated several times. Dark current were measurements were performed each time the position of the stages or the detector was moved.

As a result, the transmittance of the filters and the reflectance of the mirrors at an incident angle of 5 degree are as shown in Fig. 2.

Both filters had a maximum transmittance just under 10 %. Their spectra are so similar that no significant performance difference was found in this experiment. The reflectance of (m2) at an incident angle of 5 deg was found to be 3 times higher than that of (m1). However, when the incident angle was 10 deg, the reflectance of (m2) became 250 % at maximum (the figure is omitted). Although we re- measured in another day, the reflectance was still up to 200 %. It is possible that stray light has occurred in the experimental system. The further optimaization (stray light cut or noise reduction) for the setting are needed.



Fig. 1. The setup of the measurements.



Fig. 2. (a) Transmittance of the filters (b) Reflectance of the mirrors.

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The Influence of Space Weathering on The Wavelength of The Solar System Organic Matter PAH

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Polycyclic aromatic hydrocarbons (PAH or PAHs), known as polycyclic aromatic compounds or polycyclic aromatic hydrocarbons.

Reflectance spectroscopy can be used to analyze polycyclic aromatic hydrocarbons, because PAH has a very unique ultraviolet absorption spectrum. Each ring structure has a unique UV spectrum (Mansouri 2020), so each isomer has a different UV absorption spectrum. This is particularly useful in PAH identification. Most PAHs are also fluorescent, and when they are excited (when molecules absorb light) they emit light of characteristic wavelengths.

An analysis of the ultraviolet reflectance spectrum of interstellar dust has found an absorption band with a wavelength of 217.5 nanometers.

In order to understand the "extinction bulge" of the 217.5 nm interstellar medium (ISM), the spectral properties of carbon compounds have been extensively studied. The strongest feature in the interstellar extinction curve is the UV "bump" at 217.5 nm (Stecher 1965), also known as the 220 nm feature. The most obvious point of this feature is that the center wavelength is very stable, but the bandwidth varies with the environment of the universe. The ultraviolet spectrum of PAH has this characteristic.

It is known that those PAHs having a particularly large molecular weight have absorption band characteristics in the UV region, and PAH mixtures existing on the earth have an absorption band around a wavelength of 210 nm. Due to the weathering of the universe, PAH may increase the wavelength range of the ultraviolet absorption band in the universe. Therefore, assuming that the absorption band corresponds to the 217.5 nm absorption band appearing in the interstellar darkening curve (the curve depicting the absorption spectrum of interstellar dust), it can correspond to the PAH whose reflection band wavelength is approximately 210 nm on the earth.

This experiment is to observe and analyze the influence of space weathering on the optical properties of PAH. We have prepared PAH samples synthesized in the laboratory and PAH samples exposed on the International Space Station (ISS) (exposed samples) and similarly synthesized and stored in the laboratory (unexposed samples) for comparison experiments. (Both exposed and unexposed samples are made of PAH only, not a mixture.) We compared the reflection characteristics of these samples with the reflection characteristics of non-exposed samples in the 100-300 nm wavelength range (in lnm step).

The reflection characteristics of the coronene sample show a significant decline near the wavelength of 270 nm, and show a trend in the wavelength region of 210-280 nm, that is, the attenuation of reflected light is more obvious at longer wavelengths (Fig. 2). This trend indicates that due to spatial weathering, the wavelength corresponding to the bottom of the dip may shift to a longer wavelength.



Fig. 1. The main chamber of BL7B.



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

T. P. Stecher, Astrophys. J. **142** (1965) 1683.
E. Mansouri, V. Yousefi, V. Ebrahimi *et al.*, Sep Sci plus **3** (2020) 112.

UVSOR User 6



















