4th Japan-China Joint Workshop on Positron Science

JWPS2019

Book of Abstracts

Nara Kasugano International Forum IRAKA, Nara, Japan
October 28 – November 2, 2019

Japan-China Joint Workshop on Positron Science

Book of Abstracts of the 4th Japan-China Joint Workshop on Positron Science (JWPS 2019), Nara, Japan, October 28 – November 2, 2019

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Preface

The fourth Japan-China Joint Workshop on Positron Science (JWPS 2019) will be held on October 28 – November 2, 2019 at Nara Kasugano International Forum IRAKA, Nara, Japan. JWPS 2019 is organized by Kyoto University under the auspices of the Japanese Positron Science Society.

The workshop will gather scientists of the Asian area at the forefront of research on positron annihilation to share information on recent progress in this field. The main topics include a wide range of subjects involving fundamental aspects, applications as well as instrumentation. Keynote speakers will introduce subjects of broad interest and stimulate discussions. Plenty of time will be assigned to each presentation and informal style discussions to promote the exchange of information and ideas.

The scientific scope in the workshop is as follows.

A) Positron physics and positronium chemistry
B) Positron applications in metals, semiconductors, superconductors, and magnetic materials
C) Positron applications in porous media, polymers, membranes, and biomaterials
D) Positron applications in surfaces, interfaces, and thin films
E) Advances in positron annihilation analytical techniques and instrumental development

The first workshop, JWPS2012, was held in November 2012 at Wuhan University, Wuhan, China, and aimed to gather together scientists working in China and Japan at the forefront of research on positron science to share information on the most recent progress in relevant fields. One year later, a second workshop, JWPS2013, was held at the National Institute of Advanced Industrial Science and Technology (AIST), in Tsukuba, Japan. A third workshop, JWPS 2017, was held on June 9–11, 2017 at University of Science and Technology of China (USTC), Hefei, China. These China-Japan joint workshops provide valuable opportunities for exchanging ideas and the discussion of a wide range of subjects including positron science, material science developed/analyzed by positron techniques, and measurement techniques, etc. In particular, the workshops provide a good opportunity to promote international exchange between young researchers in positron science, thus making an important contribution to the future development of this research field.

Finally, we hope that fruitful discussion will be held at this workshop, JWPS2019, and you'll enjoy communicating with the participants.

On behalf of the local organizing committee

Hidetsugu Tsuchida

Quantum Science and Engineering Center & Department of Nuclear Engineering
Kyoto University, Japan

Workshop Venue

The workshop will be held in Nara, Japan, which is close to Osaka and Kyoto. The venue is Nara Kasugano International Forum IRAKA (http://www.i-ra-ka.jp/cn/), which is located in Nara National Park.

Welcome Reception

The welcome reception will take place on Monday, October 28 from 18:00 to 20:00. The reception venue is "KOTOWA" (Nara Park, Premium View) near Sarusawa Pond. It’s a 5 minutes’ walk from Kintetsu Nara station or a 15 minutes’ walk from JR Nara station.

Lunch & Dinner

A bento-box lunch and beverages will be provided for you during the workshop on October 29, 30, 31 and November 1. Also, dinner will be provided on October 29 and 31. Please enjoy Japanese-style dish.

Excursion & Banquet

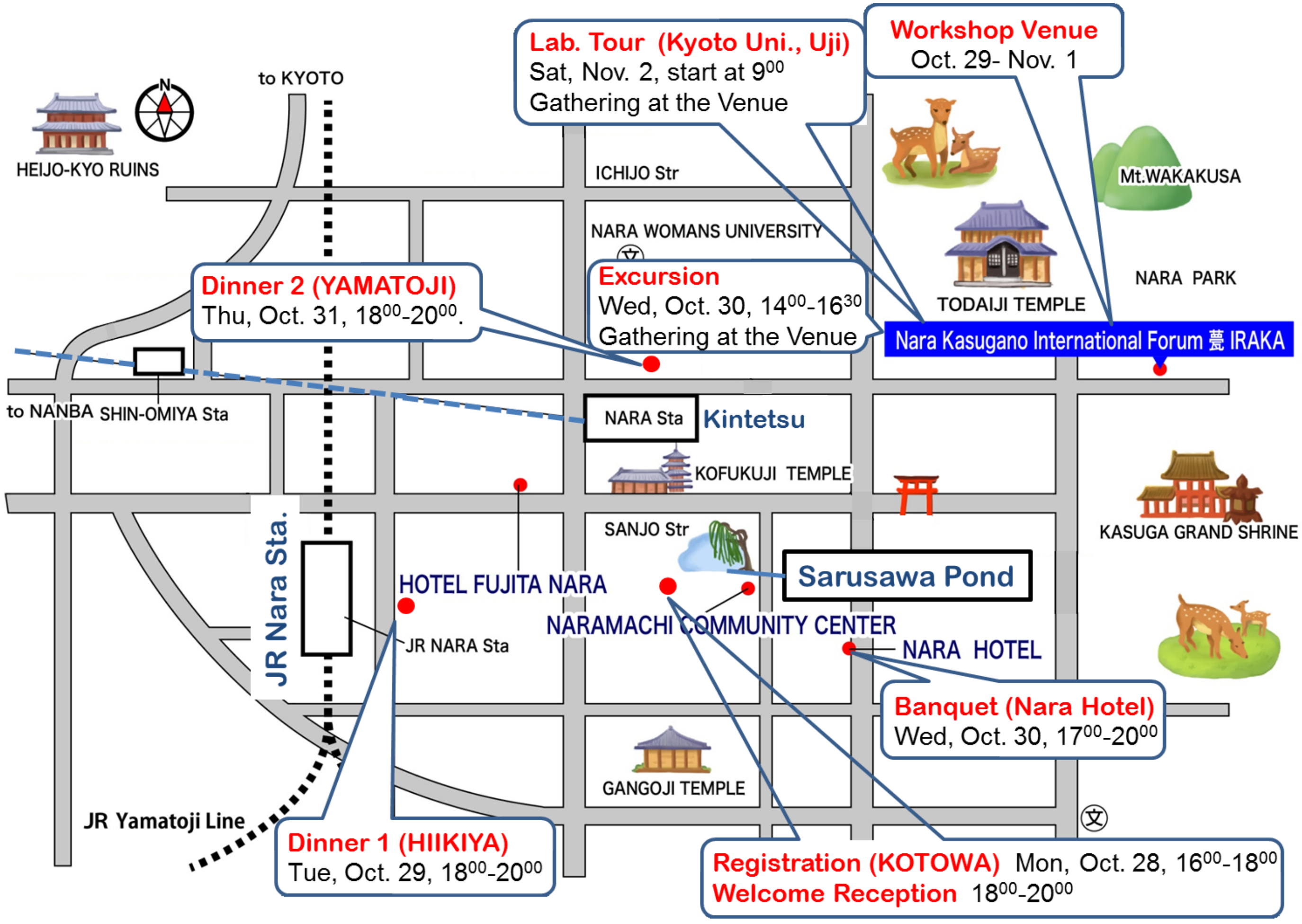
The excursion will take place on Wednesday, October 30 from 14:00 to 16:30, which is a guided walking tour around Nara Park. In this tour, we plan to visit Kasuga Grand Shrine and Todai-ji Temple (the Great Buddha Hall).

After excursion, the banquet will take place at "Nara Hotel". Please gather at 17:00 at the garden outside the banquet room. You can enjoy a welcome drink. After that, the banquet will be held from 18:00 to 20:00.

Laboratory Tour

The laboratory tour will take place on Saturday, November 2 from 9:00 to 13:00. We plan to tour the accelerator facility at Uji Campus, Kyoto University. Participants in this tour will go to there on the bus. The departure time and place is 9:00 in front of the entrance of the Workshop venue. The tour will be dismissed at 13:00 at the Workshop venue.

Event Information



Workshop Venue
Oct. 29- Nov. 1

Lab. Tour (Kyoto Uni., Uji)
Sat, Nov. 2, start at 9^{00}
Gathering at the Venue

Excursion
Wed, Oct. 30, 14^{00}-16^{30}
Gathering at the Venue

Dinner 2 (YAMATOJI)
Thu, Oct. 31, 18^{00}-20^{00}.

Dinner 1 (HIIKIYA)
Tue, Oct. 29, 18^{00}-20^{00}

Banquet (Nara Hotel)
Wed, Oct. 30, 17^{00}-20^{00}

Registration (KOTOWA) Mon, Oct. 28, 16^{00}-18^{00}
Welcome Reception 18^{00}-20^{00}

International Organizing Committee

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Supports

The workshop receives financial and other support from

- Inoue Foundation for Science
- Nara Visitors Bureau
- Quantum Science and Engineering Center, Kyoto University
- Japanese Positron Science Society
- Wuhan University
- University of Science and Technology of China
- Research Institute for Measurement and Analytical Instrumentation, AIST
- Research Institute for Material and Chemical Measurement, AIST

Sponsors

The workshop is held under the following company's auspices:

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- R-DEC Co., Ltd. (Exhibition)
- Niki Glass Co., Ltd. (Advertisement)
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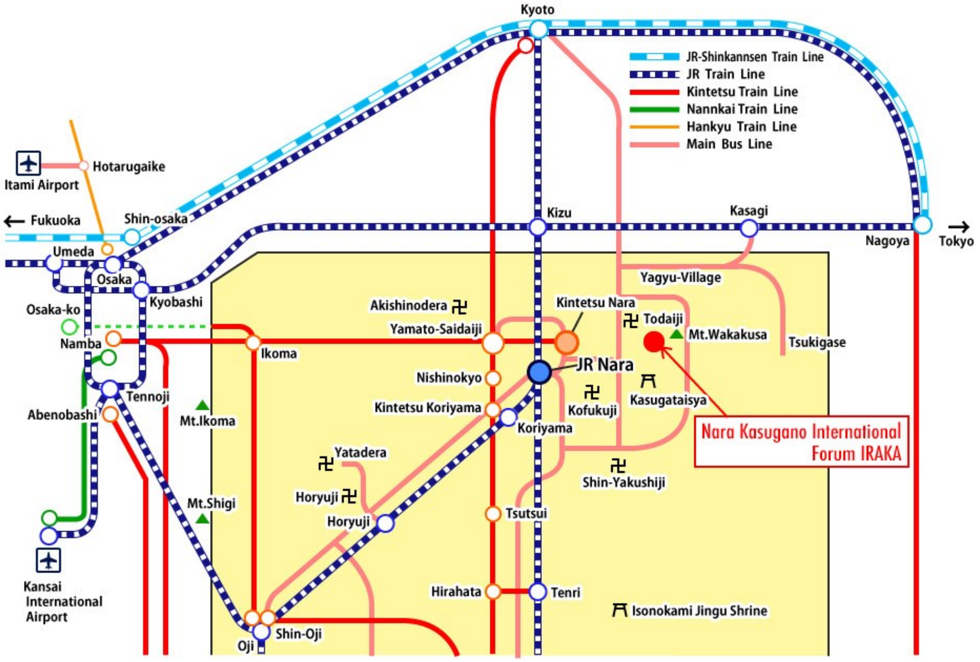
- Nitto Analysis Center Co., Ltd. (Advertisement)

Travel

The workshop will be held in Nara, Japan, which is close to Osaka and Kyoto. Participants from abroad have easy access to Nara (Kintetsu Nara Station) from Kansai International Airport (KIX). It takes about 90 min. by airport shuttle bus.
Time table “KIX ⇔ Kintetsu Nara Station and JR Nara Station is available at:
https://www.narakotsu.co.jp/language/cn/limousine/kix-nara.html

Railway Map



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I-01 Positron Annihilation in Water

Tetsuya Hirade [a, b]

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Keywords: positron annihilation methods, water, OH radical

Abstract

Water is probably one of important materials in our daily life. About 60 % of human body is consist of water and every day you need to drink water. There has been some water researches by positron annihilation. In water, many reactive species are formed by radiation. When a positron is injected in water, some excess electrons are formed even at the end part of the positron track. The injected positron is also thermalized at the same region. Therefore, the bound state of a positron and an electron, i.e. Positronium (Ps), can be formed there. When the excess electron is formed in water, a water cation is also formed and reacts with a water molecule immediately to form an OH radical. Some of the excess electrons are hydrated and live longer. Hence, there are many reactive species around Ps and the triplet Ps (ortho-Ps) has some possibility to react with these reactive species, because of the long annihilation lifetime of the ortho-Ps [1]. Longer ortho-Ps annihilation lifetimes at lower temperatures in water were explained by the ortho-Ps reactions. Positron annihilation age-momentum correlation (AMOC) measurements can observe the spin conversion reactions of ortho-Ps, because of the narrower annihilation gamma-rays energy distribution of the singlet Ps (para-Ps). AMOC measurements showed many interesting phenomena in water, especially for the reaction between spin-correlated OH radical and ortho-Ps [2]. I am going to explain the water researches performed by positron annihilation.

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I-02 Positron annihilation and proton conductivity studies of composite proton exchange membranes (PEMs)

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Keywords: Nafion, positron annihilation, proton conductivity, phase separation, sulfonated carbon nanotubes, metal oxide nanoparticles.

Abstract

Positron annihilation characteristics and proton conductivities of pristine and composite Nafion membranes were investigated under different environmental conditions. Metal oxide nanoparticles/Nafion and sulfonated carbon nanotubes(Su-CNTs)/Nafion composite membranes show improved proton conductivity, because the hydrophilic additives in membranes result in less tortuosity of the water channel network for proton transportation. PALS results show that variation in free volumes is closely associated with the development of hydrophilic ion clusters and the mobility of backbones in Nafion membranes as a function of water uptake. In particular, with increasing relative humidity, the maximum value of $\tau_{o\text{-}Ps}$ in pristine Nafion and metal oxide nanoparticles/Nafion membranes corresponds to formation of numerous water channels for proton transportation. Because the free volumes in ionic-water cluster phase and Nafion matrix phase are significantly different in size, which enable one to find two o-Ps lifetime components or bimodal lifetime distributions for the membranes at high relative humidities. Variations in the intensities of these two o-Ps lifetime components vividly demonstrate enlargement of ionic-water cluster phase in Nafion membranes during water uptake. Further, PALS results suggest that Nafion matrices were significantly reinforced and the mobility of Nafion backbones was decreased by Su-CNTs incorporated in Nafion.

References

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I-03 Overview of the PALS measurements of the chemical state in the pores of various zeolites

Luca Chiari[a], Haruka Noguchi[a], Chihiro Ohnuki[a], Masanori Fujinami[a]

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Keywords: positron annihilation lifetime spectroscopy, positronium, zeolite, chemical state

Abstract

Zeolites are aluminosilicate materials that come in various crystal structures and have regular tubular pores and cavities of sub-nanometer size. Zeolites are largely used as adsorbents, catalysts and molecular sieves owing to their large specific surface area, the tubular pores and their chemically active sites. The chemical surface properties of the pores significantly depend on the Si/Al ratio and the adsorption capacity of the zeolites [1]. Ortho-positronium (o-Ps) is well recognized as a powerful probe to study the average size of zeolite pores and any changes in their chemical state by adsorption and pore filling [2].

In this talk, we give an overview of our recent studies on the properties of the chemically active sites of zeolites pores upon gas adsorption by positron annihilation lifetime spectroscopy (PALS) measurements. Various zeolites (ZSM-5, ferrierite, beta, mordenite and Y) with Si/Al ratios of 2.5 to 115 were investigated. The zeolites were moulded into 3-mm-thick tablets and dehydrated in vacuum at 185°C for 2 h. PALS measurements were carried out in a dry environment (Ar, N_2 or dry air), as well as after exposure to the atmospheric humidity. The PALS spectra were analysed with the sum of four lifetime components and the second longest component is related to o-Ps pick-off annihilation in the zeolite pores.

In the dry state, the pore sizes calculated from the measured o-Ps lifetimes using the Tao-Eldrup model were consistent with the known values of the major axis diameter. The o-Ps lifetime and intensity decreased with smaller Si/Al ratios. This is due to the increasing number of Brønsted acid centers which partially suppress the o-Ps formation by trapping a fraction of the positrons and, at the same time, increase the o-Ps pick-off annihilation rate. After water adsorption in the pores, the o-Ps intensity decreased due to the blocking of the active sites on the pore surface causing partial quenching of o-Ps formation [2]. The effect of water adsorption was also confirmed by comparison with the measurements in dry air which showed almost the same results as in the dry state.

References

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I-04 Development of a LINAC based Neutron Source at AIST

Brian E. O'Rourke*[a,b], Takeshi Fujiwara[a,b], Kazuro Furukawa[c], Michihiro Furusaka[a,b], Noriyosu Hayashizaki[a,b,d], Hidetoshi Kato[a,b], Koichi Kino[a,b], Ryunosuke Kuroda[a,b], Koji Michishio[a,b], Takemi Muroga[b], Kazayuki Nigorikawa[c], Takashi Obina[c], Hiroshi Ogawa[a,b], Nagayasu Oshima[a,b], Daisuke Satoh[a,b], Norihiro Sei[a,b], Tamao Shishido[b], Ryoichi Suzuki[a,b], Masahito Tanaka[a,b], Yo Tomota[a,b], Hiroyuki Toyokawa[a,b], Akira Watazu[a,b]

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Keywords: Accelerator based neutron source, structural materials characterization

Abstract

Neutrons are a powerful probe of large sized samples due to their high penetration and measurement techniques which are sensitive to the internal material structure. In recent years interest in compact accelerator-based neutron sources (CANS) has increased as advances in neutron detector technology and development of techniques such as Bragg-edge imaging [1] mean that CANS facilities can produce images of lattice strain etc. in relatively large samples within a reasonable measurement time.

As part of the Innovative Structural Materials R&D project funded by the New Energy and Industrial Technology Development Organization (NEDO), and under the Innovative Structural Materials Association (ISMA) [2] we have developed a dedicated, linear electron-accelerator (LINAC) based neutron source at the National Institute of Advanced Industrial Science and Technology (AIST) in Tsukuba, Japan, for the characterization of structural materials [3].

The LINAC has a maximum design electron beam power of 10 kW (~40 MeV and ~250 mA), with neutrons generated via photonuclear reactions after the electron beam is irradiated on a water-cooled Ta target. The electron beam has a maximum pulse length of around 10 μs at a maximum repetition rate of 100 Hz. A neutron beamline designed for Bragg-edge imaging spectroscopy has been installed in combination with a decoupled solid methane moderator cooled to 20 K. In this contribution we will describe the preliminary operation and commissioning of the electron accelerator for the neutron source.

Acknowledgement: This paper is based on results obtained from a project commissioned by the New Energy and Industrial Technology Development Organization (NEDO).

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I-05 Study of Molecular Dispersion into Materials by Positrons Coupled with Other Techniques

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Keywords: molecular dispersion, open space, dielectric constant

Abstract

Dispersion of guest molecules into host porous materials is one of the most straightforward strategy that can access the nonlinear optical physics and reduction chemistry as well as high-density energy storage application [1], but the guest-host interaction limits the diffusion of guest materials [2-3]. In this study, dispersion of guest molecules by using liquid, gel, gas, and plasma were studied for a number of materials as glasses and oxides by positron annihilation spectroscopy coupled with other techniques. Intrinsic sub-nanoscale open spaces often probed by *ortho*-positronim (*o*-Ps) could play a role in loading guest materials in glass materials. Molecular dynamics (MD) simulation predicts the feasibility of physisorption for the boric acid molecule together with aqueous solution at ambient pH in the open space of MgO because the dielectric constant slightly decreases.

References

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I-06 Role of Open Spaces to Glass-Forming Ability in Bulk Metallic Glasses Studied by Positron Annihilation Spectroscopy

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Keywords: bulk metallic glass, positron, open space, glass-forming ability

Abstract

Open spaces in $(Fe_{71.2}B_{24}Y_{4.8})_{100-x}Nb_x$ (x = 3, 4, 5, 6) [1] and $Ce_{70}Ga_xCu_{30-x}$ (x = 6, 8, 10, 11, 12, 13) [1,2] bulk metallic glasses (BMGs) were studied by positron annihilation spectroscopy. Open spaces detected by positron in the amorphous matrix of BMGs are slightly smaller than the monovacancy of the main constituent elements. The following empirical some rules on glass-forming ability (GFA) were drawn based on the results of open space analysis together with literature survey [3,4]. When main constituent atoms in smaller size such as Fe, the solute atoms cannot diffuse therein and do not have an influence on GFA. On the other hand, main constituent atoms in larger size such as Ce form the large intrinsic open spaces, which are feasible to accept other elements thus being responsible for GFA. The present findings are of importance in designing BMGs with high GFA from the viewpoint of elemental combination of materials.

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I-07 Calculation of positronium-hydrogen atom reaction and its application to antihydrogen physics

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Keywords: positronium-scattering, antihydrogen atom, hydrogen negative ion, matter-antimatter science

Abstract

Positronium (Ps) scattering by an atomic target has been one of the intriguing subjects where discrepancy between theoretical calculations and experiments still remains [1]. Recent development of Ps beam [2] as well as positron accumulation techniques pave the way for future precise studies on Ps-atom scattering. Ps scattering by a hydrogen atom (H) involves fundamental aspects of Ps-atom collisions. Besides, the understanding of Ps-H scattering will be utilized for matter-antimatter science. For example, a rearrangement reaction between Ps and antihydrogen atom ($\overline{\mathrm{H}} = \overline{\mathrm{p}}\mathrm{e}^+$) has been featured recently as a promising scheme to produce an antihydrogen positive ion ($\overline{\mathrm{H}}^+ = \overline{\mathrm{p}}\mathrm{e}^+\mathrm{e}^+$) [3]. $\overline{\mathrm{H}}^+$ions are expected to be useful intermediates for preparation of ultra-cold antihydrogen atoms, which can be a good probe of gravity between antimatter and matter (the earth). $\overline{\mathrm{H}}^+$ ions can also be utilized to develop an energy-tunable antihydrogen beam that will be used in atomic collision experiments.

Recently, we have developed a 4-body scattering calculation method based on a Gaussian expansion method [4], and applied to Ps-H reactions [5]. This method allows us to obtain state-to-state reaction cross sections under rigorous boundary conditions of scattering and to obtain decay modes of resonance states. We will present our calculation framework and recent application to prediction of $\overline{\mathrm{H}}^+$ion production.

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I-08 Design of 2D Photo/Electrocatalysts for Promoting CO_2 Reduction

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Keywords: 2D catalysts, CO_2 reduction, defect structure

Abstract

Photo/electro- reduction of CO_2 into carbon-based fuels can not only decrease the concentration of CO_2 in the atmosphere but also yield high value-added chemicals such as methane and ethanol, holding promise to solve the increasingly serious energy crisis and environmental problems. To date, the main challenge for CO_2 photoreduction is the low conversion efficiency and poor product selectivity, while tackling these key scientific questions is considered to be the Holy Grail issue in chemistry. Benefiting from the large amount, highly active and nearly the same active sites of ultrathin 2D materials, we first employ them to serve as ideal models to tailor the crucial thermodynamic and kinetic parameters that determine the CO_2 conversion efficiency and product selectivity. In this report, we review our group's recent advances in the controllable synthesis and defect structure characterization of ultrathin 2D materials, and hence we investigate the role of structure variations on the CO_2 reduction efficiency and product selectivity. For instance, in order to accelerate the redox reaction kinetics, we design ultrathin 2D materials with abundant dual-metal sites, and disclose the dual-metal sites could change the CO_2 reaction pathway through converting the endoergic reaction to an exoergic reaction, thus achieving near 100% selectivity of target product.

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I-09 Time-elapsed change in the subnanoporosity for silica thin films elucidated by the slow positron lifetime technique and ellipsometric porosimetry

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Keywords: pore size, porosity, silica, time-elapsed, ellipsometry, positron, lifetime

Abstract

Control of nanoporosity for silica films has been extensively investigated in nanotech industries, to improve the functionality of various materials for sensors, separation membranes, and so on. Superior performances in those applications are believed to depend on the pore structures at the molecular level. Besides, adequate stability of the pore structure is also required to ensure the long-term usability of the devices using silica films. In the present work, we aimed to examine the effect of the elapsed time on the nanoporosity of silica films utilizing low-energy positron annihilation lifetime spectroscopy (PALS) and vapor-adsorption ellipsometric porosimetry (EP). Silica films were deposited on silicon wafers with different flow rate ratios of oxygen and tetraethyl orthosilicate (TEOS) employing plasma-enhanced chemical vapor deposition. The deposited films were kept under atmospheric conditions for 6 months. The open porosity of the present films was elucidated using a flow-type EP, while their average pore size was evaluated from the ortho-positronium lifetime using PALS. The obtained results indicated that the porosity and pore size for the time-elapsed films were decreased while the thicknesses were unchanged. This suggests that the porosity change of the present films, exposure to air for half a year, is ascribed to adsorption of water molecules from air, followed by filling up the nanoscaled pores as well as partial polycondensations between silanol groups at the silica grain boundaries of the present films. It was demonstrated that the combined use of EP and PALS is effective to elucidate the nanopore structure of time-elapsed silica thin films.

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O-01 Correlation between the Ion Permeation and Free Volume Property in Ethyl Cellulose Film during the Acid Treatment

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Keywords: Ethyl cellulose, positron science, ion permeation, acid treatment

Abstract

Ethyl cellulose (EC) can be applied as an erasable barrier coating. The microstructure of this coating is a key factor that influences the anti-corrosion property. To investigate the correlation between the hole structure and the acid treatment time, the microstructure of the ethyl cellulose immersed in acid for different time was evaluated. SEM showed that holes enlarged in the samples immersed for longer time. Electrochemical impedance spectroscopy (EIS) implied that the film resistance decreased, while the positron annihilation lifetime measurement indicated that the free-volume holes enlarged with the increase in the immersing time. All the results were in agreement with each other. A model has been proposed to explain the film resistance, where the film resistance was inversely proportional to the cross-sectional area of pores for ion permeation. The experimental data confirmed that free-volume holes acted as the tunnels for the ions permeating through the EC film. This could be a potential method to evaluate the tortuosity of holes in membranes by coupling the membrane resistance with free-volume hole size.

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O-02 Dielectric Behavior and Microstructure of Sandwich-structured High Energy Storage Poly(vinylidene fluoride) Composite Membranes

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Keywords: Dielectric behavior, Positron annihilation, Free volume, Poly(vinylidene fluoride)

Abstract

The development of advanced dielectric materials is of great important significance to the industry of electronics and energy systems. In this work, a type of polymer composite membrane with sandwich structure is fabricated to obtain high dielectric constant and superior electrical breakdown strength simultaneously. The outer layers of the sandwich-structured membrane are composed of barium titanate (BTO) particles dispersed in poly(vinylidene fluoride) (PVDF) to ensure the relatively high dielectric constant, while the central layer of the composite membrane consisted of hexagonal boron nitride nanosheets (BNNS) dispersed in PVDF to provide high electrical breakdown strength. The influence of filler contents on the dielectric properties of composite membranes is investigated. The positron annihilation lifetime spectroscopy (PALS), which is a widely recognized method for characterization of the free volume, is applied to study the effect of free volume of the PVDF nanocomposites on the dielectric properties. The results show that the dielectric properties of the sandwich-structured composite membranes is superior to that of composite membranes with single-layered structure. Consequently, the sandwich-structured composite membranes display a maximum permittivity of 35 and the maximum breakdown strength (410 $MV\cdot m^{-1}$) is achieved. Moreover, the composite membrane with 50 vol% BTO in outer layers and 12 vol% BNNS in the central layer displays a energy density of ≈14 $J\cdot cm^{-1}$ at Weibull breakdown strength of 334 $MV\cdot m^{-1}$, with an increase of 330% compared with the pristine PVDF membrane.

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I-10 Characterization of interface microstructure in a-Si:H/c-Si heterojunction solar cells via positron annihilation and ellipsometry

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Keywords: Positron Annihilation Spectroscopy, Amorphous Si, Heterojunction Solar Cells, Interface, Spectroscopic Ellipsometry

Abstract

The power conversion efficiency of amorphous/crystalline silicon (a-Si:H/c-Si) heterojunction solar cell has exceeded 26% recently [1]. Such a high efficiency is essentially achievable thanks to the notable passivation capability of the several-nm-thick amorphous silicon layer deposited on the c-Si surfaces. For further improvement of the performance it is necessary to understand and to control the structural properties of the a-Si:H/c-Si heterointerface in detail. Recently, we have found that there is a systematic correlation between the microvoid size determined by the positron annihilation spectroscopy (PAS) and the optical constant of a-Si:H by spectroscopic ellipsometry (SE) [2]. However, it has been still not clear that this correlation is universally consistent for any a-Si:H thin-films that are fabricated under various preparation condition using any different apparatus.

In this study, we deposited undoped a-Si:H films on H-terminated FZ Si(111) substrates under various chemical vapor deposition condition including different source gases (SiH_4 or Si_2H_6) and deposition systems. The average diameter of microvoids (D_{void}) and the dielectric function ($\varepsilon = \varepsilon_1 - i\varepsilon_2$) in these a-Si:H films were estimated via PAS and SE measurements, respectively. The peak values of the ε_2 (= ε_2^{peak}) were extracted from the dielectric function determined based on the Tauc-Lorentz dispersion model [3]. Interestingly, the D_{void} vs. ε_2^{peak} plots are aligned on a straight line. This result indicates that D_{void} in undoped nm-thin a-Si:H can be estimated readily from SE measurement results using the found D_{void} $-\varepsilon_2^{peak}$ linear correlation. Details in these methods and results will be discussed in the presentation.

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I-11 Structural defect effects on electrical properties of PZT-based ceramics

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Keywords: Defect, PMN-PZT ceremics, PZT ceremics, dielectric and piezoelectric properties

Abstract

PZT is the solid solution of $PbZrO_3$ and $PbTiO_3$. At high temperature it is cubic in paraelectric state. At low temperature, it is ferroelectric. Except for a narrow region close to $PbZrO_3$, the ferroelectric phase is divided into two regions of different symmetry, rhombohedral for Zr-rich compositions and tetragonal for Ti-rich compositions. The high piezoelectric response in this system is found at the boundary between these two phases, the so-called morphotropic phase boundary(MPB) [1]. The basic approach to achieve high piezoelectricity now is to locate the composition of material around the MPB[2]. However, the relationship between the local structure and macroscopic properties are far from being understood. It is well known that electrical performance of ceramics is closely related to microstructure defects. Positron annihilation technique (PAT) is a kind of powerful probe for defects in materials[3]. So it is a good choice to study the effect of defects evolution in phase transformation and electrical properties at MPB in PZT-based piezoelectric ceramics by PAT.

In this project, two series of ceramics, PZT($Pb(Zr_xTi_{(1-x)}O_3)$) and PMN-PZT(xPMN-(1-x)PZT(44/56), 0.2PMN-0.8PZTx/(1-x))ceramics, were prepared by a conventional solid state process from oxide precursors. For PMN-PZT series, defect evolution during ferro-ferro transition and its influence on electrical properties(including piezoelectric, dielectric properties) at MPB is studied by positron annihilation techniques. For PZT series, defects evolution mechanism during composition induced transition at room temperature and during temperature(20K-300K) induced transition at a fixed composition are investigated.

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I-12 Positron trapping at the effective open volume in FeCr alloy containing hydrogen/helium atoms

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Keywords: Shallow traps; helium/hydrogen; defect; positron annihilation spectroscopy; first-principles calculations

Abstract

Prior studies have shown that positron annihilation spectroscopy (PAS) is a sensitive probe of the shallow traps of light charged particles embedded in solids. The nature of the shallow traps that attract positrons—i.e., whether the properties of the light charged particles or the number of particles contained in the traps affects the probability of positron capture—has so far remained unresolved. Here, the shallow traps of positron in FeCr alloy, namely (H, He)-V nano-clusters with open volume, have been investigated by first-principles calculations and Doppler code. Various defect structures were modeled, including vacancies, interstitial helium atoms, and helium or hydrogen atoms occupying Fe vacancy sites. It was found that the charge density around a vacancy is much lower than around the neighboring He/H sites; moreover, the charge density at the He/H sites is, in turn, significantly lower than around the neighboring Fe/Cr sites. Positrons confined in the shallow traps exhibit lifetimes connected with effective open volume of (H, He)-V complexes. These results suggest that a helium atom forms a more repulsive ion core than a hydrogen atom when it occupies the vacancy, resulting in a decrease in positron lifetime.

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O-03 Effect of Free-Volume Holes on Static Mechanical Properties of Epoxy Resins Studied by Positron Annihilation and PVT Experiments

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Keywords: epoxy resins, static mechanical properties, free-volume holes, positron annihilation, PVT experiments

Abstract

The tensile, flexural, and fracture toughness properties of seven chemically different amine-cured epoxy resins were studied. Positron annihilation lifetime and pressure-volume-temperature (PVT) experiments were performed to each epoxy resin to characterize free-volume hole properties of hole size and hole fraction, respectively [1]. A negative correlation between hole fraction and hole size was revealed for these chemically different epoxy resins. Thereafter, better tensile and flexural mechanical properties (higher tensile modulus, lower tensile strain at break; higher flexural modulus, higher flexural strength, and lower flexural strain at break) were clearly observed for the epoxy resins with smaller hole size and higher hole fraction. However, no clear relationship between fracture toughness and hole properties was found. The correlations between static mechanical properties and hole properties for chemically different epoxy resins, provide a guideline for the further improvement of mechanical properties of carbon-fiber-reinforced polymers [2].

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O-04 Influences of composition and polyhedral distortion on positron annihilation parameters in perovskite $CsSnI_3$

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Keywords: Perovskite $CsSnI_3$, phase transition, positron annihilation

Abstract

With the increasing energy demand and consumption, the need to transition from fossil fuels to a more clean energy is becoming more and more urgent. Many organometal halide lead perovskites have attracted considerable attention as solar photovoltaic absorber owing to their low-cost fabrication procedure and relatively high efficiency. These developments make them promising candidates for next generation solid-state sensitized solar cell devices. However, there are many questions remain about the rapid degradation in their performance, which is preventing them from being large-scale commercialized. The less toxic tin (Sn) has been considered as a more environmentally friendly applications alternative to lead. Black polymorph $CsSnI_3$ with a bandgap energy of 1.3 eV is suitable for light absorption. It is well known that the room temperature structure of black polymorph $CsSnI_3$ is orthorhombic (B-γ) structure with a space group of Pnma. As the temperature increases, the orthorhombic phase will transform to tetragonal (B-β) phase with a space group of P4/mbm, and further transform to high temperature cubic (B-α) phase with a space group of Pm3m. The relative importance of the polymorphic behavior strongly depends on its process conditions. Carrier diffusion lengths and recombination rates are intimately associated with various defects in perovskites. Tin-based perovskites have a high density of Sn cation vacancy defects, which serve as p-type dopants and recombination centers. Positron annihilation spectroscopy is a sensitive probe for studying the structures of condensed matter on the atomic scale. The cell volume per formula unit increases throughout the phase transitions from orthorhombic to cubic and results in volume expansion of about 2.9%. However, the computational first-principles study of positron annihilations at different phases shows that the positron annihilation parameters in different phases are charged more noticeably.

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T-01 Positron microbeam experiments in AIST

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Keywords: Positron probe microanalyzer, Positron microprobe, Positron beam focusing

Abstract

The AIST positron probe microanalyzer (PPMA) is a positron lifetime measurement system using a pulsed, brightness enhanced slow positron beam [1]. A positron beam produced by an electron linear accelerator [2] is brightness enhanced by focusing the beam with a magnetic lens at a transmission type remoderator [3]. The remoderated positrons are accelerated and focused on the sample by an objective lens. The beam diameter is 30 -100 micrometers at the sample [4]. The beam is pulsed with a combination of two kinds of bunchers to measure positron lifetimes. Positron lifetime can be measured with a time resolution of 200-300 ps [5]. So far, many kinds of materials [6] including metals, semiconductor and polymers were studied with this microprobe. This slow positron beam was available in air by extracted the microbeam to the outside of the vacuum chamber through a thin vacuum window [7]. Then, it is possible to measure sample surfaces in rather practical condition [8 - 9].

Microbeam manipulation techniques and application results using the AIST-PPMA will be reviewed.

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T-02 Detector array for positron burst lifetime spectrum measurement

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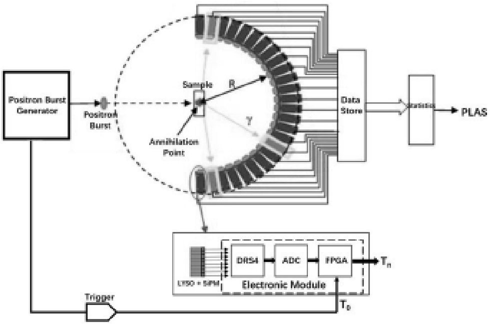
Keywords: Positron burst, detector array, time resolution, PALS

Abstract

High intensity positron bursts have been produced with the developments of positron trapping and femtosecond laser induced positron techniques. In this case, the positrons in the burst are usually injected into the target in several nanoseconds or even picoseconds and then annihilate, releasing huge number of gamma photons at almost the same time. The conventional nuclear techniques of timing measurement cannot pick out the time information for each annihilating γ-ray because of the overflow of detector. In this work, the method of a detector array, composed of enough independent detector cells, is proposed for detecting the positron burst. Based on the randomness of gamma photon emission direction, each photon in the burst can be recognized by the densely arranged detector unit in the array. We find that the detection efficiency of the array mainly depends on the single gamma detection efficiency, the intensity of the burst and the number of detector cells. If the positrons in a burst and the detector units are enough, a positron lifetime spectrum can be obtained during one shot.

For high sensitivity and good time resolution, LYSO crystal and silicon photomultiplier (SiPM) array, readout by multichannel fast waveform digitizing chip DRS4, are designed for the detector array system. There are 32 detector modules in the current system, and each module consists of 64 3 mm × 3 mm × 5 mm LYSO crystals coupled to the 3 mm × 3 mm SiPM one-to-one. All detector signals from the array are digitalized by the high-speed sampling DRS4 chip, and then the digital signals are uploaded to the field programmable gate array (FPGA), where the time of the signals is picked up by the timing algorithm, and finally collected by PC to obtain the PALS of the burst. Preliminary results have showed that the double 511 keV coincidence timing resolution of two single channel detectors can achieve 84 ps, ensuring the good time resolution of the whole system.



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T-03 Total-reflection high-energy positron diffraction (TRHEPD) and low-energy positron diffraction（LEPD） stations and experiments at KEK

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Keywords: Positron diffraction, TRHEPD, LEPD, Surface structure

Abstract

The Slow Positron Facility at IMSS, KEK provides an energy-tunable slow positron beam created by using a dedicated electron linac operated at ~50 MeV and 600W [1]. Positron diffraction experiments are conducted at two of the branches of the slow positron beamline: total-reflection high-energy positron diffraction (TRHEPD) at SPF-A3, and low energy positron diffraction (LEPD) at SPF-A4. TRHEPD [2] and LEPD [3] are positron counterparts of RHEED and LEED. It is to be emphasized that simply replacing the electron with the positron makes significant difference. In the case of TRHEPD positive charge of the positron is crucial. Since the electrostatic potential inside every material is positive, the positron incident on a crystal surface at a glancing angle smaller than a certain critical angle is totally reflected, probing only the structure as well as other properties of the topmost surface. When the incident glancing angle is greater than the critical angle, the positron penetrate into the crystal, refracting towards the surface and thus probing the atomic layers just below the topmost surface.

The main technique in THREPD has been the rocking curve analysis, i.e., glancing angle dependence of a diffraction spot intensity with azimuthal angle fixed. It has been applied to the atomic layer materials, such as graphene [2], silicene [2], germanene [2], and superconducting Ca intercalated bilayer graphene [4], as well as a surface of TiO_2 [2]. Another technique is azimuthal analysis [5], where the azimuthal angle dependence of the spot intensity with the glancing angle fixed is analyzed. It is first applied to $TiO_2(110)$-1×1 surface.

The first LEPD data obtained using linac-based high intensity positron beam was a pattern from Ge(001)-1×1 surface [5]. Currently improvement of the station is going on to replace a electrostatic lens system with a longer one for the sake of reducing γ ray background from a positron remoderator and to preplace a standard delay line detector with a hex-anode type for the sake of getting rid of a cross shape dead area [6].

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T-04 Progress of the slow-positron beamline development at the Kyoto University research reactor

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Keywords: positron source, slow positron, nuclear reactor, KUR, DBAR, PALS

Abstract

In Kyoto University, a slow positron beamline based on Kyoto University research Reactor (KUR) has been developed since 2012. KUR is a light-water moderated tank-type reactor with a thermal power of 1 MW or 5 MW and it has been used as an inter-university research reactor since its first criticality in 1964. The first positron beam was confirmed in 2014 [1] but it was necessary to stop the reactor for about 3 years to comply with new nuclear regulations. After the reactor was restarted in 2017, we continued the development of the slow positron beamline. In this talk, the following subjects are presented. (1) Temperature rise of the top of the beamline during the 5 MW operation and the reduction of the temperature. (2) Beam trajectory optimization as well as a brightness enhancement technique. (3) Development and optimization on positron analytical techniques such as Doppler broadening annihilation radiation (DBAR), positron lifetime spectroscopy (PALS), coincidence Doppler broadening (CDB) and age-momentum correlation (AMOC). We have measured actual samples simultaneously with the beamline development. Some examples from the obtained analytical results are introduced in the presentation.

Acknowledgement: We thank many colleagues of Kyoto Univ., Tohoku Univ., AIST, KEK, Tokyo Univ. of Science, Technical University of Delft and Technical University of Munich for their invaluable help during the development of the beamline.

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T-05 Improvement of a detection system for observing low-energy positron diffraction using a linac-based slow-positron beam

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Keywords: Low-energy positron diffraction (LEPD), Low-energy electron diffraction (LEED), surface structural analysis

Abstract

Low-energy positron diffraction (LEPD), which is the positron counterpart of low-energy electron diffraction (LEED), has been recognized by a LEED theorist as an ideal surface structure analysis method [1]. Unfortunately, however, LEPD experimental research has been discontinued for last two decades because of the difficulty in obtaining a low-energy positron beam with adequate intensity and quality. Recently, we have developed a LEPD experimental station, which takes advantage of a high-intensity slow-positron beam at KEK [2].

Our original LEPD system employed a two-layered delay-line detector (DLD) [3], which was a two-dimensional position sensitive detector, for observing diffraction patterns. Two wires wound in the vertical and horizontal directions were placed at the back side of the micro-channel plate (MCP), and coordinate information was obtained from the difference of signal arrival timing at the both ends of each wire. Since the LEPD detection system has a center hole for the normal beam injection, the DLD has a crossed dead area where one of the wires is not wound. This dead area forced inefficient experiments, and also prevented us from evaluating LEPD Patterson function inversion, which gave a map of inter-atomic positions. Now we are introducing a new LEPD/LEED system with a three-layered DLD (DLD with hexanode) [4], which gives no crossed dead area even with a center hole.

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T-06 Correlated positron-electron pair emission from surfaces

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Keywords: electron correlation, low-energy positron, coincidence spectroscopy

Abstract

The impact of a primary low-energy positron onto a surface leads to the emission of a correlated positron-electron pair [1,2]. In combination of a lab-based positron beam [3] and a coincidence electron/positron spectrometer dedicated for surface science, we studied this pair emission from various surfaces, such as noble metals, ferromagnetic metals and thin oxide films. We found a marked increase of the intensity levels for oxides compared to the metallic surfaces, suggesting the positron-electron pair intensity is scaled with the electron-electron interaction strength of the materials, as well as our previous studies with primary electron excitation or photon absorption [3]. Surprisingly, we also observed a correlated electron pair due to the impact of single low-energy positron, with an intensity on the same scale as the positron-electron pair intensity [4]. A similar strong material dependence of the coincidence intensity was also observed in the electron pair intensity as the positron-electron pair intensity. Our works demonstrate experimentally the feasibility of positron-impact coincidence spectroscopy in determining the electron correlation strength of materials.

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T-07 Experimental progress towards positronium Bose-Einstein condensation

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Keywords: positronium, Bose-Einstein condensation (BEC), laser cooling, antimatter

Abstract

Ortho-Positronium (o-Ps) is one of the best candidates for the first Bose-Einstein condensation (BEC) of any system containing antimatter. Ps-BEC can be used to measure antimatter gravity using an atomic interferometer. It can also be used as a source for a 511-keV gamma-ray laser. We proposed a new scheme to realize Ps-BEC using a positron focusing system and fast cooling of Ps [1]. Our target density and temperature for Ps-BEC is $\sim 10^{17}$ cm^{-3} at ~10 K. We are currently trying laser cooling of Ps at KEK slow positron facility (SPF). I will summarize our recent experimental progress towards Ps-BEC [2].

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[2] Details will be discussed by K. Yamada (Ps cooling laser), K. Hashidate (positron focusing lens), and K. Shu (Ps 1S-2P excitation) in the Student Session on Nov. 1.

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T-08 A high-quality and energy-tunable positronium beam and its applications

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Keywords: positronium beam, positronium negative ion, photodetachment

Abstract

Recently, an efficient production method of positronium negative ions, a bound state of two electrons and a positron, has been realized by the bombardment of slow positrons onto alkali-metal coated tungsten surfaces [1]. This achievement enables us to perform novel laser spectroscopic studies on positronium negative ions, photodetachment [2], resonant photodetachment [3] and subsequent production of energy-tunable positronium beam [4].

In the present work, we have constructed a high-quality and energy-tunable positronium beam system, built upon a trap-based positron beam, employing the efficient source of the ions and the photodetachment techniques [5]. Slow positrons generated from a ^{22}Na source in conjunction with a solid Ne moderator are stored in a two-stage buffer-gas trap [6] and then extracted as nano-second pulses. They are focused onto a Na-coated tungsten film (100 nm thick), and resultant positronium negative ions emitted from the opposite surface are accelerated to an arbitrary energy and then phodetached by a pulsed laser beam (1064 nm, 500 mJ/cm^2) to form an energy-tunable positronium beam. The obtained beam, which has much higher quality than previously reported, will be utilized for fundamental studies on the positronium spectroscopy by means of the motion-induced resonance technique [7], and studies on positronium interacting with surfaces [8].

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S-01 Development of cooling laser for positronium Bose-Einstein condensation

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Keywords: positronium, Bose-Einstein condensation (BEC), laser cooling, antimatter

Abstract

One of the challenges to realize Ps-BEC is fast cooling of Ps [1]. We perform the fast cooling of Ps by thermalization between Ps and cold porous Ps convertor followed by laser cooling. Several special features of cooling laser are necessary because of the short lifetime (142 ns) and the light mass of Ps: 243 nm (1S-2P transition), long pulse width (>300 ns), and broadband (>150 GHz). The core part of the cooling laser system has been completed. We have produced a long pulsed laser (500 ns) by long-lifetime Ti:Sapphire cavity, and broadened the laser by generating sidebands up to 300th order using electro-optic phase modulator (EOM) in the cavity. We are going to perform a Ps laser cooling experiment at KEK slow positron facility (SPF) hopefully in this winter.

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S-02 Development of focusing lens for high-density positron beam

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Keywords: dense positron beam, positron focusing, brightness enhancement system

Abstract

One of the challenges to realize Ps-BEC is to create dense Ps atoms (~10^{17} cm^{-3}) [1]. We achieve high-density Ps by increasing the brightness of the incident positron beam (10^8 e^+/ 50 ns bunch, 5 keV, polarized). We have proposed a scheme consisting of a positron trap, a 2-stage brightness enhancement system (BES), and an adiabatic guiding using solenoids, which in calculation has enough focusing performance for Ps-BEC. As a first step to design a dedicated positron focusing lens for BES, we started with focusing positron beams using a magnetic lens prototyped by AIST. We used the beamline for Ps laser cooling experiment at KEK Slow-Positron Facility (SPF) and measured the performance of the lens. 5-keV positron beams were focused from 5.0 mm to 1.5 mm, which agreed with our simulation. I will present a brief overview of our scheme of positron focusing, details of the measurement of the prototype lens at KEK, and future prospects to develop a positron focusing system for Ps-BEC.

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S-03 Excitation of positronium by laser for efficient cooling

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Keywords: positronium, laser cooling, 1S-2P transition

Abstract

One of the biggest challenges to realize Ps-BEC is rapid cooling of *o*-Ps in around 300 ns before the most of created Ps annihilate into gamma rays. We have proposed and developed a new method in which spatially confined Ps are cooled by Doppler cooling by an ultraviolet 243 nm laser[1]. A proof-of-principle experiment to excite ground (1S) state *o*-Ps into 2P state was conducted to study its unclear behavior in silica pores of 50—100 nm size. As a similar report by using porous silica thin films [2], we observed a high annihilation rate of Ps in 2P state. We also found that the resonance width of the 1S-2P transition was as broad as 1 nm. I will discuss the details of the experiment, possible mechanisms of the enhanced annihilation, and ongoing experimental attempts for laser cooling of weakly confined Ps in vacuum.

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S-04 Timing performance of scintillation detector based on SiPM

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Keywords: PET, coincidence resolving time, SiPM, LYSO, LFS-3

Abstract

Positron emission tomography (PET) is a tool for metabolic imaging that has been utilized since the earliest days of nuclear medicine. The scintillator is a key component which determines the overall performance of PET detectors. Scintillators with fast timing in addition to high light yield are required to achieve better performance. Since been used as a fast PET photosensor, increased attention has been paid to silicon photomultiplier (SiPM) arrays. Compared to the photomultiplier tube, SiPM has a higher quantum efficiency, a more compact size, and a much lower price. Considering the evident advantages of SiPM, we conducted a series of experiments to obtain the best coincidence resolving time (CRT) with SiPM-based scintillation detectors using LFS-3 and LYSO scintillators. The performance of the detector was studied with four different scintillator lengths of 5.0, 9.5, 13.8, and 20.0 mm. At the same experimental conditions, with LFS-3 scintillator length decreasing from 20.0 to 5.0 mm, the CRT (in FWHM) of detector was significantly improved from 186.7 to 154.2 ps. For the detectors with LYSO scintillators, the CRT increased from 183.4 to 142.2 ps with decreasing scintillator length from 20.0 to 5.0 mm. The aim of this work is to present timing capabilities of detectors based on SiPM coupled with different scintillators and increasing length.

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S-05 Investigation of defect states in light-irradiated single crystal ZnO by low-temperature positron annihilation lifetime spectroscopy

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Keywords: zinc oxide, electron irradiation, Electron Spin Resonance (ESR), visible LED

Abstract

It is commonly recognized that wide-bandgap compound semiconductor zinc oxide (ZnO) has potentially better properties compared with widely developed Si and GaN. However, the nature of native defects, in particular, persistent photoconductivity (PPC), has not been sufficiently clarified yet. Previous theoretical and experimental studies suggested that transient energy levels related to charge states of the anion vacancy (V_o) cause PPC [1–3]. In this study, we use positron annihilation lifetime spectroscopy to investigate defects relating to PPC.

A single crystal ZnO synthesized by a hydrothermal growth method was irradiated to 6×10^{18} e^-/cm^2 with an 8 MeV electron beam from a KURNS-LINAC for introducing point defects. After that, the sample was measured by electron spin resonance (ESR) and positron annihilation lifetime spectroscopy at 77 K under light illumination with blue and red light emitting diodes (LED). We found that the average positron lifetime during the red-LED illumination were lower by about 10 ps than that during the blue-LED illumination. Calculated positron lifetimes for V_{Zn}, V_{Zn}-H and V_O have been reported to be 207 ps, 179 ps and 159 ps, respectively [4]. The average lifetime change depending on illumination of blue and red LEDs can be attributed to the ionization states of V_O. In principle, positron annihilation in the positively ionized vacancies cannot be observed. The excitation of V_O during the blue LED illumination increased the number of positively ionized V_O and then the annihilation in V_{Zn} or V_{Zn}-H is considered to be dominant. The excited V_O returned to the ground state by illumination with the red LED, and some of the positively charged V_O were neutralized, leading to the decrease in the average positron lifetime. These results provide new insight into our understanding into the mechanism of PPC caused by anion vacancy at ZnO.

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S-06 Study of interaction mechanism between positrons and Ag clusters in AlAg alloys at low temperature

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Keywords: AlAg alloy, Ag clusters, positron annihilation, monovacancy, shallow trapping

Abstract

The positron trapping and annihilation mechanism in AlAg alloys embedded with Ag clusters in various structures was investigated. The evolution of positron trapping and annihilation behavior at low temperatures ranging from 10 K to 300 K was investigated by combined use of Positron Annihilation Lifetime Spectroscopy (PALS), Transmission Electron Microscopy (TEM) and Coincidence Doppler Broadening Spectroscopy (CDB). It is shown that Ag clusters in AlAg alloys act as shallow trapping sites for positrons at low temperature and the positron annihilation rate is considerably enhanced with the decreasing measurement temperature. Based on a simulation using a positron annihilation three-state trapping model, it is inferred that the trapping rate of Ag clusters and monovacancies will have the same trapping rate at higher temperatures, and the measured results suggest this crossover occurs around 200 K.

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S-07 Annealing behavior of vacancy-type defects in rare-earth implanted GaN studied by a slow positron beam

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Keywords: positron annihilation, GaN, rare-earth, ion implantation, gallium vacancy

Abstract

GaN has been extensively studied as a promising material for the application of ferromagnetic semiconductor devices. Ga vacancies in rare-earth implanted GaN are expected to affect magnetic properties [1] and the implantation of rare-earth element having a large radius will affect the distribution of vacancies in GaN. In this study, the annealing behavior of Ga vacancies in rare-earth implanted GaN was investigated by a slow positron beam. The GaN film was grown on sapphire substrates by a MOCVD technique with a thickness of 2 μm and 50 keV Tb^+ was implanted into GaN film by ion implantation with a dose of 2×10^{14} cm^{-2}. The GaN film was annealed in an infrared-lamp furnace for 20 seconds per 200°C in the range from 200°C to 1000°C. After each annealing, Doppler broadening spectra of the annihilation radiation were measured as a function of incident positron energy. When the annealing temperature increased, the increases of *S* parameters were observed and the clustering of vacancies was suggested from the (*S*, *W*) plot.

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S-08 Data-scientific software for the surface structure analysis by total-reflection high-energy positron diffraction (TRHEPD)

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Keywords: total-reflection high-energy positron diffraction (TRHEPD), surface structure, data science, supercomputer

Abstract

A data scientific software has been developed for the surface structure analysis by the total-reflection high-energy positron diffraction (TRHEPD). The experiments intensively conducted at the Slow Positron Facility (SPF), Institute of Materials Structure Science (IMSS), High Energy Accelerator Research Organization (KEK) are revealing the structure of the surfaces of interest [1]. The present paper reports the recent activity of the software development for the analysis of TRHEPD data and demonstrates the application to some known surface structures, as preliminary attempts. It is based on the inverse problem in which the atomic positions $X = (X_1, X_2, \ldots, X_N)$ of a surface structure are determined from the experimental diffraction data (rocking curve) D_{exp} ($D_{\mathrm{exp}} \Longrightarrow X$). The forward problem ($X \Longrightarrow D_{\mathrm{cal}}(X)$) is solved, for many trial atomic positions X, by the numerical solution of the partial differential equation in quantum scattering problem [2]. The R-factor $R(X) = |D_{\mathrm{cal}}(X) - D_{\mathrm{exp}}|$, the residual error between the experimental and calculated diffraction data, is minimized as a function of the atomic position. A method is tried where a global search procedure by the grid or stochastic sampling (Monte Carlo) method followed by a local search procedure by the gradient-free optimization (Nelder–Mead) method. The global search procedure requires a large computational cost and is realized on supercomputers with parallel computation. The program code is written mainly in the Python language and will be available online in near future.

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S-09 Gamma induced Positron Spectroscopy for bulk materials by using MeV energy direct current Laser Compton Scattering gamma beam

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Keywords: positron annihilation, non-destructive test, LCS gamma, bulk material

Abstract

We have tried a new positron annihilation method by directly implantation the 16.9 MeV Laser Compton scattering (LCS) gamma beam into the bulk materials at NewSUBARU synchrotron radiation facility, LASTU, University of Hyogo, JAPAN. In this method called Gamma-ray induced Positron annihilation Spectroscopy (GiPS), positron creation and annihilation take place simultaneously in the samples. Therefore, GiPS can nondestructively detect the information about defects in a bulk material, and some facilities have studied it so far [1,2]. Almost of them are few MeV order X-rays in maximum, but in our LCS gamma source is direct current and higher energy more than 10 MeV created at synchrotron radiation facility. Using this high energetic gamma photon, we have three advantages in positron annihilation experiment; one is higher efficiency of positron production in target materials, the second one is measurable defects in centimeters depth without sample destruction and the last one is that positron experiment can be done in any environments for example in an atmosphere. LCS gamma photon is generated by scattering with laser photon and relativistic electron. The energy of LCS gamma photon is determined by the wavelength of the laser and kinetic energy of the electron. By using Nd:YVO_4 laser (wavelength 1064 nm) and 982 MeV electron from circling in the storage ring, 16.9 MeV LCS gamma photon flux is produced as a gamma beam. In this study, Doppler broadening measurement by the direct implantation of this LCS gamma beam into bulk amorphous and crystalized $Zr_{55}Cu_{30}Al_{10}Ni_5$ alloys of the size of 40 mm x 30 mmφ without sample destruction has performed. These samples have already studied by using 8 MeV fast positron beam, showing the decreasing of open volume by the crystallization in a bulk amorphous alloy [3]. However, the result of GiPS reveals that not whole the sample is crystalized but amorphous state remains slightly in the crystallized sample.

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S-10 Development of AMOC measurement system for radiation damage in materials under ion irradiation

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Keywords: AMOC, ion irradiation, damage evolution, free volume

Abstract

We study ion irradiation-induced damage evolution in materials by in situ positron annihilation spectroscopy. Previous investigations using positron annihilation Doppler broadenings [1] and lifetime spectroscopy [2,3] have demonstrated that transient defects are produced under irradiation. In this talk, we will report in situ observations of ion damage in amorphous materials by positron age-momentum correlation (AMOC) measurement. The AMOC system is based on β^+–γ coincidence method with ^{68}Ge positron source.

The irradiation experiments were performed at the ion accelerator facility at the Quantum Science and Engineering Center, Kyoto University. Target specimens were fused quartz with a thickness of 125 μm (Goodfellow Co.). The target was irradiated with 2 MeV H^+ beams in the flux range 2.3×10^{11} cm^{-2} s^{-1}–1.5×10^{12} cm^{-2} s^{-1} at a fluence up to 8×10^{16} cm^{-2}. The AMOC spectra were measured during ion irradiation.

In this study, we focus on radiation damage effect around free volume of fused quartz, and investigate its damage evolution from changes in S parameter for *ortho*-positronium (o-Ps) pick-off annihilation. Results showed that the S parameter increases by ion irradiation, suggesting the pick-off annihilation of o-Ps with low-momentum electrons. We will discuss influence of beam flux on radiation damage around free volume.

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S-11 Enhancement in photoelectric properties of ITO films by regulating defects and impurities with supercritical fluid treatment

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Keywords: ITO films, $SCCO_2$, doping, defect.

Abstract

Tin-dopping in In_2O_3 can supply extra electrons to increase the carrier concentration of indium tin oxide (ITO) thin films. However, defects and impurities which are rich at grain boundaries will result in strong carrier scattering. In this work, ITO films, prepared by magnetron sputtering, were subjected to supercritical carbon dioxide ($SCCO_2$) fluid treatment with different concentrations of $InCl_3$ solution for the purpose of regulating defects and impurities at the grain boundaries. The samples were studied by X-ray diffraction (XRD), atomic force microscope (AFM), X-ray photoelectron spectroscopy (XPS), UV-Vis spectrophotometer and Hall measurements. Compared to the untreated samples, the photoelectric performance of the $SCCO_2$ fluid treated samples were improved significantly. Results indicated that, upon supercritical fluid treatment, the dehydration effect could passivate dangling bonds at the grain boundaries and the indium ions diffused to the grain boundaries, which formed a structure similar to tin-doped In_2O_3. The defect evolution of ITO films upon $SCCO_2$ fluid treatment will be further investigated by positron annihilation lifetime spectroscopy based a pulsed slow positron beam.

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I-13 Zn-vacancy related defects in Zn-polar and O-polar ZnO fabricated by pulsed laser deposition

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Keywords: ZnO, Zn-vacancy related defects, Zn-polar, O-polar

Abstract

Zn-polar and O-polar ZnO films were grown on c-sapphire using pulsed laser deposition by controlling the MgO buffer layer thickness [1]. Surface to volume ratio (s_{GB}) of the grain is studied by x-ray diffraction. SQUID measurement shows that these undoped ZnO samples are magnetic at room temperature. Zn-vacancy related defects in the O-polar and Zn-polar ZnO films are studied by Coincidence Doppler broadening spectroscopy. The W-S plots of the as-grown O-polar ZnO samples fabricated with different oxygen pressures ($P(O_2)$=0 Pa, 1 Pa and 3 Pa) and post-growth annealed at 750 °C lie on a straight line, thus indicating that the presence of a single type of V_{Zn}-related defect in these samples. Comparing with the theoretical W-S lines of the V_{Zn}, $V_{Zn}V_O$, $2V_{Zn}$-V_O, V_{Zn}-$2V_O$ and $4V_{Zn}$ in ZnO [2], the V_{Zn}-related defect in the O-polar ZnO samples lie very close to the theoretical W-S line of V_{Zn}-$2V_O$ and is thus associated to V_{Zn}-$2V_O$. Increasing $P(O_2)$ and annealing has the effect of increasing and reducing the V_{Zn}-$2V_O$ concentration respectively. Correlation between the V_{Zn}-$2V_O$ concentration, saturated magnetization and s_{GB} is observed, thus suggesting that the V_{Zn}-$2V_O$ defects reside on the grain surface and is associated with the magnetization observed. For the Zn-polar ZnO samples fabricated with $P(O_2)$=0 Pz, the W-S data of the as-grown and 700 °C annealed samples lies between the theoretical W-S line of V_{Zn}-$2V_O$ and that of a W-S line for which V_{Zn}, $V_{Zn}V_O$ and $2V_{Zn}$-V_O are indistinguishable. This shows probably the presence of more than one type of these V_{Zn}-related defects in these samples. After annealing at 800 °C, only a single type V_{Zn}-related defect which is V_{Zn} monovacancy is found in the sample. Results of the luminescence spectroscopic study on the two types of ZnO films will also be discussed.

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I-14 Post-irradiation annealing and re-irradiation study of high-dose proton-irradiated RPV steel by slow positron beam

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Keywords: Matrix defects, Irradiation, RPV steel, Slow positron beam

Abstract

Investigation of microstructures and hardening property of initial irradiated, post-irradiation annealed, and re-irradiated reactor pressure vessel (RPV) steel were conducted by slow positron beam (SPB), TEM, and nanoindentation [1-3]. Results of the SPB measurements indicated that a large number density of open volume defects such as vacancies, vacancy clusters, vacancy-solute/H complexes, and dislocation loops were introduced in both initial-irradiated and re-irradiated specimens. The TEM results indicated that interstitial-type dislocation loops with a number density of ~10^{22} m^{-3} were formed and the mean size (~3 nm) of the dislocation loops was almost unchanged in both initial-irradiated and re-irradiated specimens. The open volume defects such as vacancy-type defects and dislocation loops were almost annealed out and some stable defects still existed in the post-irradiation annealed specimen. The nanoindentation results identified that the obvious hardening phenomena were found in the initial irradiated, post-irradiation annealed and re-irradiated specimens. The quantitative analysis suggested that irradiation hardening of RPV steel were attributed to matrix defects including large-size vacancy clusters, vacancy-solute/H complexes, and dislocation loops produced during initial irradiation and re-irradiation. On the other hand, the existed stable defects such as solute-atom (Mn, Ni, and Si) complexes/precipitates, which cannot be distinguished by SPB or TEM, might be responsible for the rest fraction of irradiation hardening of highly initial irradiated and re-irradiated RPV steel.

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O-05 Si effects on precipitates in neutron-irradiated low activation ferritic/martensitic steel

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Keywords: Silicon, Ferritic/martensitic steel, Neutron irradiation, Phase separation

Abstract

Ferritic and ferritic/martensitic (FM) steels are prospective structural materials for nuclear reactors. Addition of minor alloy elements can affect much of the materials properties. It is found [1] that the addition of Si makes these steels resistant to corrosion in a lead–bismuth eutectic, which is considered as a coolant for the fast reactors. Study also showed that the addition of Si increases the accumulation of vacancy type defects and their thermal stability on post-irradiation annealing in Fe16Cr alloy [2]. However, Si can be considered as undersized solutes, and they are expected to segregate at defect sinks under irradiation, leading to the nucleation of G-phase. In this study, two kinds of 9Cr–2W steels with and without the addition of 0.1 wt.% Si were irradiated with neutrons up to a fluence of 4.8×10^{23} n/m^2 at 563 K. Positron Annihilation Spectroscopy was applied to study the microstructural evolution in the two steels upon annealing after irradiation. Coincidence Doppler Broadening (CDB) results show an apparent peak for the steel with Si after irradiation. The phase separation corresponds to Si containing nano-clusters. The irradiated samples were isochronally annealed for 5 h from 623K to the corresponding temperature. Positron annihilation lifetimes and CDB were conducted after each step. The nano-cluster evolution and its effects on defects evolution are discussed thoroughly.

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P-01 Influence of Fe, Co and Ni cations on the positronium formation

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Keywords: Metal cation, Positronium, Annihilation, PMMA film.

Abstract

Positrons injected into solid materials usually undergoes three periods: thermal diffusion, annihilation and release of γ-rays. There are two kinds of positronium (Ps) (*p*-Ps: the spins of e^+ and e^- are antiparalledl, and *o*-Ps: the spins of e^+ and e^- parallel) for positrons in the solid materials. Herein, $FeCl_2$, $FeCl_3$, $CoCl_2$ and $NiCl_2$ were separately evenly dispersed inside the poly(methyl methacrylate) (PMMA) films. The positrons injected into the films can form the Ps-M complexes (M = Fe^{2+}, Fe^{3+}, Co^{2+} and Ni^{2+}), and *o*-Ps-M and *p*-Ps-M are interchangeable,

$$\text{Ps}\ (p\text{-Ps},\ o\text{-Ps}) + \text{M} \rightleftharpoons \text{Ps-M}\ (o\text{-Ps} \overset{k}{\rightleftharpoons} p\text{-Ps}) \longrightarrow \gamma$$

When the concentration of Fe^{3+} cations in the PMMA film increases, the corresponding intensity of I_3 decreases, which can be ascribed to the conversion of *o*-Ps to *p*-Ps. The fiting slope is the constant k. The influence of $FeCl_2$ on the interchange between *o*-Ps and *p*-Ps reaches the equilibrium with Fe^{2+} concentration of 8.0 mol‰. $CoCl_2$ and $NiCl_2$ have no obvious effect on the intensity of I_3. As the interchange between *p*-Ps and *o*-Ps was associated with the radius, ionization energy and spin quantum number of cations. The influence of Co^{2+} and Ni^{2+} cations on the positrion annihilation is still in process.

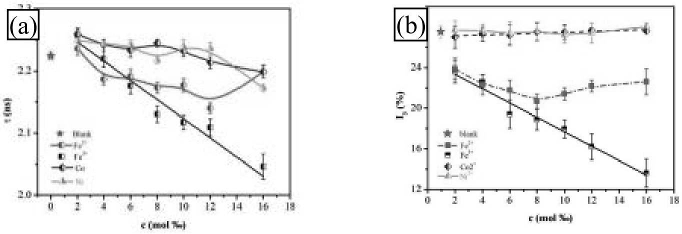

Fig. 1. Dependence of (a) the long life-time (τ_3) and intensity (I_3) on metal cation concentration in PMMA film.

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P-02 Monte Carlo simulation of positron creation and heat generation at the KUR reactor-based slow positron beamline

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Keywords: pair creation, reactor-based slow positron beamline, cadmium, prompt gamma-ray, Monte Carlo simulation, PHITS

Abstract

At the Kyoto University Research Reactor (KUR) slow positron beamline [1,2], a positron source is surrounded by a cadmium cap in order to enhance the gamma-ray intensity through the ^{113}Cd(n,γ)^{114}Cd reaction in addition to the fission gamma-rays emitted from a reactor core. A feature of the positron source of the KUR slow positron beamline is that the Cd-cap is housed in two sleeves. Such a structure makes it difficult to remove the heat generated at the top of the vacuum duct including the Cd-cap. Thus, to estimate how much the Cd-cap contributes to positron creation is an interesting matter for us. In this study, the amounts of positron creation and heat generation in the KUR slow positron beamline were simulated, and the differences between the cases with and without using a Cd-cap were compared.

Positron creation and heat generation were simulated by using the PHITS code [3,4] that simulates radiation transportation and interaction with matter. The positron source structure was reproduced in a simulation model. In the simulation, neutrons or gamma-rays were emitted from the planar source in both models with and without using the Cd-cap. The number of positrons emitted from the W-disk into a vacuum was counted in each case where only neutrons or only gamma-rays were emitted from the planar source. The amount of heat generation at the top of the vacuum duct was also calculated. As a result, the amount of positron creation was estimated to become 2.0±0.1 times higher by installing the Cd-cap to the positron source. However, it was also confirmed that the amount of heat generation of the positron source nearly doubles when the Cd-cap is used. In the presentation, we will also show a potentiality for enhancing the beam intensity of the KUR slow positron beamline.

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P-03 Positron Annihilation study of Tungsten exposed to Low-energy Deuterium Plasma

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Keywords: positron annihilation methods, Tungsten, Deuterium Plasma

Abstract

Positron annihilation lifetime (PAL) measurements by use of a positron source of ^{22}Na were performed for polycrystalline ITER-grade tungsten samples exposed to low-energy deuterium plasma. The energy of deuterium plasma was low and then it was expected that it would affect just near-surface region [1]. However, we obtained the longer mean positron annihilation lifetime in the tungsten samples exposed to the low-energy deuterium plasma than the virgin tungsten samples. Moreover, almost same longer values were obtained even on the other (no exposed) side of the samples, although the thickness of the samples were about 2 mm. There has been no report of observation of defect formation by existence of hydrogen or deuterium in tungsten. We will explain the newly observed results in detail.

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P-04 Investigation of Point Vacancy Defects in Hexagonal Boron Nitride by First-principles Calculation

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Keywords: Hexagonal Boron Nitride, Defects, Density Functional Theory, Positron Annihilation

Abstract

Hexagonal boron nitride is a wide-band-gap (~6.0 eV) semiconductor with wide applications for use in far-ultraviolet light emitting devices and two-dimensional electronics. Due to its complex microstructure, defects in h-BN are challenging to characterize. Here, we study the formation energies of native point vacancy defects of hexagonal boron nitride by using first-principles method within the framework of the density functional theory. The plane-wave pseudo-potential code Vienna ab initio simulation package (VASP) is used. The core-electron interaction is modeled by projector wave (PAW) formalism and exchange-correlation potential is Perdew-Burke-Ernzerhof (PBE) method within generalized gradient approximations (GGA). We consider a super-cell with a total of 128 atoms. The plane-wave cut-off energy is chosen as 500 eV, and the Brillouin zone is sampled by using 5×5 × 3 Gamma-centered Monkhorst-Pack grids. The energy convergent criterion is 10^{-6} eV per unit cell, and forces on all relaxed atoms are less than 0.02 eV/A. The plane-wave cut-off energy is chosen as 500 eV. The effect of Van de Waals interactions is taken into account by using optB88-vdW correction scheme.

The lower the formation energy of vacancy is, the more stable the vacancy is. From our obtained results, the V_N^{+1} seems to be much stable for p-type h-BN in both N-rich and N-poor growth condition, while V_B^{-3} is stable for n-type h-BN in both N-rich and N-poor growth condition. Also, V_N^{-2} becomes stable for n-type h-BN in N-poor growth condition.

Positron lifetime calculation is also performed with atsup program developed by Finland group. The obtained positron bulk lifetime of h-BN is about 180.6 ps, positron lifetime of vacancy boron is 183.6 ps, and positron lifetime of vacancy nitrigon is 181.5 ps. Their positron lifetime difference is small, but the tendency is clear, showing with that of $\tau_{bulk} < \tau_{V_N} < \tau_{V_B}$.

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P-05 Hydrogen trapping behavior at vacancies introduced by electron irradiation with different energy in B2 ordered Fe base alloys

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Keywords: Radiation damage, intermetallic compound, positron annihilation

Abstract

B2 ordered intermetallic compounds is widely used as a high strength material at high temperature, because of their good properties such as specific strength to weight ratio and oxidation resistance. However, it is also known that corrosion fatigue with hydrogen embrittlement tend to occur for B2 type Fe-Al alloy. Our result of first principle calculation shows that a few hydrogen atoms possibly trapped by one vacancy and its trapping behavior strongly depends on the type of vacancies in some B2 ordered alloys. There are A-type and B-type vacancies in a B2 ordered A-B compound alloy at least. In addition, it is difficult to confirm experimentally which type of vacancy is trapping hydrogen atoms in compound alloys. On this point of view, we have investigated the hydrogen trapping behavior in B2 ordered Fe-Al and Fe-Rh alloys with electron irradiation followed by hydrogen charging and H+ irradiation by positron annihilation techniques, X-ray diffraction and thermal desorption spectrometry (TDS). Also the hardness change was measured for these alloys before and after hydrogen charging. Positron annihilation coincidence Doppler broadening measurement results show that V_{Fe} in Fe-Rh and V_{Al} in Fe-Al are dominantly introduced by low energy electron irradiation, and it found from positron lifetime and TDS measurements that hydrogen atoms are trapped by these vacancies introduced by the irradiation.

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P-06 Water diffusivity transition in polydimethylsiloxane-fumed silica nanocomposite used in high voltage insulator: Correlation with free-volume properties

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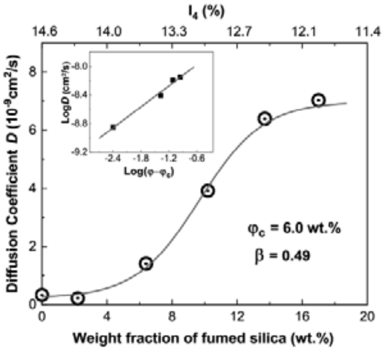
Abstract

High temperature vulcanized polydimethylsiloxane (PDMS) composite is the outside dielectric material for insulation device used in high-voltage transmission lines [1-2]. As a kind of inorganic filler, fumed silica (FS) could affect the water diffusion pathways in the PDMS composite, thus leading to the poor dielectric performance of the insulation device. However, this issue has not drawn much attention for study yet. In this paper, the free volumes and water barrier properties of the PDMS composites with different weight fraction of FS were investigated by positron annihilation lifetime spectroscopy (PALS) and electrochemical impedance spectroscopy (EIS), respectively. Two long lifetime components were found in the PDMS composite, i.e. τ_3 and τ_4. Among which, τ_3 is ascribed to the o-Ps annihilation in the FS/PDMS interface, while τ_4 the o-Ps annihilation in the interconnected free volumes in PDMS network. The value of τ_4 (~3.6 ns) does not vary the weight fraction of FS in PDMS composite, indicating an unchanged crosslink density of the material. By contrast, τ_3 firstly remains around 1.01 ns and then decreases linearly as the FS filling level increases in the PDMS composite, where the transition filling point is 6.4 wt.%. This transition of τ_3 indicates the two kinds of existing states of FS in the PDMS network: dispersed state and aggregated state. The low content dispersed FS does not change the structure of the FS/PDMS interface, while the high content (⩾ 6.4 wt.%) FS can easily aggregated and enhance the FS/PDMS interface, thus resulting the decreased τ_3 values. Moreover, the water diffusion coefficients increase rapidly as the FS content exceeds 6.0 %, suggesting the more easily diffusion of water in the aggregated FS filled PDMS composites.



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P-07 Influence of curing agent content on free volumes and water barrier property of high temperature vulcanized silicone rubber

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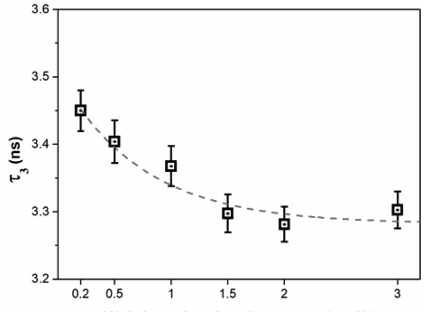
Abstract

Polydimethylsiloxane (PDMS) based high temperature vulcanized silicone rubber (HTV) is an important dielectric material for composite insulator used in high-voltage transmission lines [1]. For the vulcanization process of HTV, the curing agent decomposes at about 180 °C and then activate the addition reaction of vinyl groups PDMS matrix, finally turning the linear PDMS into a three-dimension cross-linked one [2,3]. By now, the relationship between crosslinking density and water barrier performance of HTV has not been studied yet, which is important for us to understand the dielectric performance of HTV on high-voltage lines. In this study, the free volumes and water barrier performance of HTV with different contents of curing agent were investigated by positron annihilation lifetime spectroscopy (PALS) and electrochemical impedance spectroscopy, respectively. Only one long lifetime component, τ_3, was found in HTV, which is due to the o-Ps pick-off annihilation in the free volume holes or cavities in the PDMS network. Thus, the values of τ_3 reflect the crosslink conditions of the HTV. As the weight ratio of curing agent in HTV increases from 0.2 wt.% to 1.5wt.%, τ_3 decreases from 3.45 ns to 3.29 ns, indicating a better crosslinked condition. While curing agent content exceeds 1.5 wt.%, τ_3 remains a constant around 3.30 ns, suggesting that the vinyl groups are well crosslinked in these HTVs. Interestingly, the intensity of τ_3 (I_3), is not affected by the adding of curing agent, which always remains around 12 %. The water diffuses easily in these HTVs with high curing agent content ($\geqslant$1.5 wt.%), due to the cracks formed on these sample surfaces after corona discharge treatment. We proposed that the uncross-linked low molecular weighted PDMS chains could diffuse from the bulk the surface and has an protect effect during the corona aging process.



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P-08 Long-term oxidative degradation of electron-beam irradiated high density polyethylene studied positron annihilation lifetime technique

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Keywords: oxidation, cross-linking, scission, carbonyl groups

Abstract

Polyethylene (PE) is widely used for an insulator and a covering material in nuclear plants, and it degrades with irradiation or radiation induced oxidation during long-term usage. Previously, we reported the one-year degradation of electron-beam irradiated polyethylene and found out that *ortho*-positronium (*o*-Ps) intensity had a linear relationship between the gel fraction of the sample [1]. In this work, we will investigate the further long-term oxidative degradation of the samples stored in air for ~2 years (total ~3 years from the irradiation).

Additive free 2 mm-thick high density polyethylene (HDPE) sheet was used as a sample. Electron-beam was irradiated 100 kGy and 1000 kGy under vacuum at room temperature. Chemical structure of the samples was examined by micro-FT-IR spectroscopy, gel fraction measurement, and electron spin resonance (ESR) spectroscopy, nanostructure of the samples was examined by positron annihilation lifetime spectroscopy (PALS), periodically.

Three years after the irradiation, *o*-Ps intensity still shows the linear relationship between the gel fraction, the relationship shifts toward the smaller *o*-Ps intensity and lower gel fraction, suggesting that the HDPE samples are still degrading during the long-term storage. Micro-FT-IR results show that carbonyl groups continuously increase with storage time. On the other hand, from ESR results show that allyl radical is completely disappears but hydroperoxide is produced in the sample even after 1.5 years from the irradiation. These species may play an important role on the inhibition of the Ps formation and the degradation of the samples. The results examined by variable-energy PALS will be also discussed.

A part of this work was supported by AIST Nanocharacterization Facility (ANCF) platform as a program of "Nanotechnology Platform" of the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan.

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P-09 Study of the chelation of palladium(II) cations with chitosan inside the nanofibers

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Keywords: Palladium, Modified chitosan, Chelating, Electrospinning, Nanofiber

Abstract

Palladium embedded suitable nano-matrices has been proved to be active and stable heterogeneous catalysts. The interaction between the palladium and the nanomaterials is critical for the activity and stability of palladium species inside the nano-matrices. Herein, the amino groups in chitosan were separately post-modified with 2-pyridylimine and phenylimine groups. Then, we applied electrospinning technique to embed Pd(II) cations inside chitosan and modified chitosan composite nanofibers with sodium polyacrylate as the co-spinning agent. The composite nanofibers were subsequently heated at 180 ºC to crosslink the chitosan and sodium polyacrylate polymer chains inside the nanofiber. The sizes of free volume holes of composite nanofibers were determined by PALS analysis. Incorporating palladium cations into chitosan composite nanofibers can expend the free volumes and the sequence of mean diameter of free volume holes is palladium doped pyridylimine modified chitosan nanofibers > palladium doped chitosan nanofibers > palladium doped phenylimine modified chitosan nanofibers, which is consistent with sequence of chelation energies of palladium(II) cations with corresponding chitosan and modified chitosan. In addition, this result can be associated with the catalytic activity of corresponding palladium embedded chitosan and modified chitosan composite nanofibers in the further study.

This work was supported by National Natural Science Foundation of China (Grant No. 11705117 and 11905132).

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P-10 Role of the resonance states of the muonic molecular in muon catalyzed fusion

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Keywords: Muon catalyzed fusion, Exotic atom and molecule, Muonic atom, side-path model

Abstract

A muon is one of elementary particles and has 207 times heavier mass than an electron. A negatively charged muon behaves like heavy electron in materials. The size of the muonic atom is 207 times smaller, and the binding energy of the muonic atom is 207 times larger compared with usual electronic atom. Muon beam is produced at high energy accelerator facilities, for example J-PARC/MLF (Tokai, Japan) which provides the strongest pulsed muon beam in the world [1].

Muon catalyzed fusion (μCF) is known as a cold nuclear fusion reaction where a muon acts like a catalysis [2]. However, it is also known that the μCF reaction cycle has rate-limiting processes which are muon transfer (dμ + t → d + tμ) and muonic molecule formation (tμ + D_2 → [dtμ-d]ee).

In this study, we focus on the side-path of the μCF cycle via resonance states of dtμ* molecule, so called "side-path model" [3]. The resonance states can be formed below the tμ*+d threshold energy by the Vesman mechanism, and can dissociate into a dμ+t scattering state. The number of dμ in the ground state eventually increases, and the q_{1s} problem can be solved with the side-path model [4]. We estimate the formation rate of the resonance states within the side-path model by using current experimental data.

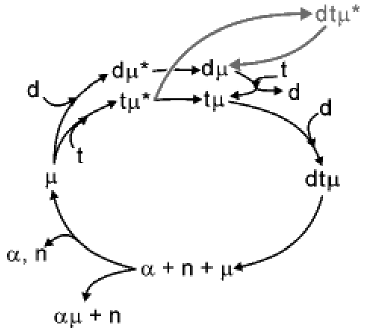

Figure of the μCF cycle. Red part corresponds to the side-path via resonance states muonic molecule.

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P-11 The microstructure investigation on the degradation of PLA/PBAT blend

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Keywords: Japan-China friendship, positron science, encouragements for young scientists

Abstract

Biodegradable materials are promising for various applications, among which PLA is a typical kind. To meet diverse requirements, modifications are needed for PLA,[1, 2] and adjusting and furtherly controlling the degrading behavior of PLA is a very important aspect. Herein PLA is blended with PBAT in different ratios for adjusting the degrading behavior.[3] PAT (Positron Annihilation Technique) is applied to trace the development of defects in the PLA/PBAT blends together with SEM and FTIR.[4, 5] Results from the three characterizing techniques reveal that PBAT delays degrading rate of the blend. In FTIR spectra, the absorbance of the carbonyl groups in ester groups of the PLA/PBAT blend decreases with the degrading going on. Developing of defects on the surface of the blend is observed through SEM. The relative intensity I_3 in PAT shows a slight increase at the beginning and then decreased obviously, which indicates that defects in the blend appear while degrading starts, and develop into smaller amount but larger size with degrading going on. Furthermore, *o*-Ps lifetime τ_3 also show the similar trend reveals the small defect sizes at the beginning and developing into larger size as degradation going on. The introducing of PBAT into PLA system also gives the possibility to further improve the mechanical properties of blend. These results lie foundations for further investigations to better understand the impact of PBAT contents in the blend on the degradation and mechanical properties.

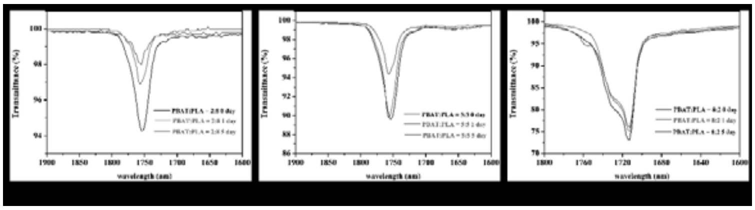

Figure 1. The FTIR results of PLA/PBAT blend before and after degradation.

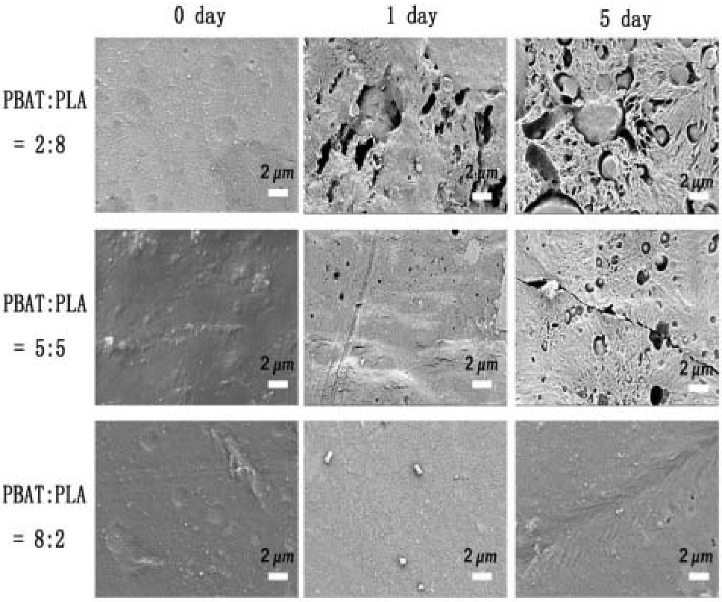

Figure 2. The SEM images of PLA/PBAT blend before and after degradation.

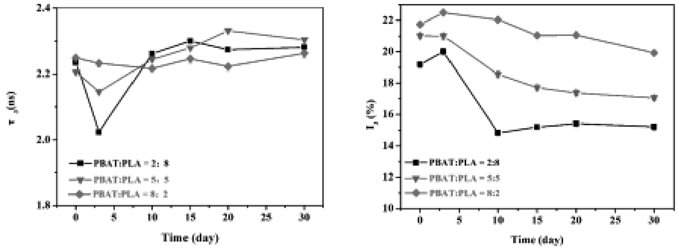

Figure 3. o-Ps lifetime and intensity as a function of degradation time.

This work was supported by the National Natural Science Foundation of China (No. 11575117 and 11975157).

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P-12 Fitting Analysis of Lifetime Spectra using an Exponential Function with a Single-Component

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Keywords: positron annihilation lifetime, shot-peening, ΔT_0

Abstract

Conventional positron annihilation lifetime measurements have focused on the lifetime and intensity of each component deduced by multi-component analysis or ‘mean’ lifetime deduced by single-component analysis, and little attention has been paid towards the starting time (T_0) on the spectrum’s time axis. However, as shown in Fig. 1, when analysing a positron lifetime spectrum with multiple components using an exponential function with a single-component, there is a difference between the spectrum and fitted data. To compensate this difference, T_0 is predicted to shift in the analysis result (ΔT_0) [1].

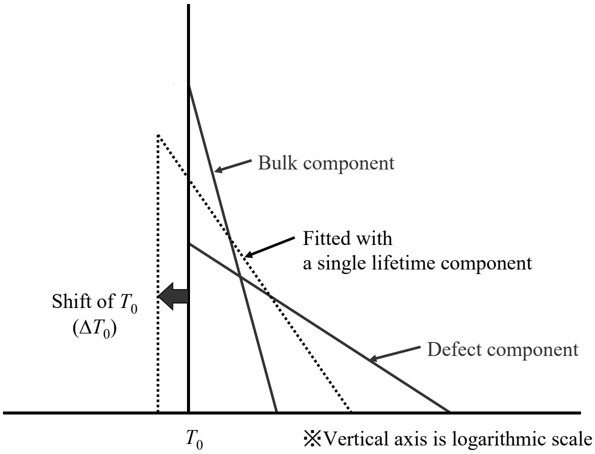

Fig.1 Shift of the staring time (T_0) as a result of single-component analysis of multi-component positron lifetime spectrum.

References: [1] Japanese patent application No. 2018-228103

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P-13 Study on the relationship of the microstructure of palladium nanoparticles doped CPVC nanofibers and its catalytic performance

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Keywords: Palladium nanoparticles, crosslinked CPVC nanofiber, microstructure, catalytic performance

Abstract

Palladium catalysis has been widely used in industrial and academic synthetic chemistry. Herein, palladium(II) cations doped chlorinated poly(vinyl chloride) (CPVC) nanofiber were prepared by electrospinning, followed by cross-linking and in situ reduction to prepare palladium nanoparticles doped CPVC nanofibers (Pd@CPVC) catalyst. The SEM image shows that the Pd@CPVC could retain their fibrous structure in the THF solution and the TEM images shows that the palladium nanoparticles with uniform size dispersed very evenly inside the nanofibers. This Pd@CPVC nanofiber exhibited high activity for the Heck and Sonogashira reaction of aromatic iodides separately with n-butyl acrylate and phenylacetylene (Yield > 80%). Specially, this Pd@CPVC could be reused for 10 times for Heck reaction and 6 times for Sonogashira reaction without loss of initial activity. The size of free volume holes in the nanofibers were determined by positron annihilation lifetime spectroscopy. It was found that the mean size of the free volume holes decreased after cross-linking. However, the free volumes size increased after reuse, which could be attributed to the degradation of the cross-linked CPVC polymer molecules, resulting in the leaching of active palladium nanoparticles.

This work was supported by National Natural Science Foundation of China (Grant No. 11905132 and 11705117).

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P-14 Free-volume study of radiation-irradiated polymers using low-energy AMOC technique

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Keywords: positron age-momentum correlation technique, low-energy positron beam, free volume, polymer

Abstract

Olefin-derivative polymers are widely used as insulating materials for cable/wire coatings at nuclear power plants, disposable medical instruments, container packages, and so on [1,2]. Many studies have been performed to investigate the degradation mechanism for polymer materials induced by radiation irradiation, as well as to predict their lifetime, necessary to ensure the safety and reliability under severe environments such as nuclear plants. The free-volume structure of such materials is one of the most important parameters relevant to various properties such as mechanical, optical, as well as gas permeability. Not only structural changes such as oxidation, cross-linking, and scission, but also changes in the free-volume structure are important to investigate the degradation associated with oxygen diffusion and radical generation. In the present work, we applied the positron age-momentum correlation (AMOC) technique to investigate radiation-induced degradation of polystyrene and polyethylene using an AMOC system with a Na-22 based pulsed positron beam [3]. In the presentation, the effect of the irradiation dose on the free-volume holes is discussed based on the obtained AMOC data.

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P-15 The Effect of Free Volume on Gas Permeation in ABS/Graphene Oxide composite Membrane Investigated by Positron Annihilation Lifetime Spectroscopy

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Keywords: Gas permeation, Positron annihilation, Acrylonitrile Butadiene Styrene, Free volume

Abstract

In order to explore the effect of free volume on gas permeation in polymer membranes, the free volume holes parameters of an Acrylonitrile Butadiene Styrene (ABS) membrane were adjusted by annealing and addition of graphene oxide (GO). In this work, we measured the water vapor transmission rate (WVTR), oxygen transmission rate (OTR) and positron annihilation lifetime spectroscopy (PALS) for the various membranes. The results show that the addition of GO significantly affects the free volume of ABS, which affects the diffusion of small gas molecules in the ABS matrix. It is suggested that when analyzing the gas permeability of the polymer/nanosheet composites, the influence of the fillers on the matrix itself cannot be ignored.

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P-16 Local Structural Change of ZrCuAl Intermetallic Alloy by Swift Heavy Ion Irradiation

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Keywords: Intermetallic alloy, Heavy ion irradiation, Amorphization

Abstract

We are trying to make new functional materials by the modification of local structure and character using high energetic particles irradiation, such as electron and heavy ions. So far, we found that heavy ion irradiation changes local ordered structure in Ni-based intermetallic compounds, which are used as structural materials with excellent high-temperature resistance and high strength, from a crystal structure to an amorphous state [1]. Amorphous is a non-equilibrium phase and has no long range ordered lattice structure so that the physical and mechanical properties are different from those of a crystal state. Therefore, we suggest that heavy ion irradiation induced amorphization can be used as a method of surface modification of materials. However, the amorphization of metallic materials by high energetic particles irradiation depends on radiation conditions and kind of materials. Then the amorphization process of alloys is not cleared yet so far. In this study, 200 MeV Xe, 16 MeV and 200MeV Au ions irradiation have performed for $Zr_{50}Cu_{40}Al_{10}$ intermetallic compound, which can be produced for bulk amorphous alloy easily by quenching method [2]. Positron annihilation spectroscopy and X-ray analysis (XRD and EXAFS) have performed for this alloy before and after irradiation, in order to investigate the behavior of vacancy-type defects and the changing of local ordered structure. Also the Vickers hardness was measured for this alloy. XRD result shows that different behavior of heavy ion irradiation between two phases of Zr_2Cu and Zr_7Cu_{10} involved in this alloy. It is supposed that Zr_2Cu phase amorphized preferentially by the effect of elastic displacement, and Zr_7Cu_{10} phase amorphized by the effect of electronic excitation mainly.

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P-17 Study of SiPM-PALS's timing performance based on Geant4 simulation

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Keywords: Monte Carlo, Geant4, Timing performance, SiPM, LYSO

Abstract

Positron lifetime spectroscopy is one of the important experimental methods to measure the microstructure of a substance. At present, a positron annihilation lifetime spectrometer (PALS) detector is typically composed of a scintillator coupled to a photomultiplier tube (PMT). In recent years, silicon photomultiplier (SiPM) based photosensitive detectors have emerged, featuring high gain, high sensitivity, low bias voltage, insensitivity to magnetic fields, and a compact structure. We plan to construct a PALS detector using a SiPM instead of a PMT. In this study, GEANT4 (Monte Carlo simulation software) is used to study the timing performance of silicon photomultipliers coupled to different scintillators, which provides a reference for building spectrometers. In the simulation process, physical processes such as photoelectric effect, Compton scattering, and electron pair effect are carefully considered to obtain more accurate results. We study the effects of the scintillators' size, material, light yield, rise time and other properties on timing performance. The simulation serves as an important guide for spectrometer construction.

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P-18 Effect of gamma irradiation dose on radiation damage in polystyrene and fused quartz

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Keywords: gamma-rays irradiation, AMOC, free volume

Abstract

Irradiation damage causes a change in material properties. In amorphous materials such as polymer, nanometer scaled free volume strongly effects on material property. Positron annihilation spectroscopy is utilized as a sensitive probe for detecting radiation damage at nanometer scale. In this work, we apply the positron age-momentum correlation (AMOC) technique for investigating irradiation damage in amorphous materials. We study effect of dose of gamma irradiation on damage around free volume.

The experiments were performed at ^{60}Co gamma-rays irradiation facility at the Institute for Integrated Radiation and Nuclear Science, Kyoto University. Polystyrene with a thickness of 2 mm (Goodfellow Co.) was used as a target specimen. The specimens were irradiated to various doses of ^{60}Co gamma radiation (30 kGy, 200 kGy, 300 kGy, and 400 kGy). In AMOC measurements, the radiation damage around free volume induced by gamma irradiation was investigated from changes in S parameter for *ortho*-positronium (o-Ps) pick-off annihilation. For polystyrene the S parameter decreases with increasing gamma radiation dose. For fused quartz the S was almost unchanged before and after irradiation, indicating high resistance of gamma radiation comparted to the polystyrene case.

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P-19 Study of the Ion Diffusion in Graphene Oxide Membrane during the Initial Immersing Process

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Keywords: graphene oxide, ion diffusion, immersing process

Abstract

Graphene oxide (GO) is a two-dimensional material, which contains a large number of polar oxygen-containing groups, including hydroxyl, epoxy and carboxyl groups. Owing to these polar groups, the GO membrane exhibits dramatic water flux. However, a better understanding of the ion diffusion through the GO membrane is necessary for the development of novel GO membranes with superior performance.

In this work, the ion diffusion through the GO membrane under different concentration gradients was examined. The electrochemical impedance spectroscopy results showed an additional inductive loop at low frequency in the Nyquist plot at the initial diffusion stage, which would be more visible for the GO membrane immersed at lower ion concentration. This inductive loop could be attributed to the uneven distribution of ions in the GO membrane. In addition, the charge transfer resistance and inductive resistance became smaller with increasing immersing time because of the ion diffusion in GO membranes. Higher concentration led to lower resistances, which suggested that higher concentration gradient would result in more ions permeating through the GO membranes.

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P-20 Study of Open Spaces in Pillared Layer Metal-Organic Frameworks by Positron Annihilation Spectroscopy

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Keywords: CPL MOF, open space, pillar ligand

Abstract

Pillared layer metal-organic framework (MOF) known as CPL MOF series is a jungle-gym-type porous coordination polymer, in which two dimensional (2D) layers consisted of copper ions and pyradine dicarboxylic acetate are separated by dipyridy pillar ligands forming open spaces [1]. It is expected that the size of open space between 2D layers in the CPL MOFs changes depending on the length of pillars. In the present work, positron annihilation spectroscopy was conducted for a number of CPL MOFs synthesized with different pillar ligands varying the length of pillars together with x-ray diffraction and thermal analyses. The results are discussed with respect to the interaction between positrons and π electrons of ligand.

References

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P-21 Efficient Perovskite Solar Cells with Alkali-treated Mesoporous TiO_2 Electron-Transporting Layers

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Keywords: alkali salts, perovskite solar cells, conductivity, interface engineering

Abstract

The interfacial engineering to the perovskite layer/electron transporting layer (ETL) interface has proved to be critical for achieving highly efficient perovskite solar cells (PSCs). In this work, interface modifications of the me-TiO_2 (mesoporous TiO_2) by facile post treatment of the films with alkali salts was performed. No obvious influence on optical properties, surface morphology of perovskite films was found. n-doping of me-TiO_2 and enhancement of the electronic conductivity were confirmed from XPS and EIS measurements. Due to the improved electronic property of the ETL, alkali salts treated me-TiO_2 based PSCs produce substantially higher performances compared with untreated samples, improving the power conversion efficiency (PCE) from 18 % to 20 %.

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P-22 Lattice defects in hydrothermally grown ZnO and their contribution to electroconductivity

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Keywords: Zinc oxide, Impurity hydrogen atoms, Positron annihilation lifetime spectroscopy, Nuclear reaction analysis

Abstract

Zinc Oxide (ZnO) is a semiconductor material which is highly expected for applications to functional devices in various fields of technology. Commercially available ZnO is known to show *n*-type conduction due to various lattice defects generated unintentionally during the crystal growth and heat treatment processes [1]. Impurity hydrogen atoms are regarded as one of the origin of *n*-type conduction because they behave as shallow donors with their concentration of as high as 0.3 at.% [2]. However, there are few reports in which the correlation between their concentration and conductivity in ZnO samples is discussed because of the difficulty in the quantitative analysis of hydrogen atoms. For the investigation of the correlation, in this work, $^{1}H(^{15}N, \alpha\gamma)^{12}C$ nuclear reaction analysis (NRA) [3] was employed to determine the impurity hydrogen atoms in hydrothermally grown ZnO single crystals, and step-by-step heat treatments at temperatures up to 973 K were performed for the sample to examine thermal behavior of H atoms. In addition, the state of zinc vacancies was observed by means of positron annihilation lifetime spectroscopy to investigate their bound states to impurity hydrogen atoms. The present results of the NRA suggest that the impurity hydrogen atoms take at least two different bound states to the lattice.

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P-23 The effect of irradiation temperature on defects in ODS steel irradiated by multi-energy helium ions

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Keywords: ODS steel, helium bubbles, multi-energy helium ions implantation, Slow positron Doppler broadening spectra, X-ray small-angle scattering

Abstract

Oxide dispersion strengthened (ODS) ferritic and ferritic/martensitic steels appear to be promising candidates as structural materials for future fusion reactors due to their high temperature mechanical properties and their potential radiation resistance. Studies show that the oxide dispersion particles in ODS steel have good inhabiting effect on the generation of point defects caused by irradiation and the formation of helium bubbles. To simulate the evolution process of defects caused by helium in the nuclear transmutation process, the investigation adopts multi-energy helium ions implantation. SRIM was used to simulate helium ion irradiation damage and the distribution of helium in ODS steels. The irradiation experiment was carried out with multi-energy helium ions at high temperature and room temperature. Slow positron Doppler broadening spectra (DBS) was used to study the defects of radiation damage. Results show that high temperature can promote the migration and aggregation of defects. Combined with X-ray small-angle scattering technique of synchrotron radiation (SAXS), the size distribution of helium bubbles in the materials was obtained and indicates that the size of helium bubbles is more widely distributed at high temperature than that at room temperature.

References

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P-24 Synthesis and characterization of metal nanoparticles in SiO_2 amorphous glass by ion irradiation method

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[b]National Institutes for Quantum and Radiological Science and Technology

Keywords: ion irradiation, nanoparticle, electron excitation, radiation damage

Abstract

The metal nanoparticles may show a specific property in electric state such as the quantum effect from the lower periodicity of crystal unlike bulk metal. They are expected as a new functional material by their properties, such as catalyst or surface plasmon resonance. However, the powdery nanoparticles have limits to apply for industry use, so the synthesis of them in and on bulky materials is useful way. It may develop a specific property like a simple substance particle even if I produce nanoparticles in an inorganic material in that. In general, it is well known that colloidal nanoparticles in liquids sometime show characteristic optical property called surface plasmon absorption (SPA) [1]. It is very difficult to control the shape and size of nanoparticles during synthesis. Ion implantation is candidate as one of the methods to synthesis the nanoparticles in glassy solids [2]. Furthermore, we found that it is possible to control the shape of nanoparticles synthesized in an amorphous SiO_2 by heavy ion irradiation. In this study, we have tried to synthesize Ni nanoparticles by the implantation of Ni ions with energy of 30 – 300keV into SiO_2 amorphous glass. Also we have investigated them by UV-vis absorption spectroscopy, X-ray diffraction and positron annihilation spectroscopy in order to estimate the character and structure of nanoparticles. In cases of Ni ion implantation with the energy more than 100 keV, the SPAs of Ni in ultraviolet and visible band appears with low irradiation fluence. This result shows the formation of Ni nanoparticles in SiO_2 without annealing process. In these samples, decreasing trend of positron annihilation Doppler S parameter by the irradiation showing the shrinkage of free volume in SiO_2 matrix.

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P-25 The Effect of Free Volume on Gas Permeation in Polyetherimide/Graphene Oxide Composite Membrane Investigated by Positron Annihilation Lifetime Spectroscopy

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[b] Department of Physics and Technology, Wuhan University, Wuhan 430072, China

Keywords: Gas permeation, Positron annihilation, Polyetherimide, Free volume

Abstract

Incorporation of nanosheets is known to be effective in the reduction of gas permeation of polymer membranes, which has been typically attributed to the torturous path effect. In order to explore the effect of free volume holes on gas permeation of polymer membranes, polyetherimide (PEI), a completely amorphous polymer was selected as the matrix. The free volume of PEI was adjusted by annealing and/or adding graphene oxide (GO) and the average size and distribution of free volume were measured by positron annihilation lifetime spectroscopy (PALS). The results show that the addition of GO significantly affects the free volume of PEI, which affects the diffusion of small gas molecules in the PEI matrix. It is suggested that when analyzing the gas permeability of the polymer/nanosheet composites, the influence of the fillers on the matrix itself cannot be ignored.

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P-26 Proton Conductivities of ferroferric oxide modified Sulfonated Carbon Nanotubes/Nafion Composite Membranes

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Key Laboratory of Nuclear Solid State Physics Hubei Province, School of Physics and Technology, Wuhan University, Wuhan 430072, China

Keywords: Nafion membranes, magnetic fields, functionalized carbon nanotubes, anisotropy, proton conductivity.

Abstract

We have prepared and characterized of a new type of composite membrane based on ferroferric oxide modified sulfonated carbon nanotubes (FS-CNTs) and Nafion for proton exchange membrane fuel cell (PEMFC) applications. The FS-CNTs/Nafion composite membranes were prepared by the sol-gel method under a strong magnetic field. Due to the presence of ferroferric oxides on the surface of sulfonated carbon nanotubes (Su-CNTs), the mechanical properties and proton conductivity of FS-CNTs/Nafion membranes were found to be anisotropic. Remarkably, the anisotropic mechanical properties and proton conductivity strongly depend on the FS-CNTs content, magnetic field, water uptake and temperature. Results showed that FS-CNTs content, magnetic field, water uptake and temperature play a synergistic effect on the anisotropic mechanical properties and proton conductivity of Nafion/FS-CNTs composite membranes, which provides a new strategy for fabrication of PEMs with high proton conductivity as well as good mechanical properties.

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For notes

Presenting author index

Turbo pumping station
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Turbo Pumps
HiPace , ATH series

He leak detector
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  〜ポリマー自由体積［<1nm］〜ナノ空孔［<10nm］）
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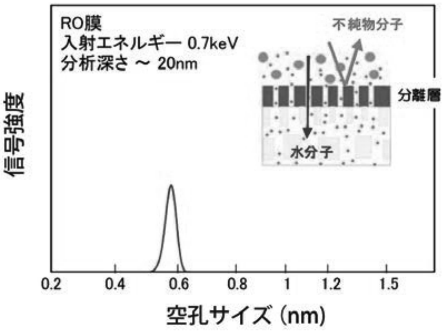
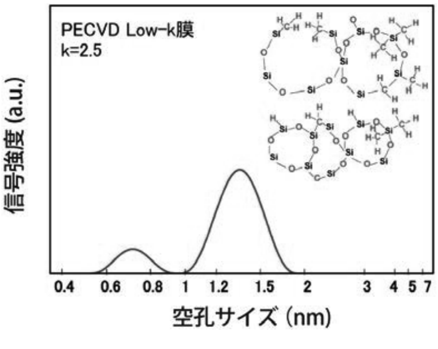


海水淡水化に用いる分離膜（RO 膜）の分析例。RO 膜では表面に形成した分離層（厚さ数 10nm）の自由体積空孔サイズが、不純物分子の阻止率に強く影響する。



先端 LSI の多層配線絶縁膜として用いられている低誘電率（Low-k）膜の分析例。プラズマ CVD による SiOCH 膜ではシリカ骨格の空隙を広げることにより低誘電率化を実現している。

■ 仕様と性能

- 装置占有スペース
  ：4.7m（南北）x 3.2m（東西）x 2.2m（高さ）
- 陽電子源　：Na-22 密封線源（最大1GBq）
- 陽電子ビームエネルギー：0.5〜15keV（可変）
- 時間分解能：＜300ps
- γ線計数率：＞500cps@1GBq
- 測定時間　：１スペクトル＜１時間

■ アプリケーション

- LSI 材料
  Low-k、High-k、Cu 配線、歪みSi、バリア膜、
  レジスト膜、イオン注入誘起欠陥、etc
- 化合物半導体薄膜
  GaN、ZnO、SiC、GaAs、etc
- 光学材料、ディスプレイ材料、太陽電池材料、FC 材料
- ポリマー自由体積
  分離膜（RO 膜）、ガスバリア膜（太陽電池バックシート、
  有機ＥＬバリア層）、メソポーラス材料、etc

■ オプション

- 空孔連結性の測定（オープンポア/クローズポア）
- 加熱測定機構（条件設定しサンプルセット後は自動測定）

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Positron Annihilation Lifetime Spectroscopy

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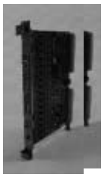
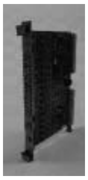
<td> </td>
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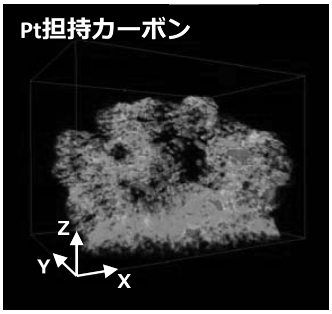

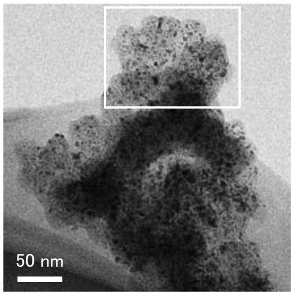

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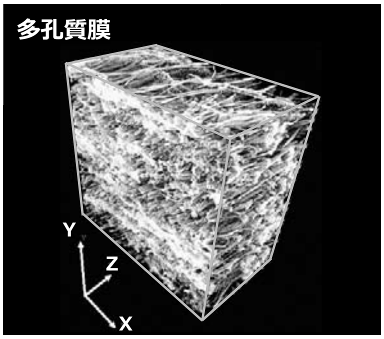

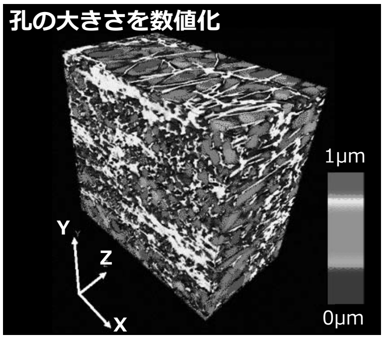

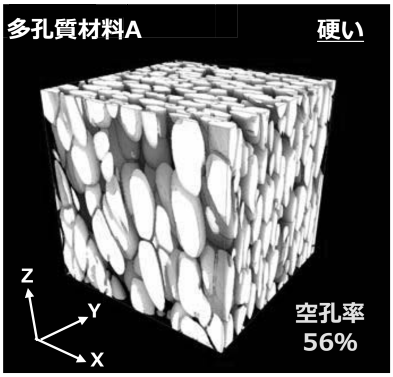

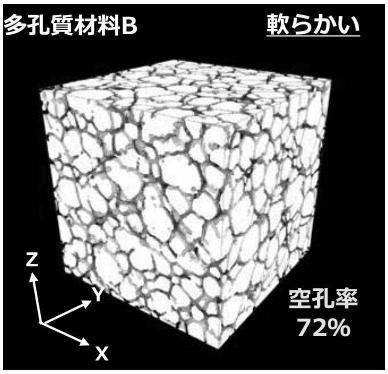

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Scientific Program
(Chair List)

	Oct. 28	Oct. 29	Oct. 30	Oct. 31	Nov. 1	Nov. 2
8:30	Plenary, Invited: 30min Contributed, Student: 20min Including discussion	**Registration**	JST Sakura Program (Late 10/30 to 11/2)			
9:00				Poster Session 2 (12 papers)	**Students Session 1** Chair: B. O'Rourke	Lab. Tour QSEC, Kyoto Uni. (by Bus)
9:10						
9:20						
9:30						
9:40						
9:50						
10:00		**Opening**	**Oral Session 4** Chair: K. Sato			
10:10						
10:20						
10:30		**Oral Session 1** Chair: K. Ito & B. Wang				
10:40				Break	Break	
10:50						
11:00				**Oral Session 6** Chair: Q. Xu	**Students Session 2** Chair: A. Ishida	
11:10			Break			
11:20						
11:30			**Oral Session 5** Chair: F. Ling			
11:40						
11:50						
12:00						
12:10				Lunch		
12:20						
12:30		Lunch	Workshop photo 1			**Closing**
12:40			Lunch			
12:50						
13:00				13:10-18:30 **TIA Kakehashi Symposium** **Application of Positron Beams at Major Facilities** (SO: N. Oshima) **Chair: H. Tsuchida** N. Oshima B. Wang T. Hyodo A. Kinomura **Chair: C. He** K. Wada Z. Wei A. Ishida K. Michishio	Lunch	
14:00		**Oral Session 2** Chair: T. Oka	Excursions around the Nara Park			
14:10						
14:20						
14:30					**Oral Session 7** Chair: X. Cao	
14:40						
14:50						
15:00		Break				
15:10						
15:20						
15:30		**Oral Session 3** Chair: T. Hirade				
15:40						
15:50					**Summary & Remarks**	
16:00	**Registration**					
16:10						
16:20						
16:30		Poster Session 1 (14 papers)			Workshop photo 2	
16:40						
16:50						
17:00			Get together at the Garden			
17:10						
17:20						
17:30						
17:40						
17:50						
18:00	Welcome Reception @ the Kotowa	Dinner 1 near JR Nara	Banquet @ the Nara Hotel	Dinner 2 near Kintetsu Nara		

Scientific Program

	Oct. 28	Oct. 29	Oct. 30	Oct. 31	Nov. 1	Nov. 2
8:30	Plenary, Invited: 30min Contributed, Student: 20min Including discussion	**Registration**	JST Sakura Program (Late 10/30 to 11/2)			
9:00				Poster Session 2 (12 papers)	Student: K. Yamada	Lab. Tour QSEC, Kyoto Uni. (by Bus)
9:10						
9:20					Student: K. Hashidate	
9:30						
9:40					Student: K. Shu	
9:50						
10:00		**Opening**	Invited 9: S. Yoshimoto		Student: H. Wang	
10:10						
10:20					Student: M. Nakajima	
10:30		Invited 1: T. Hirade	Oral 1: Z. Chen			
10:40				Break	Break	
10:50			Oral 2: W. Zhou			
11:00		Invited 2: C. He		Invited 12: X. Cao	Student: X. Liu	
11:10			Break			
11:20					Student: T. Karatsu	
11:30		Invited 3: L. Chiari	Invited 10: N. Matsuki	Oral 3: H. Zhang		
11:40					Student: K. Tanaka	
11:50				Oral 4: J. Liu		
12:00		Invited 4: B. O'Rourke	Invited 11: T. Zhang		Student: K. Sugita	
12:10				Lunch		
12:20					Student: H. Minagawa	
12:30		Lunch	Workshop photo 1			**Closing**
12:40			Lunch		Student: Z. Liu	
12:50						
13:00				13:10-18:30 **TIA Kakehashi Symposium** **Application of Positron Beams at Major Facilities** (SO: N. Oshima) N. Oshima B. Wang T. Hyodo A. Kinomura K. Wada Z. Wei A. Ishida K. Michishio	Lunch	
14:00		Invited 5: K. Sato	Excursions around the Nara Park			
14:10						
14:20						
14:30		Invited 6: Y. Zhao			Invited 13: F. Ling	
14:40						
14:50						
15:00		Break			Invited 14: Y. Wu	
15:10						
15:20						
15:30		Invited 7: T. Yamashita			Oral 5: S. Huang	
15:40						
15:50					**Summary & Remarks**	
16:00	**Registration**	Invited 8: Y. Sun				
16:10						
16:20						
16:30		Poster Session 1 (14 papers)			Workshop photo 2	
16:40						
16:50						
17:00			Get together at the Garden			
17:10						
17:20						
17:30						
17:40						
17:50						
18:00	Welcome Reception @ the Kotowa	Dinner 1 near JR Nara	Banquet @ the Nara Hotel	Dinner 2 near Kintetsu Nara		