

In the cross field of wood science and human sciences: microscopic wood identification of important cultural properties

(Laboratory of Biomass Morphogenesis and Information, RISH, Kyoto University)

Mechtild Mertz and Takao Itoh

The present research project, supported by the Japan Society for the Promotion of Science (JSPS), focuses on the microscopic wood identification of important cultural properties, more precisely on Japanese and Chinese Buddhist sculptures, as well as excavated wooden artefacts. The wood identification of Japanese Buddhist sculptures already looks back onto a history of more than forty years [1]. Furthermore, this research has been adopted as a basic approach by Japanese art historians in the last ten years [2]. However, wooden Buddhist sculptures from China and Korea, the two empires from where Buddhism has been introduced to Japan, have not yet been the object of wood identification. The present research is the beginning of a broad investigation in order to fill this gap. The aim is not only to find out the wood species the sculptures are made of and the analysis of the results, but also to introduce this approach to the community of art historians of East Asian art worldwide.

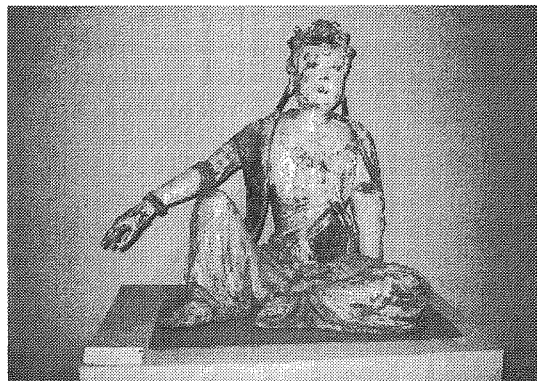


Fig. 1. Watermoon Kannon identified as willow, *Salix* sp., China, Song Dynasty, around 1200, h=90cm. Rietberg Museum, Zurich.

Nowadays, a great number of Chinese wooden Buddhist sculptures is preserved in Western Museums. In order to obtain the precious samples we had to collaborate with Museums in Europe and in the USA, such as the Guimet Museum in Paris, the Rietberg Museum in Zurich, the Royal Museum of Art in Brussels or the Spencer Museum in Kansas. In total we collected samples from 45 Buddhist and 7 Taoist sculptures. The samples had to be extremely tiny and were taken “invisibly”, viz in hollowed-out parts, on the bottom of the sculpture or in cracks. The wood species identified throughout our research can be seen in table 1. This is the first time that Chinese wooden sculptures have been identified on a larger scale. The final results will be presented this fall at the Third Forbes Symposium on Scientific Research in the Field of Asian Art at the Freer Gallery of art of the Smithsonian Institute and thus introduced to the human sciences.

Table 1. Woods of Buddhist sculptures

China	Japan
<i>Salix</i> sp.	<i>Cinnamomum camphora</i>
<i>Paulownia</i> sp.	<i>Chamaecyparis obtusa</i>
<i>Tilia</i> sp.	<i>Torreya nucifera</i>
<i>Populus</i> sp.	<i>Cercidiphyllum japonicum</i>
<i>Populus euphratica</i>	<i>Zelkova serrata</i>
<i>Liquidambar formosana</i>	<i>Magnolia obovata</i>

A further project is the identification of excavated shipwreck parts from the Takashima Underwater Site (Nagasaki prefecture). Most of them belonged to the war fleet of the Mongol Emperor Kublai Kahn which sank in 1281 in front of the Japanese coast after a devastating typhoon. This research is done in cooperation with A. Matsuo of the Takashima Board of Education and with T. Mitsutani of the Cultural Properties Research Institute, Nara.

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Degradation of polymeric substances by free radicals and multifunctional peroxidase produced by white rot basidiomycetes

(Laboratory of Biomass Conversion, RISH, Kyoto University)

Takashi Watanabe, Takahito Watanabe and Yoichi Honda

Degradation of lignin by white rot basidiomycetes proceeds by oxidative depolymerization either directly by fungal ligninolytic enzymes, or indirectly *via* mediator molecules oxidized by the enzymes or transition metal complexes. The extracellular oxidative systems have been extensively studied for pulp and paper production and bioremediation of polluted environments containing various hazardous organic compounds. Lignin peroxidase (LiP) and manganese peroxidase (MnP) have been isolated and characterized from numerous white rot fungi. LiP from *Phanerochaete chrysosporium* is unique in its ability to oxidize polymeric substances such as a synthetic azo dye, Poly R-478 and ribonuclease (RNase) *via* its long-range electron transfer pathway, but the oxidation of these molecules by LiP is dependent on the presence of mediator molecules such as veratryl alcohol. In *Pleurotus* species, hybrid-type peroxidases sharing the functions of LiP and MnP have been isolated. The multifunctional peroxidase (versatile peroxidase, VP) possess a manganese binding site, heme access channel and long-range electron transfer pathway. Recently we first demonstrated that the multifunctional peroxidase (VP, MnP2) from *Pleurotus ostreatus* directly oxidized the polymeric substances, Poly R-478 and RNase without the aid of redox mediators, and that a Trp residue exposed on the enzyme surface is involved in the polymer oxidation [1]. We also demonstrated that expression of VP (MnP2) was down-regulated at the transcription level by nutrient nitrogen, e.g., NH_4^+ , arginine or urea [2]. When the fungus was cultivated in chemically-defined media containing Poly R-478, the azo dye did not act as a transcriptional inducer but suppressed inactivation of VP (MnP2) from excess of H_2O_2 [2].

MnP abstracts one electron from phenolic compounds to generate a phenoxy radical, although it also oxidizes recalcitrant compounds with high ionization potential exceeding 7.5 eV in the presence of lipids. The MnP-dependent lipid peroxidation is involved in lignin degradation by a selective white rot basidiomycete, *Ceriporiopsis subvermispora*. The MnP-catalyzed lipid peroxidation is initiated by hydrogen abstraction from enolic form of fatty acids and proceeds by acyl radical chain reactions to produce aldehydes, accompanied by emission of chemiluminescence [3,4]. We found that vulcanized rubbers were degraded by the lipid peroxidation initiated by MnP and laccase [5]. In collaboration with SRI R & D Ltd., research on the recycling system of waste rubber products by the use of lipid peroxidation is in progress. We also found that *C. subvermispora*, degraded vulcanized natural rubber sheets in wood cultures, accompanied by cleavage of sulfide bonds between the polyisoprene chains [6]. To our knowledge, this is the first report of basidiomycetes capable of degrading vulcanized rubber. The enzymatic lipid peroxidation were also applied to degradation of ether-type polyurethane in collaboration with Toyota Motor Corporation. Studies on the radical reactions catalyzed by ligninolytic enzymes would allow us to decompose various polymers which are hardly recognized by a substrate binding site buried in enzymes.

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Comprehensive metabolic analysis of the cinnamate/monolignol and lignan pathways

**(Laboratory of Metabolic Science of Forest Plants and Microorganisms,
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The cinnamate/monolignol pathway supplies precursors for various phenylpropanoid compounds such as lignins, lignans, and norlignans, which are involved in cell-wall and heartwood formation of herbaceous and woody plants. The lignan pathway which follows the cinnamate/monolignol pathway is involved in heartwood formation and production of bioactive compounds. Thus, these pathways play central roles in plant secondary metabolism and are of importance in secondary xylem formation, which is composed of cell wall formation and heartwood formation.

During the last decade, substantial progress has been made in studies of these pathways, mostly due to the development of molecular biological techniques. For example, a novel pathway towards syringyl lignin via 5-hydroxyconiferylaldehyde was elucidated, and a transgenic aspen with less lignin and greater cellulose contents was reported. However, the comprehensive mechanisms controlling these pathways remain to be elucidated.

In the post-genomic era, to understand the mechanisms, comprehensive analyses such as transcriptomics, proteomics and metabolomics are becoming key strategies. However, accurate and comprehensive quantitation methods for whole metabolites, i.e. true metabolomics, have not yet been established.

As a first step, we focused on the cinnamate/monolignol and lignan pathways and established a comprehensive quantitation system for metabolic intermediates of the pathways. For this purpose, we employed a stable-isotope-dilution method because this is the most reliable quantitation method.

First, we synthesized deuterium-labeled and unlabeled standards for each of more than 30 metabolites in these pathways, and established standard calibration curves for the target compounds. Next, the system was successfully applied to characterization of the pathways in *Carthamus tinctorius* (safflower) seeds where biosynthesis of both lignins and lignans increases rapidly during maturation. In addition, ¹³C-labeled precursors were administered to the seeds, and ¹³C incorporation into the downstream metabolites was measured comprehensively. These metabolic profiling data during seed maturation were analyzed together with time-dependent gene expression data obtained by real-time PCR, resulting in identification of several cDNA clones involved in lignin and lignan biosynthesis. Furthermore, the presence of a biosynthetic route specific to lignan biosynthesis among many possible routes in the cinnamate/monolignol pathway was strongly suggested.

We are now trying to apply the metabolic analysis system to evaluating the effects of various factors on the growth of tropical fast growing trees, such as *Acacia* spp.

Isoprene emission from plants – its physiological role for plants -**(Laboratory of Plant Gene Expression, RISH, Kyoto University)**

Kazufumi Yazaki

Isoprene is a volatile C₅ terpenoid that is released mainly from the leaves of many deciduous broad-leaved trees, such as *Salix*, *Quercus* and *Populus* species. The annual global emission of isoprene from these trees is estimated to be as high as 5×10^{14} g of carbon, which is similar to the level of methane, the most abundant naturally emitted hydrocarbon. Isoprene has been suggested to potentially provide general protection against environmental stress, such as heat and water as well as to protect against singlet oxygen. It has been demonstrated that isoprene emission rates are correlated with photosynthetic photon flux densities and leaf development.

Recent studies have demonstrated that isoprene in plants is biosynthesized by isoprene synthase from DMAPP via MEP pathway. In poplar, foliar isoprene emission appears to depend on isoprene synthase activity, since its emission rate parallels enzyme activity according to temperature. Despite the purification of isoprene synthase proteins from several plants, isolation of its gene has only been reported from hybrid poplar (*Populus alba* x *P. tremula*) and *P. tremuloides* and *Pueraria montana*, and very little is known about its physiological role in plants; e.g. even its subcellular location has not yet been clarified.

To obtain biochemical and molecular biological insights into isoprene synthase, we cloned isoprene synthase cDNA from *Populus alba* (PaIspS) and studied gene expression in response to environmental stress [1]. Moreover, we examined the subcellular localization of PaIspS and also characterized its enzymatic function with a recombinant protein.

Isoprene synthase cDNA from *P. alba* (PaIspS) was isolated by RT-PCR. This *PaIspS*, which was predominantly observed in the leaves, was strongly induced by heat stress and continuous light irradiation, and was substantially decreased in the dark, suggesting that isoprene emission was regulated at the transcriptional level. The subcellular localization of PaIspS protein with GFP fusion was shown to be in plastids. PaIspS expressed in *Escherichia coli* was characterized enzymatically: it had an optimum pH of approximately 8.0, and an optimum temperature 40°C. Its preference for divalent cations for its activity was also studied, to show the strongest preference for Mg²⁺ ion, while Mn²⁺ and Co²⁺ can be also accepted.

The predominant expression of PaIspS in leaves suggests that its enzyme activity may be positively regulated under illumination in plastids because photosynthetic electron transport results in the accumulation of Mg²⁺ in the stroma, along with an increase in stromal pH. In addition to the transcriptional activation of PaIspS by light, this is advantageous for the production of isoprene under strong light conditions. The optimum temperature observed in this study is also in conformity with the fact that the highest isoprene emission occurred between 30°C and 40°C in nature. On the other hand, the treatment with methyl jasmonate or methyl salicylate did not influence *PaIspS* expression. This is in clear contrast to the results with pathogen-inducible terpenoid synthases such as *epi*-aristolochene synthase and indicates that isoprene emission does not play an important role as a defense reaction against insect and pathogen attack in poplar.

Isoprene is a very reactive hydrocarbon and is thought to rapidly react with hydroxy radicals in the atmosphere, which prolongs the lifetime of methane, resulting in the enhancement of a greenhouse effect in the atmosphere. PaIspS cDNA may be used as a molecular tool to suppress isoprene emission in high-emitting trees.

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Enhancement of Tree Growth by Decrease in Xyloglucan Tethers

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Takahisa Hayashi

An ongoing goal in the field of forest-tree biotechnology is to induce woody plants to grow faster and to increase cellulose deposition. Since woody plants have a long generation time, it is difficult to apply traditional breeding methods for their improvement. The improvements mentioned above are required not only to increase the production of timber, paper materials and energy but also to ameliorate problems from rising atmospheric carbon dioxide levels by virtue of the large carbon sink offered by trees. In this study, we sought to accelerate the growth in a forest tree by taking advantage of knowledge about growth mechanisms gained from herbaceous plants.

We examined the constitutive degradation and removal of wall xyloglucan to the loosening of the cell wall. For the expression of a xyloglucanase in poplar, we used 28 kDa xyloglucanase (*AaXEG2*) isolated from *Aspergillus aculeatus* [1]. We also exchanged the native signal sequence of the enzyme for that of poplar cellulase (*PaPopCell*) to ensure efficient secretion [2]. The transgenic expression of xyloglucanase increases the length of stems in poplar. The decreased Young's modulus in the elongating regions of the transgenic lines is consistent with a decreased amount of xyloglucan tethers between cellulose microfibrils.

Overexpression of xyloglucanase in poplar caused an increase in cellulose content and density in the cell walls. Since the deposition of cellulose was increased in the secondary xylem of the transgenic lines as well as in the primary wall, it is possible that cellulose deposition is affected by xyloglucan cross-links. If cellulose formation is restricted by the entanglement with xyloglucan, the relaxation by resulting from cleavage of cross-linking xyloglucans may accelerate cellulose biosynthesis and deposition. We suggest that modification of sink tissue function may be a widely applicable strategy for enhancing carbon fixation. Future forestry could be greatly improved by such trees and begin a new era of wood production and quality.

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Molecular Diagnosis for Sustainable Forest
----- from an individual to a population -----

(Laboratory of Plant Gene Expression, RISH, Kyoto University)

Hiroyuki Kuroda

A natural forest, which is a population made up of individuals, carries genetic diversity even if they consist of the same species. Such diverse population provides the traits resistant against environmental stress. On the contrary, plantation prefers generally to being consisted of a dominant tree or a selected clone because diverse quality is undesirable character. Even in a natural forest stand, the population may suffer from a selective pressure by pathogen, causing biased traits in the population. The latter example is a breeding by selection of survived trees in the natural forest stands suffered from pine wilt diseases.

Japanese pine forest has been severely suffered from pine wilt diseases and the dead trees are the biggest loss in biomass of Japan. Furthermore, the diseases have ignited in East Asia and Europe, causing political affairs. Pesticide spray for controlling pine wilt diseases has gradually been diminished because of environmental concerns. New strategies are now required for controlling pine wilt disease. In administration related works, survived pine trees have been selected from the natural pine forest stands, being suffered from the pine wilt disease. There have been many debates on the diversity of a population from viewpoints of wood utilization and ecology. Newly selected traits such as the resistant pine trees will be examined in various aspects.

We found that a gene in a secondary metabolism shows such diversity in a pine population. Furthermore, the diverse gene translates, or enzymes, can distinctly control the nematocide biosynthesis, suggesting important roles on the resistant against pine wilt diseases [1]. In other words, these diverse genes are distinctly produced a series of phytoalexins, some of which probably control the wood nematodes. Thus a 3-year project for pine trees has started from this year, where studying biochemical and molecular diagnosis for the resistance against pine wilt diseases. We have already successfully extracted mRNAs from tree trunks [2] and cloned several cDNAs with full coding sequences. Few dozens of samples can be simultaneously analyzed for the gene expression [3]. In addition to those methods, biochemical and molecular diagnosis will be studied for an individual and a population of pine trees in the new project.

Lastly, let me touch on the expected output of this project. Tree EST libraries, especially in pine and aspen, are rich in the source of cDNA fragments. Virtual full coding sequences, which may or may not represent substantial genes, are now easily obtained from the fragments. We have successfully obtained a substantial cDNAs from a trunk by using such virtual sequences [2]. This technique is useful for providing molecular markers for the diagnosis of a tree and probably of a population. We may need diagnostic markers, for example, for active oxygen control, vapor production, carbon fixation and resistant against pathogen and so on. This strategy is also applicable to tropical forests and expected to be a strong diagnostic tool for environmental cleanup and conservation of forest, wood quality and productivity. This diagnosis will also give useful information to evaluate forest in social standpoint of view.

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Application of Precise Satellite Positioning for Monitoring the Earth's Environment

(Laboratory of Atmospheric Sensing and Diagnosis, RISH, Kyoto University)

Toshitaka Tsuda

We briefly introduce here a collaborative project named “the application of precise satellite positioning for monitoring Earth’s environment” (Project leader, T. Tsuda). The main purpose of this study is concerned with two novel satellite techniques; (1) GPS occultation and (2) satellite gravity missions. The former provides a refractive index profile by analyzing the propagation delay and the bending of GPS radio signals passing through the atmosphere and ionosphere, which can further be utilized to derive water vapor, temperature and electron density. The latter measures the detailed spatial and temporal variations of the precise gravity field of the Earth, from which the distribution of groundwater and deep ocean currents can be inferred. By coordinating a number of universities and research institutes including Kyoto University, NICT, ENRI, MRI, JMA, NAO, the University of Tokyo and so on, this research was conducted from August 2002 to March 2005 as one of the projects on “Challenge to Leading Edge of Science and Technology” with financial support received from the Special Coordination Funds for Promoting Science and Technology (SCF) of MEXT.

In this project we are mainly concerned with the technical and scientific developments of GPS occultation experiments from a mountain-top (Mt. Fuji), an airplane and a low-Earth orbiting (LEO) satellite. We continued airplane experiments using a newly designed GPS receiver, and derived a refractive index profile in the lower troposphere (see Fig. 1). We also promote a GPS occultation mission on a Brazilian LEO satellite; Equatorial Atmosphere Research Satellite (EQUARS) (see Fig. 2) in collaboration with the Brazilian space agency (INPE). The analyzed results are further assimilated into a numerical weather prediction model with global (3D-var) and regional (4D-var) scales at JMA and MRI, respectively, which effectively improves the prediction accuracy.

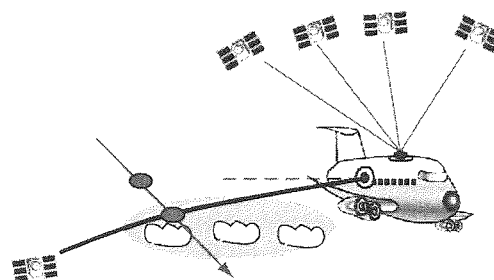


Fig. 1. Schematic diagram of GPS occultation experiment from an airplane..

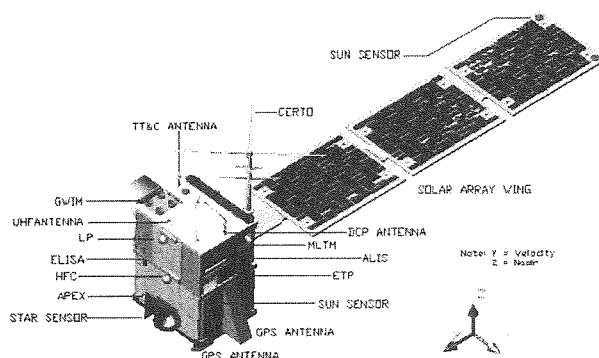


Fig. 2. Concept design of EQUARS. GPS antennas for occultation and POD are displayed in green. Z axis points toward the Earth...

Ozone and water vapor observations in the equatorial Pacific

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Ozone and water vapor play crucial roles in chemical and radiative processes especially in the upper troposphere and the lower stratosphere (UT/LS). Ozone in the stratosphere shields us from the Sun's ultraviolet (UV) radiation, making life on Earth possible; that in the troposphere acts as a strong greenhouse gas and an environmental pollutant. Water vapor in the upper troposphere is a main emitter of the Earth's infrared radiation, controlling the Earth's radiative balance; that in the lower stratosphere affects the stratospheric ozone photochemistry and the recovery of the stratospheric ozone depletion. Due to lack of observational data, however, space-time variations of ozone and water vapor in the UT/LS region have not been well described yet.

The Soundings of Ozone and Water in the Equatorial Region/Pacific (SOWER/ Pacific) mission has been running campaigns since 1998 to improve our knowledge of ozone and water vapor distributions in the UT/LS in collaboration with domestic and international researchers, filling the gap of data sparse regions such as in the equatorial UT/LS. Ozone and water vapor sonde observations have been made at several places in the equatorial Pacific: the Galapagos Islands (Ecuador), Christmas Island, Tarawa (Kiribati), Watukosek, and Bandung (Indonesia), including shipboard observations from the research vessel (e.g. Shiotani et al., 2002; Fujiwara et al., 2003).

On the basis of these experiences we plan to perform comprehensive observation campaigns to examine the dehydration process in the tropical tropopause layer (TTL) during northern winter when dehydration operates very efficiently. The first coordinated campaign was conducted in December 2004 at several stations described above including Ha Noi (Vietnam) in Indochina and a shipboard base; another campaign is expected from December 2005 to January 2006. In these campaigns we will focus dehydration processes and their efficiency with horizontal advection through the cold core region around the tropical tropopause in the western and central Pacific. We also propose to contribute to the satellite (EOS-Aura) validation, and plan to use Aura data to examine the internal consistency in a much wider space-time regime.

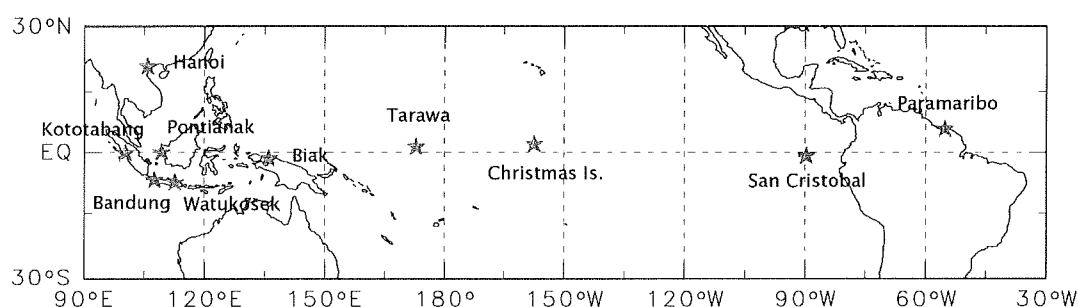


Fig. 1 Tropical stations related to the SOWER project

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Studies on dynamical processes in the tropical atmosphere with the Equatorial Atmosphere Radar (EAR)

(Laboratory for radar atmospheric sciences, RISH, Kyoto University)

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The equatorial Indonesia is the region where the most active cumulus convection occurs all over the world. Cumulus convection formed over the region works as an engine of the global circulation of the earth's atmosphere and a major source of atmospheric waves that transport momentum flux from the lower atmosphere into the middle and upper atmosphere. However, generation, propagation, and dissipation processes of these atmospheric waves are not well understood yet due to the scarcity of observations over the region.

Our research group took a leading role in the development and installation of the Equatorial Atmosphere radar (EAR) at the Equatorial Atmosphere Observatory (0.2S, 100.32E, 865 m above sea level) near Bukittinggi, West Sumatra, Indonesia in March 2001. EAR is an atmospheric radar operated with the center frequency of 47 MHz and the peak output power of 100 kW. EAR can observe winds in the troposphere and lower stratosphere, and ionospheric irregularities in the E- and F- regions [1]. Using results derived from EAR, our research group has revealed new convective features over the equatorial Indonesia in relation to atmospheric waves [2], ionospheric irregularities in the equatorial thermosphere [3], and coupling processes between the troposphere and the stratosphere [4][5].

EAR is a principal observational instrument used in a scientific project "Coupling Processes in the Equatorial Atmosphere (CPEA)" supported as Grant-in-Aid for Scientific Research on Priority Area by the Ministry of Education, Culture, Sports, Science and Technology of Japan. Using EAR and other observational instruments, the CEPA project has been producing innovative results that lead to the clarification of vertical coupling processes of the atmosphere over the equatorial Indonesia. As one of the international collaborative researches of RISH, part of the EAR operation time will be provided to domestic and international researchers from October 2005. Further explorations of the equatorial atmosphere will be carried out using observational data from EAR.



Figure 1: Picture of EAR installed at Koto Tabang, West Sumatra, Indonesia

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Optically Transparent Composites Reinforced with Networks of Bacterial Nanofibers

(Laboratory of Active bio-based materials, RISH, Kyoto University)

Hiroyuki Yano

Mechanical reinforcement of optically functional materials is of significant interest to various industries, due to the rapid expansion of related devices, e.g. displays. Nanocomposite materials with components less than one-tenth of the wavelength in size are free from scattering, making them acceptable for a variety of optical applications. *Acetobacter* (*Acetobacter xylinum*) cellulose fiber is an extracellular product excreted into the culture medium in the form of pellicles. Its fiber content is structured in a web-like network, composed of continuous nanofibers of about ten nm in thickness and 50 nm in width (Fig.1). Each nanofiber is a bundle of cellulose microfibrils, each of which is about 4 nm thick and 4 nm wide. Since the cellulose microfibrils are aggregates of semi-crystalline extended cellulose chains, their thermal expansion is as small as quartz glass.

The density, Young's modulus, and tensile strength of the cellulose microfibrils are almost equal to those of aramid fibers, a well known high strength fiber. Thus, we undertook the development of a transparent polymeric nanocomposite, with the web-like bacterial nanofiber network as the mechanical reinforcing agent.

We used bacterial cellulose (BC) pellicles as the starting material and created composites by filling the cavities of the BC sheets with transparent thermosetting resins such as epoxy and acrylic by impregnation under vacuum. Surprisingly, the composite is optically transparent at a fiber content as high as 70% as well as flexible as shown in Fig. 2, with low thermal expansion coefficient (similar to that of silicon crystal), and mechanical strength five times that of engineered plastics.

These significant improvements in thermal and mechanical characteristics of the BC composite make it an excellent candidate for transparent substrate of organic EL (OLED) flexible display, since one of the greatest barriers to realize OLED flexible display is that the metal wiring, transparent conductive film, and gas barrier film configured on the traditional substrates made of polymer materials could be broken or damaged by the temperatures involved in the assembly and mounting processes because of the difference of their thermal expansion coefficients from that of the substrate material.

This optically transparent composites material was created by the fusion of all of the information required among the Research Institute for Sustainable Humanosphere with deep knowledge of cellulose microfibrils, Mitsubishi Chemical Corporation and Nippon Telegraph and Telephone Corporation, the material manufacturer, with the knowledge of transparent polymer materials and composite materials.

Part of these results was published in *Advanced Materials*, 2005, 17(2), 153-155.

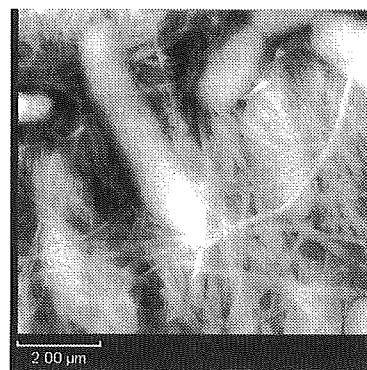


Fig. 1. AFM image of bacterial cellulose pellicle (bar: 2μm)



Fig. 2 Flexibility of 65-μm-thick bacterial cellulose sheet with acrylic resin, 60% fibre content sheet.

Development of High-performance Kenaf Bast Oriented Fiberboard and Kenaf Core Binderless Particleboard

(Laboratory of Sustainable Materials, RISH, Kyoto University)

Shuichi Kawai

INTRODUCTION

The laboratory aims to establish the sustainable cycle of forest and forest products by developing the production, utilization and recycling/desposal system of wood biomass. New wood based materials and wood carbon composites harmonized with both global and regional environment are being developed by making use of the functions of wood as a cellular solid. The on-going research projects are 1) Fundamental methodology, machines and systems for producing the high-performance wood composites and wood composites with characteristic functions, 2) Environmentally Friendly Wood adhesives, and 3) Integrated projects such as life cycle assessment of wood composites, the preservation of wooden cultural properties, the aging of wood and prediction of service life of wood, and the sustainable production and utilization system of a large-scale plantation forest of acacia mangium.

One of the recent topics of the laboratory is the development of high-performance oriented kenaf bast fiberboard and kenaf core binderless particleboard.

KENAF BAST ORIENTED FIBERBOARD AND KENAF CORE BINDERLESS PARTICLEBOARD

Kenaf (*Hibiscus cannabinus* L.) is a fast-growing annual plant. The stalk consists of a thin outer layer of dense bast fibers with an inner of light core. The kenaf bast fiber provides extremely high strength, which can be converted into a high- performance medium density fiberboard (MDF). Whereas the core is extremely light with a density of 100-200 kg/m³, which is suitable material for producing low-density board.

The oriented medium density fiberboard (MDF) from kenaf bast fibers was manufactured with newly developed pilot-scale equipment. The oriented MDF with a density of 800kg/m³ provides 2-3 times higher in mechanical performance than plywood. The MDF is now commercialized and used as a bearing wall.

The binderless particleboards from kenaf core with a density range from 200 to 650 kg/m³ were successfully developed by using a steam-injection press. The bonding performance of the binderless boards was excellent while the board density were relatively low. The mechanical performance of binderless boards was improved with increasing the steam pressure and the longer pressing time contributed to the better dimensional stability. The chemical changes and self-bonding characterization of kenaf core is also investigated.

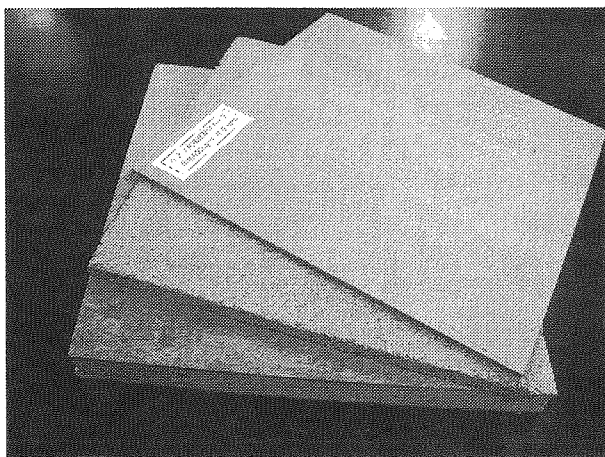


Figure shows the kenaf bast oriented MDF (top), kenaf core binderless particleboard (middle), and the composite panel of kenaf MDF as faces and the core binderless particleboard as a core (bottom).

Development of wooden rigid frame with Lagscrewbolts

(Laboratory of Structural Function, RISH, Kyoto University)

Takuro Mori, Makoto Nakatani and Kohei Komatsu

Lagscrewbolts (registered) were developed as a simple and economical fastener to constitute moment-resisting joint for glulam constructions. Lagscrewbolts have thread like lagscrews on the outside surface and, thread like a nut in the inside or thread on the outside surface at one end of the shank. Photo 1 shows two types of Lagscrewbolts.

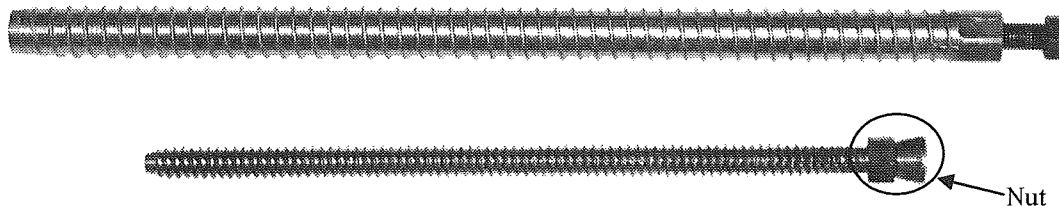


Photo 1. Lagscrewbolts. (Up: thread in the inside, Bottom: thread on the outside)

Our laboratory and Hara Tec Co. have developed the joints for wooden rigid frame with Lagscrewbolts. These joints do not require large diameter Lagscrewbolts. Because the joints using large diameter Lagscrewbolts tended to split due to the difference of stiffness between Lagscrewbolts and wooden members. Therefore we thought that it will be much better to avoid the split failure mode by construction with small diameter Lagscrewbolts. The small diameter Lagscrewbolts such as the bottom of Photo 1 was developed. In addition, a new type of base plate having a special nut as shown in Figure 1 was developed. The plate has a taper and the nut has a space for the deformation. This joint was designed to break in the nuts, not wooden members, nor Lagscrewbolts. The failure mode of this joint is pull-out of the nuts from the plate.

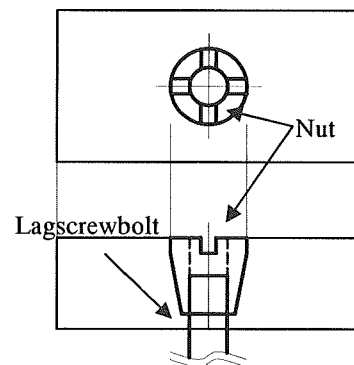


Fig. 1. Mechanism of between nut and bolt.

In the previous studies, pull-out properties of embedded Lagscrewbolts have been evaluated. As the results we could get good values of strength (P_{max}) and slip modulus (K_s). So the T shape specimens were examined for evaluating the properties of the moment-resisting joint. Figure 2 shows the T shape specimen. Table 1 shows the results of strength (P_{max}), slip modulus (K_s) and Energy absorption. As those mechanical properties were sufficient enough, we are going to design a three stories glulam building in this year.

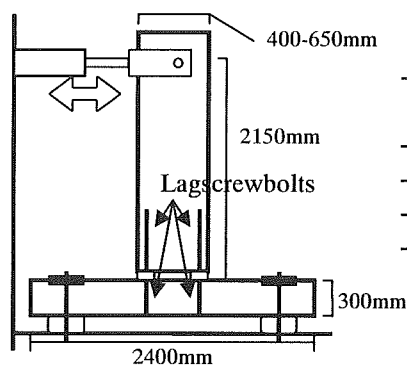


Fig. 2. Test set-up for T-shape Specimen.

Table 1. Results of the bending test for new joint.

	P_{max} (kNm)	K_s (kNm/rad.)	Energy (kNm-rad.)
Beam depth 400mm	47.9	2527	1.58
Beam depth 525mm	75.1	4679	2.18
Beam depth 650mm	84.0	7334	1.44

Development of advanced carbon materials from carbonized Japanese cedar

(Laboratory of Innovative Humano-Habitability, RISH, Kyoto University)

Toshimitsu Hata

The task of our laboratory is to establish the society with proper resource recycle system in the future humanosphere. Fundamental and innovative investigations are being conducted with emphasis on the symbiotic relations with forest and wood resources. Prof. Yuji Imamura, Dr. Kunio Tsunoda, Dr. Tshuyoshi Yoshimura, myself and other members of the Lab. are dedicating their constant efforts to achieve the goal. Here, one of the topics of our laboratory, development of advanced carbon materials from carbonized Japanese cedar is presented.

Japanese cedar, i.e. Sugi (*Cryptomeria japonica*), was at first carbonized in an electric furnace at 700 °C under Ar flow, at 4 °C/min heating rate, for one hour. The resulting charcoal was milled and then soaked in a 40 % isopropyl alcohol solution of Al-triisopropoxide. After drying, the specimen was carbonized in a pulse current sintering apparatus up to 1300 °C for 5 min [1]. Without catalyst and after “classical” carbonization, such carbonized-wood consists in a non-graphitizing carbon with a highly porous texture. In the experiment, due to catalyst addition, the intermediate reaction of Al₂O₃ with carbon leads to the formation plate-like Al₄C₃. Then this latter compound dissociates under the proper CO pressure and temperature, leading to the formation of Al vapor and well-ordered graphitizing carbon at low temperature. The modification of the texture, microtexture and structure of such carbonized samples was followed by scanning and transmission electron microscopies.

Subsequently, on this carbonized then sintered samples, we demonstrated that growth of catalytic multiwall carbon nanotubes was possible. Experiments were performed at 650 °C under N₂/H₂ then N₂/C₂H₄ atmospheres. Multiwall carbon nanotubes with a diameter of about 50 nm were produced (Fig.1). Possible applications could be in the field of electrochemistry.

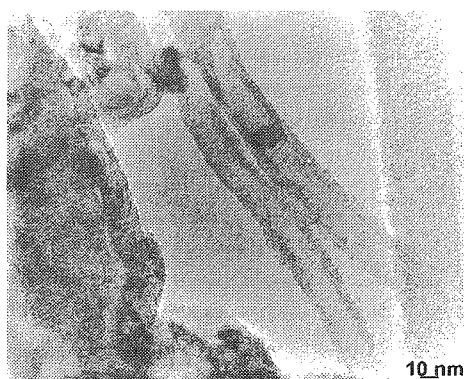


Fig. 1. Growth of Multiwall carbon nanotubes at the surface of wood, successively carbonized, impregnated with an Al-based solution, sintered and used as support for catalytic decomposition of acetylene [2].

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ACKNOWLEDGEMENT

The author would like to acknowledge the favors from Sylvie Bonnamy (CNRS-CRMD), Yannick Breton (CNRS-CRMD), Paul Bronsveld (Groningen Univ.), and the Grant-in-Aid for Scientific Research (15380119) from the Ministry of Education, Culture, Sports, Science and Technology of Japan for financial support.

Development of Geospace Environment Simulator (GES)

(Laboratory of Computer Simulations for Humanospheric Science,
RISH, Kyoto University)

Yoshiharu Omura and Hideyuki Usui

In exploration and utilization of the geospace environment, it is very important to understand the interactions between spacecraft/structures and space plasma environment as well as the natural phenomena occurring in space plasma. In order to evaluate the spacecraft-plasma interactions quantitatively to contribute to the progress of space utilization and space technology, we aim to develop a proto model of “Geospace Environment Simulator (GES)” by making the most use of the conventional full-particle, hybrid and MHD plasma simulations. The concept of GES is shown in Figure 1. The GES can be regarded as a numerical chamber in which we can virtually perform space experiments and analyze the temporal and spatial evolution of spacecraft-plasma interactions. The GES will be able to provide fundamental data regarding various engineering aspects such as the electrostatic charging and electromagnetic interference of spacecraft immersed in space plasmas, which will be useful and important information in determining designs and detailed specifications of spacecraft and space systems.

In our laboratory, we are particularly interested in the plasma kinetics and its effects on the space environment. Therefore we hire full particle-in-cell (PIC) method in the computer experiments and developed a skeleton 3D domain-decomposition EM-PIC code called NuSpace which has been well tuned for the Earth simulator. Prior to the simulations we improved the efficiency of parallelization of NuSpace. We successfully achieved 99.75% of the efficiency of parallelization.

As a test model, we focus on the situation where heavy ion beam is emitted in the magnetosphere from an ion propulsion engine used for the future orbit-transfer of large space structure such as SSPS. For the charge neutralization, thermal electrons are also emitted from the beam source. A snapshot showing the ion and electron dynamics as well as the potential profile in a plane is displayed in Figure 2. It is found that the electrons in small yellow accompanying with the ion injection are modulated by the local magnetic field and cannot perfectly neutralize the ion beam. This is also shown in red color in the potential contour map. We have working on the further analysis on field perturbation and its effect on the spacecraft environment.

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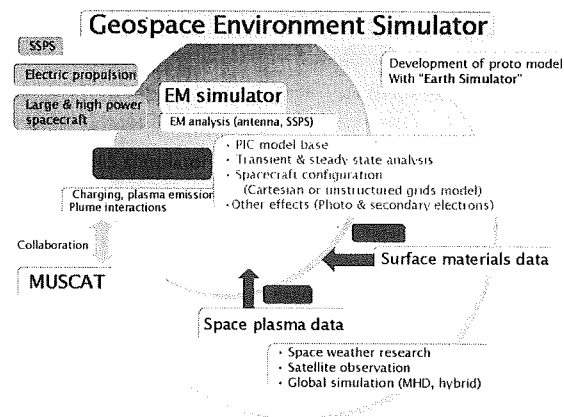


Figure 1: Concept of GES

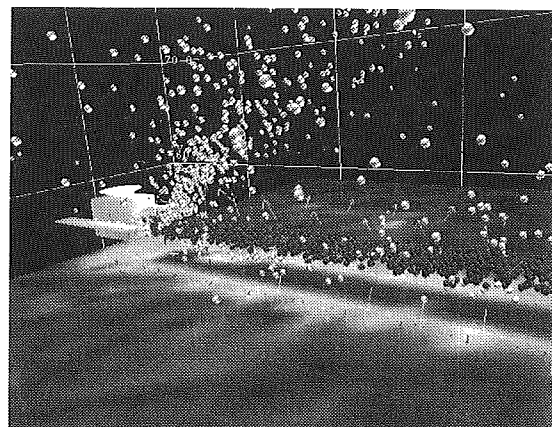


Figure 2: Snapshot of heavy ion injection from spacecraft into space plasma

A self-steering array and its application to phase synchronization of transmitter units and Solar Power Satellite

(Laboratory of Applied Radio Engineering for Humanosphere,
RISH, Kyoto University)

Kozo Hashimoto, Naoki Shinohara and Tomohiko Mitani

POINT: Microwave power of Solar Power Satellite is radiated from a huge phased array antenna. A beam pattern of the microwave is controlled by phases of the antenna elements. Although their phase reference is important, it is difficult to make. We proposed a simple and unique method for the reference based on a revised self-steering array.

The concept of Solar Power Satellite (SPS) is very simple. It is a gigantic satellite designed as an electric power plant orbiting in the geostationary earth orbit. It consists of mainly three segments; a solar energy collector to convert the solar energy into DC electricity, DC-to-microwave converters, and a large antenna array to beam down the microwave power to the ground. The first solar collector can be either photovoltaic cells or solar thermal turbine. The second DC-to-microwave converters can be either a microwave tube system and/or semi-conductor system. It may be their combination. The third segment is a gigantic antenna array. The required accuracy of the beam control is less than 0.0005 degree.

SHARP (Stationary High Altitude Relay Platform) is a platform consisting of an aircraft powered by microwave energy sent from the ground. A unique self-steering array which automatically tracks the receiver (the spacecraft) by adjusting phase shifters based on its altitude and the reception intensity on the ground was used. We propose a revised system which does not require the altimeter and converges faster. When the distance between the transmitter and the receiver is large, the propagation delay makes the response time longer. We also propose a new method which overcomes this delay.

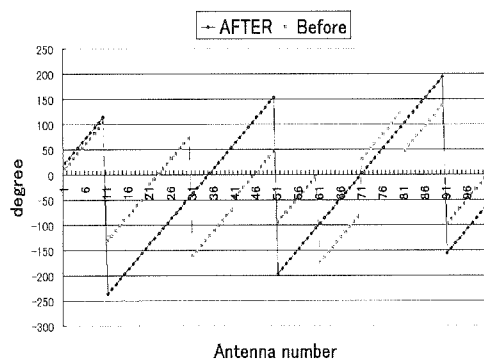


Fig. 1. Phases of array elements before and after the self-steering.

the array are adjusted only in each unit. After the self-steering (blue line), their phases are adjusted as a 10-unit system. The system works as a 100-element array.

When a system is so large like SPS, the array would be composed of a lot of units. The system is too large to distribute a reference signal generated by a single reference oscillator. Although the beam steering is possible in each unit, a beam radiated from a unit could cancel that of another one depending on the phases of their reference signals. If independent oscillators are used, their requirement for the stability and accuracy could be quite strict. Although their frequency can be synchronized, it would be difficult to adjust the phases. The phase of each reference oscillator could be adjusted using the self-steering technique if each unit works under its own retrodirective system. Fig. 1 demonstrates an array of 10 units with 10 antenna elements. Before applying the present technique (pink line), phases of

Plasma wave investigation in Mercury magnetosphere

(Laboratory of space radio science, RISH, Kyoto University)

Hiroshi Matsumoto, Hirotsugu Kojima, and Yoshikatsu Ueda

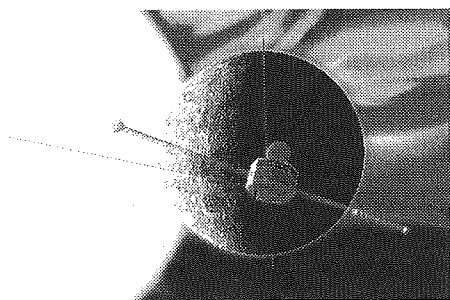


Figure 1: Mercury Magnetospheric Orbiter(MMO) of the BepiColombo mission (Artistic impression illustrated by C. Noshi.).

Mercury is the closest planet to the Sun. It is characterized by the highest density of all planets, very rarefied atmosphere and very weak intrinsic magnetic fields. Only American probe Mariner 10 has returned data from Mercury. It made three flybys of Mercury in 1974-1975 and obtained images of its surface and measured the plasma environments in Mercury. One of the most significant results in Mariner 10 mission to Mercury is to discover its intrinsic magnetic fields. Further, the data suggest the unexpected existence of the magnetosphere. However, the data in only three flybys of Mariner 10 are insufficient for revealing the features of this mysterious planet.

ESA (European Space Agency) and JAXA (Japan Aerospace exploration Agency) started the new mission to Mercury called “BepiColombo mission” under their collaboration. The BepiColombo mission consists of two independent spacecraft. They are the MPO(Mercury Planetary Orbiter) and MMO(Mercury Magnetospheric Orbiter). JAXA is responsible for developing the MMO spacecraft, which has the objective to investigate the Mercury magnetosphere.

To meet the scientific objectives of BepiColombo/MMO, we proposed the plasma wave receiver system called PWI (Plasma Wave Investigation) to the Announce of Opportunity issued by JAXA. Fortunately, JAXA selected and approved our proposal in November, 2004. We made a start for the detailed design of PWI. PWI is developed under the collaborations of Japanese and European scientists (Principal Investigator (PI): Hiroshi Matsumoto, Kyoto Univ.). The composition of PWI is summarized in Table 1.

PWI will address a wealth of fundamental scientific questions pertaining to the magnetosphere and exosphere of Mercury, the solar wind at Mercury location and solar radiation from the view point of Mercury. Together, these measurements will provide ample new information on the structure of the Herman magnetosphere as well as on its dynamics. New knowledge will be gained about energy transfer and scale coupling. We will learn more about wave-particle interactions in the Herman plasma environment. The MMO spacecraft is scheduled for launch in 2012.

Table 1: Composition of Plasma Wave Investigation

Sensors

Component	Frequency	Development/Responsibility
WPT	<i>E</i> : 0Hz – 10MHz	Japan
MEFISTO	<i>E</i> ; 0Hz – 10MHz	Sweden
LF-SC	<i>B</i> : 0Hz – 20kHz	Japan
DB-SC	<i>E</i> : 0Hz – 20kHz <i>B</i> : 20kHz – 640kHz	France

Receivers

Component	Frequency	Data	Development/Responsibility
EW0	<i>E</i> : 0Hz – 120kHz <i>B</i> : 0Hz – 20kHz	Spectrum/Wave-Form /Spacecraft Potential	Japan
SORBIT	<i>E</i> : 2.5kHz – 10MHz <i>B</i> : 2.5kHz – 640kHz	Spectrum/Electron temperature	France
AM ² P	< 120kHz	Antenna impedance	France

Onboard software: Japan and Hungary

Disordered Manganese Oxide Nano-powder
Prepared by Low-temperature Synthesis Followed by Acid Treatment

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ABSTRACT

Disordered manganese oxide, prepared by low-temperature synthesis followed by acid treatment is introduced. Aggregated nano-powder of disordered manganese oxide was obtained in this method. The disordered manganese oxide is suitable starting material for the preparation of efficient adsorbents for the removal of harmful metals from the environment.

INTRODUCTION

Crystal forms of manganese oxide are categorized into various phases such as the rock-salt-type MnO (cubic), spinel-type λ -MnO₂ (cubic), ramsdellite λ -MnO₂ (monoclinic), and hausmannite Mn₃O₄ (tetragonal). The crystal structures of manganese oxide contain fundamental building blocks of MnO₆ octahedron. However, the oxygen array of the crystal lattice usually features other octahedral and tetrahedral sites that may accommodate Mn and other cations via subtle distortion/tilting of the MnO₆ octahedra and/or formation of oxygen defects. These properties in conjunction with the variation of Mn²⁺ and Mn⁴⁺ valence states and the interactions with the Mn magnetic moments, give rise to a variety of very intriguing crystal morphology and structural transformations as well as magnetic ordering at low temperatures that are of fundamental interest. Technologically, once the properties of materials are understood, novel applications can be tailored. New batteries, ion exchangers for environmental decontamination, and magnetic spin-valve devices are such examples among many suggested potential applications.

The authors have studied manganese oxide-based materials for the research and development of efficient adsorbents in order to remove harmful metals from the environment. Recently, we synthesized the disordered phase of manganese oxide and discovered the exhibition of high adsorption capability of pollutants such as Cd and As ions and of rare metal such as Au [1]-[6]. These phenomena occur only in the disordered manganese oxide powder after protonation by acid treatments. The disordered-manganese oxide powder show the quantity of adsorption to be at least more than 10 times higher compared with the manganese oxide without the acid treatments.

EXPERIMENTAL

MnCO₃ powder (Wako, 99% purity) as the starting material was heated using an electric furnace at 200 °C in air for 4.5 h. Acid treatment began by adding the powder into 0.5 mol/L of nitric or hydrochloric acid while stirring (using a magnetic stirrer) for a certain period of suspension time. Afterward the suspended particles were filtered from the solution using a glass filter (0.2 μ m mesh), followed by washing with distilled water. This first stage processed with a 60 min suspension time for an initial acid treatment enabled the growth of nanometer-size crystalline Mn₂O₃ grains on the surfaces of micron-size crystalline MnCO₃ particles. Subsequent acid treatments, typically for 1 h suspension each, allowed the removal of MnCO₃ component and the self-assembly of adsorbed H⁺ ions (protons) on the Mn₂O₃ nanoparticles. This second acid treatment resulted in substantial increase of the population of protonated sites. Furthermore, remaining MnCl₂ or MnNO₃ in the solution after the acid treatment and filtration of the adsorbent can be readily converted to MnO₂ powder with useful high surface area by adding an appropriate amount of KMnO₄ to the solution. This reduces the amount of waste and negative environmental impacts.

RESULTS AND DISCUSSION

Fig. 1 shows the Variation of XRD pattern on the disordered-manganese oxide powder prepared by low-temperature synthesis followed by acid treatment. The XRD of the prepared sample (no acid treatment) heated less than 200 °C showed similar pattern with the starting material (MnCO_3). However, the color was different from each other. The flesh-colored of MnCO_3 has changed the black of Mn_2O_3 [6]. The peaks on the XRD patterns have changed the broadness according to increase in the frequency of the acid treatment, and indicated the disordered crystal phase of the manganese oxide remarkably. We assume that this disordered phase is the result of acid treatment of the surface layer of Mn_2O_3 .

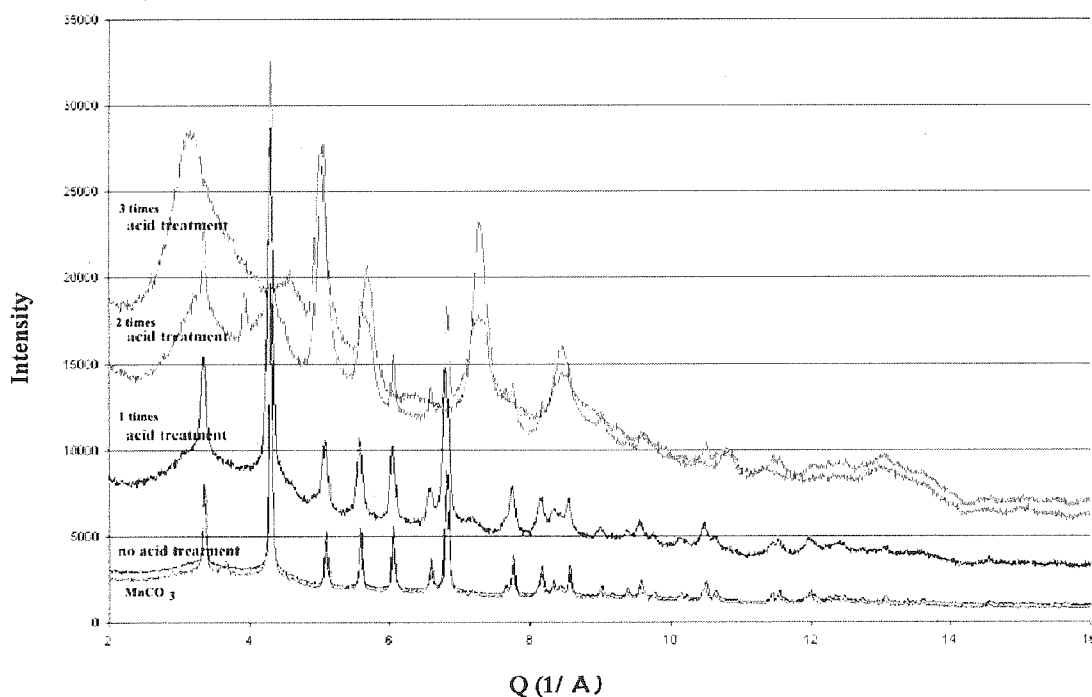


Fig. 1 Variation of XRD pattern on the disordered-manganese oxide powder prepared by low-temperature synthesis followed by acid treatment.



Fig. 2 TEM image of the disordered-manganese oxide powder.

Fig. 2 shows the TEM image of the disordered -manganese oxide powder obtained after 3 times of acid treatment. Aggregated nano powders were observed in the image. These powders construct aggregated powders in micro-meter size, and show remarkable adsorption ability for the complex ions such as gold, palladium, and silver in aqueous solution [4]-[6]. The electrons are supplied from the manganese oxide to each complex adsorbed according to the each redox potential. The adsorbed complex is deposited on the surface of the manganese oxide as the metallic nano-particles.

CONCLUSIONS

A new method to prepare nano-powders of the disordered-manganese oxide based on Mn_2O_3 was introduced in this report. In principle, this synthesis method can produce useful manganese

oxide-based catalysts supporting different metallic nanoparticles such as Au, Pd, and Ag.

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Degradation of *cis*-1,4-Polyisoprene Rubbers by White Rot Fungi and Manganese Peroxidase-catalyzed Lipid Peroxidation

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Natural rubber, exclusive *cis*-isoprene units linked to each other by 1,4-addition, is produced by more than 2500 different species of plants and some fungi. Natural rubber has been commercially exploited for more than 100 years by cultivating and tapping the rubber tree, *Hevea brasiliensis*. As an alternative to biological production, synthetic *cis*-1,4-polyisoprene has also been obtained since polymerization of isoprene by the Ziegler catalyst was achieved. These raw rubber materials are converted to rubber products by the process of vulcanization that leads to cross-links between rubber chains [1]. Sulfur vulcanization creates a strong chemical network that gives recalcitrance toward physical, physicochemical, and microbial destruction and superior physical properties of elasticity, whereas recycling of spent rubber products becomes problematic due to the irreversible process [2].

White rot basidiomycetes have been the focus of research with respect to the biodegradation of lignin in wood and the bioremediation of environmental hazards. White rot basidiomycetes and ligninolytic systems have also been reported to degrade natural and synthetic polymers. However, to our knowledge, the degradation of rubber products by basidiomycetes has not been reported. In this study, the degradation of vulcanized natural rubber sheets by basidiomycetes was investigated, and it was demonstrated that a white rot basidiomycete, *Ceriporiopsis subvermisporea*, degraded vulcanized natural rubber sheets in wood cultures [3]. The fungus decreased total sulfur content of the rubber by 54% in 200 days, accompanied by the cleavage of sulfide bonds between the polyisoprene chains. X-Ray photoelectron spectroscopy (XPS) demonstrated that *C. subvermisporea* reduced the frequency of S–C bonds by 69% with the concomitant formation of S–O bonds during the culture. Dipolar decoupling/magic angle spinning (DD/MAS) solid state ^{13}C NMR revealed that the fungus preferentially decomposed monosulfide bonds linked to a *cis*- and *trans*-1,4-isoprene backbone. When the rubber sheets were exposed to a culture of a white rot fungus, *Dichomitus squalens*, for 200 days, a 15% decrease in the total sulfur content and the formation of S–O bonds in the rubber was observed. However, a decrease in S–C bonds and an increase in the volume swelling ratio in toluene were not observed. These results indicate that *D. squalens* did not cleave S–C bonds but removed unbound sulfur or oxidized sulfide to sulfoxide. The oxidative cleavage of sulfide bonds by *C. subvermisporea* demonstrates that ligninolytic basidiomycetes are microbes with the potential to devulcanize rubber products.

Lipid peroxidation (LPO) is a ligninolytic system proposed for selective white rot. The fungus, *C. subvermisporea* produces unsaturated fatty acids (USFAs) and cause extracellular LPO of the USFAs catalyzed by ligninolytic enzymes [4, 5]. In the present study, the LPO of USFAs catalyzed by oxidative enzymes and transition metals were applied to the degradation of vulcanized and nonvulcanized synthetic polyisoprene. It was demonstrated that nonvulcanized and vulcanized polyisoprene rubber materials were degraded by controlling the free radical chain reactions of lipids using oxidative enzymes, manganese peroxidase (MnP), laccase (Lac), and horseradish peroxidase (HRP) [5]. Nonvulcanized synthetic polyisoprene was degraded by the free radicals from a USFA, linoleic acid (LA) produced by MnP, HRP, and a combination of Lac/1-hydroxybenzotriazole. The degradation of nonvulcanized polyisoprene was also observed in the LPO of LA initiated by the Fenton reaction (FR) and Mn(III), an oxidation product produced by MnP. While lipoxygenase (LOX) can directly oxidize LA as a substrate, LOX caused no apparent degradation due to the differences in radical chain reactions in the LPO. Vulcanized polyisoprene rubber sheets were degraded by the LPO of LA initiated by HRP, MnP, Mn(III), and FR. Pyrolysis GC–MS analysis demonstrated that the LPO liberated isoprenoid fragments extractable with chloroform. The mechanism for the decomposition of nonvulcanized polyisoprene should be explained by hydrogen abstraction from a β -position of double bonds in isoprene chains by free radicals from lipids and the β -oxidation of the alkoxyl radical. Concerning the decomposition of vulcanized polyisoprene rubber sheets, scission of sulfide linkages in the sheets by the free radicals may be also involved in the decomposition, together with breakdown of isoprene chains.

In addition to the actinomycetes, bacteria, and fungi imperfecti previously reported as rubber-degrading microorganisms, this is the first report of basidiomycetes capable of degrading

vulcanized rubber. A white rot basidiomycete, *Ceriporiopsis subvermispora*, oxidatively cleaved sulfide bonds in vulcanized polyisoprene rubber. It was also demonstrated that *cis*-1,4-polyisoprene and vulcanized rubber products were degraded by the oxidation of unsaturated fatty acids with oxidative enzymes and transition metals. Control of free radical reactions of LPO by enzymes and transition metals will allow us to develop novel techniques for safe disposal and recycling of vulcanized rubber wastes.

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Metabolic Analysis of the Cinnamate/Monolignol and Lignan Pathways

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Fossil resource-based industrial society has provided us prosperity, especially in the developed countries. However, it also has brought serious negative impacts on the global environment due to the increase in the atmospheric concentration of carbon dioxide, accompanied by a number of pollution problems. Therefore, it is becoming very important to establish a sustainable and recycling-based society, which depends on renewable resources.

Wood biomass is the most abundant and potentially renewable resource. However, utilization of wood biomass has been based on the paradigm of a fossil resource-based society. Therefore, it is necessary to establish the sustainable production and utilization system for forest resources, so that a sustainable, recycling-based society can be established.

Wood biomass is composed mostly of secondary xylem which is formed through two metabolic events, cell-wall formation and heartwood formation. Hence, biochemical and molecular biological studies of secondary xylem formation provide the basic knowledge for establishing systems for sustainable production of forest resources or wood biomass.

Because both cell wall and heartwood formation comprise a wide variety of biochemical reactions, it is not an easy task to elucidate their integrated biochemical and molecular biological mechanisms. Fortunately, however, phenylpropanoid biosynthesis occurs commonly in both cell wall and heartwood formation as principal metabolic events. For example, lignin is one of the major cell wall components, while lignans and norlignans are deposited in significant amounts in heartwood regions of trees.

During the last decade, due to the recent development of molecular biological techniques, significant advances have been made in the biosynthetic studies of phenylpropanoid. This has presented many new questions to be elucidated in this field. For example, phenylpropanoid biosynthesis involves several pathways where many possible and parallel routes can be envisaged, and identification of a true, physiological route among the possibilities are still open to question.

In the present study, the author focused on the identification of the physiological route by the use of comprehensive metabolite quantitation (metabolic profiling). First, the author worked on the biosynthetic route for yatein from matairesinol in the lignan pathway [1], and then characterizing the cinnamate/monolignol pathway in relation to lignan biosynthesis [2].

A dibenzylbutyrolactone lignan, yatein, is of interest because it is not only a typical heartwood lignan but also a key biosynthetic intermediate for an antitumor lignan, podophyllotoxin. In 1980s, it was shown that matairesinol was a precursor of podophyllotoxin [3]. Later, the biosynthesis of matairesinol from coniferyl alcohol was established [3]. However, the route from matairesinol to yatein remains unknown. The conversion of matairesinol to yatein involves four steps, and many possible orders of their occurrence can be envisaged, suggesting that a metabolic grid might be present in the transformation.

First of all, the author synthesized deuterium-labeled and unlabeled standards for 10 lignans which are the possible precursors of yatein. Then, using these standards, the author established a comprehensive quantitation system for the precursors of yatein based on a stable-isotope-dilution method.

The system was applied to characterizing the yatein biosynthesis in *Anthriscus sylvestris*, which contains significant amounts of yatein and other lignans. In addition, deuterium-labeled lignan and [U-ring- $^{13}\text{C}_6$]phenylalanine were administered to the plant, and stable isotope incorporation into downstream metabolites were examined comprehensively. Taken together, the results of these experiments established two independent branch pathways from matairesinol; one giving rise to yatein and the other to bursehernin [1].

Next, the author expanded the quantitation system to the cinnamate/monolignol pathway, because, in the post-genomic era, much attention has been focused on the overall understanding of the integrated control mechanisms for the pathway in relation to xylem formation.

Again, the author synthesized deuterium-labeled and unlabeled standards for all the compounds on the pathway, and established a comprehensive metabolite quantitation system for the pathway. Using the system and that for lignan biosynthesis established previously [1], the author measured comprehensively the amounts of the metabolites on the cinnamate/monolignol and lignan pathways in the *C. tinctorius* cv.

Round-leaved White seeds. In addition, the author carried out the simultaneous administration of two distinctly-labeled compounds to the seeds. Taken together, the results of these experiments suggested strongly the intermediacy of ferulic acid in lignan biosynthesis in *C. tinctorius* seeds. This is in sharp contrast to the current view of lignin biosynthesis that ferulic acid is not involved in lignin biosynthesis as a precursor [4].

In conclusion, the present study established for the first time the precise and comprehensive metabolite quantitation (metabolic profiling) systems for the cinnamate/monolignol and lignan pathways by the use of a stable-isotope-dilution method. The system was successfully applied to the metabolic analysis of lignan pathway in *Anthriscus sylvestris*, and the pathway from matairesinol to yatein was established. In addition, the intermediacy of ferulic acid in lignan biosynthesis in *Carthamus tinctorius* cv. Round-leaved White was strongly suggested. The quantitation systems would be useful tools for elucidating integrated mechanisms for xylem formation in trees.

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Involvement of ABC proteins in the transport of endogenous low molecular weight metabolites in plants

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Alkaloids comprise one of the largest groups of secondary products, and have divergent chemical structures and diverse biological activities. Plant alkaloids are used in both modern and traditional medicine, e. g., vincristine and taxol are prescribed as anticancer drugs, morphine and scopolamine are used as analgesics, and berberine, a benzyloquinoline alkaloid, is conventionally used as an antibacterial and antimalaria drug. These alkaloids also often show strong cytotoxicity to prokaryotic and eukaryotic cells; e. g., vincristine inhibits microtubule formation, and berberine inhibits DNA and protein synthesis. Because of these activities, alkaloids are presumed to play an important role as a biological barrier to protect the plant tissue from pathogens. Indeed, berberine shows strong antimicrobial activity to both Gram-positive and Gram-negative bacteria as well as other microorganisms.

On the other hand, alkaloid-producing plant cells seem to be insensitive to their metabolites. Berberine-producing plant cells must have a mechanism protecting them from the cytotoxicity of berberine, although how it is detoxified in plant cells is still unclear. One of such detoxification mechanisms is probably the sequestration of berberine into vacuoles or the efflux of berberine by the plant cells to keep apart it from the cytosol and also from the nucleus. We have been studying the alkaloid transport mechanism in berberine-producing cultured cells of *Thalictrum minus* and *Coptis japonica* as model systems to elucidate the detoxification mechanism.

I have demonstrated in this study the high tolerance of cultured *T. minus* cells that produce a large amount of berberine, in comparison with cells that do not have berberine biosynthetic pathway. While cultured *T. minus* cells preferentially excreted the endogenous berberine into the medium, they also excluded berberine exogenously added to the culture, as well as a heterocyclic dye, neutral red, and calcein AM, a fluorescent probe to measure the pumping activity of multidrug efflux transporter in an ATP-dependent manner. Further analyses using inhibitors of ATP-binding cassette (ABC) proteins have suggested that a member of ABC transporters is involved in the transport of berberine in the *Thalictrum* cells [1].

In order to identify plant ABC proteins, I applied the vanadate-induced nucleotide trap, which is conventionally used as an effective analytical technique to characterize mammalian ABC-type drug efflux pumps. ABC proteins show drug-stimulated ATPase activity, and the catalytic sites have low affinity and specificity for nucleotides. The catalytic site is stably labeled with 8-azido-ATP by UV when the activity of ABC proteins is inhibited by vanadate. This study showed that this technique could be applicable to plant cells for characterizing ABC proteins expressed in berberine-producing cell cultures.

Thus, the vanadate-induced nucleotide trapping technique was applied to berberine-producing plant cell cultures, *T. minus* and *C. japonica*. One membrane protein at ca. 180 kDa was photoaffinity-labeled with 8-azido-[α -³²P]ATP in the *T. minus* cells in the presence of vanadate, which was specifically induced by the addition of benzyldadenine in a similar manner as the induction of berberine biosynthesis in these cell cultures, whereas three bands were observed in the *C. japonica* cells in the size region between 120 and 150 kDa corresponding to full-sized ABC protein [2]. The benzyldadenine-induced band in *T. minus* showed properties similar to those of human MDR1, including the recognition of berberine, which suggests that the ABC protein detected in *T. minus* takes this endogenous alkaloid as a putative substrate for transport. This was the first application of this technique to plant cells.

To address more general questions, what kind of role plant ABC proteins are playing, I chose a model plant *Arabidopsis thaliana*, and found 22 members that belong to MDR subfamily among ca. 130 ABC protein genes in the genome. The most resemble members with *Thalictrum* MDR type ABC transporter have been analyzed on gene expression level, as well as the functional level in *Arabidopsis*.

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Bio-nanocomposites based on cellulose microfibril

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The objective of this study was to develop a new process to manufacture high-strength biocomposites exploiting the unusually high-strength properties of cellulose microfibrils [1, 2]. Most of the studies that have been carried out heretofore were based on film casting techniques of composite fabrication as a way to assure good dispersion of cellulose whiskers or fibrils in the matrix. Some of the studies tried different methods but attained reduced reinforcements due to poor dispersion of cellulose.

Here, a novel method to obtain composites by lamination of phenolic resin impregnated sheets of microfibrillated cellulose was proposed. The concept was based on utilizing microfibrillated cellulose (MFC), a cellulose morphology obtained through microfibrillation of kraft pulp fiber by mechanical processess of refining and high-pressure homogenization [3, 4]. The treatment confers drastically large surface area to the material, characterized by a nano-scalar, web-like networked fibrils and microfibrils, which have the potential to increase interactive forces between reinforcing elements and matrix in a composite. When the mechanical properties of MFC-based composites were compared with those of non-fibrillated kraft pulp-based composites, there were no significant differences in Young's modulus, around 18-19GPa. However, the ultimate strength of MFC composites achieved 370MPa, a value 1.4 times higher than that of pulp composites [5]. The higher strength was an effect of the larger yield strain resulting in enhanced toughness of MFC composites. The work of fracture is a consequence of the highly extended surface area of networked nano-scalar fibrils, which generates an increased bond density resulting in a crack delaying mechanism. As a consequence of the nano-scalar dimensions of the fibrils, fracture sites will be smaller and more widely distributed in the material volume. The nanostructured material failure is therefore delayed and the strength is increased. Such a deforming behavior makes MFC-based composites as strong and tough as commercial magnesium alloy.

The degree of fibrillation of pulp fibers was evaluated concerning its effect on the mechanical properties of the final composites [6]. It was found that the strength of composites dependency on fibrillation level is not linear. There was no change in strength for composites prepared using pulp treated by refiner up to 16 passes, however, a sudden increase occurred when the treatment attained 30 passes through the refiner (Fig.1). SEM observations revealed that fibrillation of the fibers surface solely did not increase fiber interactions. Only the complete fibrillation of the bulk of the fibers resulted in an increment of mechanical properties, and additional fibrillation by homogenization treatment led to a linear increase of strength. Microfibrillation eliminates defects or weaker parts of the original fibers that would act as the starting point of cracks, but also increases interfibrillar bond densities creating a structure that favors ductility. Such ductility contributes to the material failure delay resulting in increased strength of the composites.

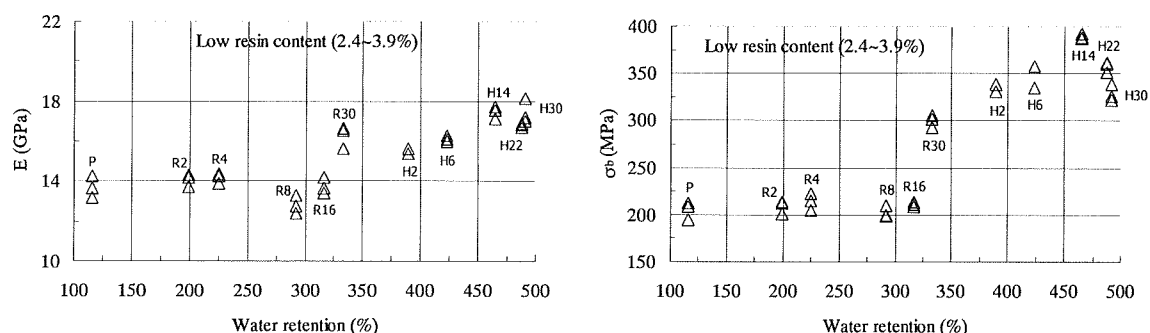


Fig. 1 Young's modulus and bending strength of composites vs. water retention of fibrillated kraft pulp with resin contents between 2.4 to 3.9%. P refers to non fibrillated pulp, plots labeled R relate to kraft pulp treated by refiner only, and those labeled H refer to kraft pulp additionally treated by homogenizer after 30 passes through the refiner. Numerals denote the number of passes through the refiner or homogenizer. The effect of fiber content on the mechanical properties of MFC composites was also assessed. The

relationship was not linear, exhibiting a linear raise in Young's modulus at fiber contents up to 40wt% and lowering the increasing ratio at higher contents. This tendency in reinforcement was also shown by the CTE measurements, the thermal expansion decreased rapidly, about 6 times from the CTE of PF resin to values similar to e-glass (10ppm/K) at fiber contents above 60wt%. The fast decrease in CTE can be attributed to the much larger Young's modulus of cellulose microfibril (138GPa [1]) compared to the PF resin (5GPa) and to the extremely low CTE of cellulose microfibril (0.1ppm/K [7]). Effective reinforcement of mechanical properties as well as thermal expansion restraint could be attained at fiber contents from around 50% up, demonstrating the effective reinforcing capability of cellulose microfibrils and the advantages of microfibrillation.

Finally, in order to compare the effect of different cellulose morphologies on the mechanical properties of composites, bacterial cellulose (BC) was used as reinforcement, and compared with those of MFC composites [8]. The singular structure of BC pellicles, with dimensionally uniform, somewhat straight, and continuous fibrillated structure was considered as a perfect model of the ultimate microfibrillated cellulose. The strength of BC-based composites was slightly higher than that of MFC-based composites, nevertheless the modulus exceeded by about 1.5 times, achieving 28GPa. On the other hand BC composites exhibited very limited yield strain showing a brittle fracture behavior. Such characteristics were attributed to the continuity of the BC structure comprised of continually connected straight fibrils which are stiff and do not deform under stress. Another reason for the high modulus could be the in-plane orientation of fibrillar elements through compression of BC pellicles [9]. When composites were made using fragmented BC, the mechanical properties became very similar to that of MFC composites as in terms of modulus, strength and ductility, which is an indication that the geometrical arrangement of BC fibrils is responsible for the higher Young's modulus. From these results, it was concluded that although the Young's modulus achieved by MFC composites was not a match for the modulus of BC composites, MFC has the advantage of resulting in composites with high work of fracture. This toughness is likely due to the micro-scalar structure of loose and entangled networked fibrils that deforms when the composite is subjected to stress, resulting in large elongation and strength as opposed to the straight and continuous structure of BC fibrils.

Microfibrillation of plant fibers is definitively one of the most prominent means to exploit the remarkable mechanical properties of cellulose in the fabrication of high-strength and tough composites.

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Changes in Dielectric Properties and the Mechanism of Water Adsorption of wood by Heat Treatment

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INTRODUCTION

In the heat treatment under nitrogen gas, wood degrades between 60°C and 200°C, decomposes between 160°C and 450°C, carbonizes between 600°C and 1800°C, and graphitizes between 1600°C and 3000°C¹⁾. Chemical changes mainly occur up to the early stage of carbonization, but after that physical changes become dominant¹⁾. In the field of wood physics, the heat treatment of wood has been investigated to improve the dimensional instability of wood due to moisture changes, to enhance the acoustical properties of wood, and to fix permanently the large compressive deformation of wood. These treatments are restricted within 200°C. Recently, however, as the requirement of high-grade utilization for the treated wood raises, much attention has been paid to the changes in the structure and properties of wood by the treatment in much higher temperature range. The electrical properties of the treated wood drastically change depending on the treatment temperatures. It is known that the treated wood is an insulator below 300°C, a semiconductor between 300°C and 800°C, and a conductor above 800°C¹⁾. On the other hand, it is known that functional groups of wood constituents almost disappear²⁾ by heat treatment up to 400°C and nanometer-scale micropores are produced in wood through the formation of graphite^{18, 19} above 450°C. Therefore, it is considered that the mechanism of water adsorption on wood depending on treatment temperature. In this paper, the changes of dielectric properties in the wide range of temperature (-150~20°C) and frequency (20~1MHz) for wood treated at temperatures up to 800°C are investigated. Moreover, the dielectric relaxation due to motions of water molecules adsorbed on wood treated at various temperatures was examined to clarify the state of the adsorbed water.

RESULTS

A relaxation was detected in the dry specimens treated below 300°C and between 500°C and 600°C, respectively. The Cole-Cole's circular arc law was well applicable to these relaxations. The former relaxation has been ascribed to the motions of methylol groups in the non-crystalline region of the cell wall. This relaxation decreased in magnitude with increasing treatment temperature and disappeared above 400°C(Fig.1). The latter relaxation had a large magnitude depending on measuring temperature(Fig.2). The distribution of relaxation times was very narrow. The values of conductivity remarkably began to increase above 500°C. This result suggested the formation of two-phase system including portions with large conductivity in an insulator. Therefore, the relaxation may be ascribed to that due to the interfacial polarization. Dielectric measurements were impossible for the specimens treated above 650°C because of their extremely high conductivities.

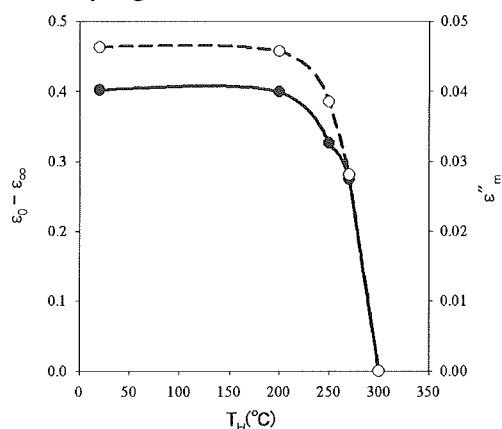


Figure 1 Relationship between relaxation magnitude ($\epsilon_0 - \epsilon_\infty$) due to the motions of methylol groups and treated temperature (T_H) for wood.

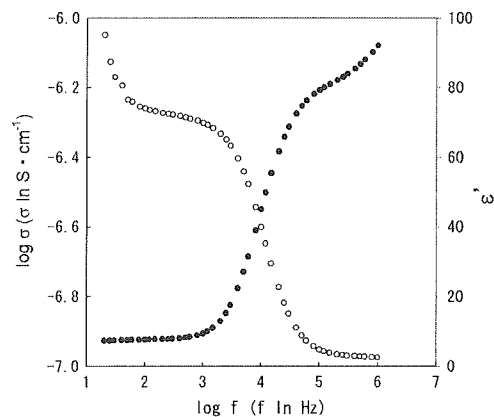


Figure 2 Relationship between logarithmic conductivity ($\log \sigma$) or dielectric constant (ϵ') and logarithmic frequency ($\log f$) at -30 °C for wood treated at 600 °C.

Three relaxations were observed in the specimens conditioned at high levels of relative humidity. The relaxation in the highest frequency range was ascribed to the motions of adsorbed water molecules. The relaxation in the middle frequency range remained unchanged by the alcohol–benzene extraction of specimens. Its location was independent of measuring directions, but moved to higher frequency range with increasing moisture content. The relaxation in the lowest frequency range was remarkably affected by extractives involved in the specimens. However, it was not detected in the specimens impregnated with methyl methacrylate (MMA)(Fig.3). This result suggested that it was due to the electrode polarization. The Cole-Cole's circular arc law was well applied to two relaxations recognized in the specimens impregnated with MMA. The relaxation magnitude in the middle frequency range was extremely large and the distribution of relaxation times was very narrow. These characteristics suggested the relaxation of the Maxwell-Wagner's type which resulted from the interfacial polarization in the heterogeneous structure including portions of adsorbed waters with large electric conductivity in an insulator of the cell walls.

The dielectric relaxation due to motions of water molecules adsorbed on wood treated at various temperatures up to 550°C was investigated from observed relationships (Fig.4) between activation enthalpy (ΔH) and entropy (ΔS) in the relaxation. The relationships assumed two straight lines with different slopes depending on treatment temperature. Given the same ΔS , the ΔH for water molecules adsorbed on wood treated at temperatures below 400°C were larger than those treated above 450°C. It was considered that the former water molecules were adsorbed mainly on hydroxyl groups by strong hydrogen bonds to form ice-like structures. On the other hand, since hydroxyl groups of wood constituents were not detected in heat treatments above 400°C, it was considered that water molecules are condensed in nanometer-scale micropores formed during the carbonization of wood at higher temperatures. The relationship between ΔH and ΔS for the motion of water adsorbed on wood treated above 450°C was similar to the value extrapolated from the value of bulk water under 0°C. This result suggested that water molecules adsorbed on charcoals were in the supercooled state.

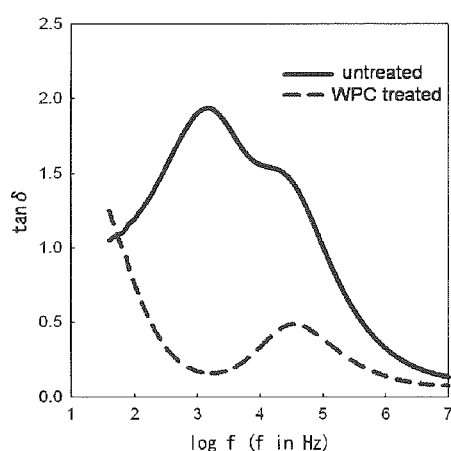


Figure 3 The logarithm of dielectric constant ($\log \epsilon'$), and the loss tangent ($\tan \delta$) against the logarithm of frequency ($\log f$) at 20°C in the longitudinal directions for the extracted and methyl methacrylate impregnated hinoki wood specimens conditioned at 97% RH.

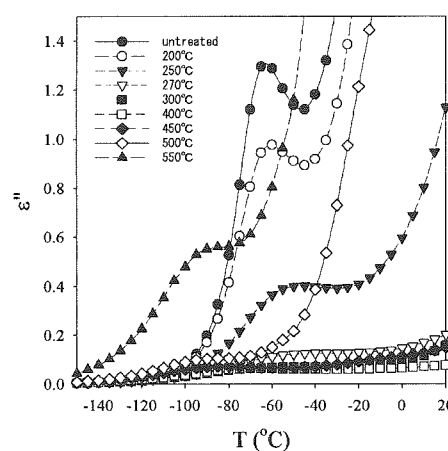


Figure 4 Relationships between dielectric loss (ϵ'') and temperature T at 1MHz for wood treated at the indicated temperatures and conditioned at 97%RH.

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Self-Bonding Characterization of Non-Wood Lignocellulosic Materials

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Adhesive is generally accepted to be the most expensive raw material for making wood composite. Rising prices of petroleum and great uncertainties of its future supply, however, caused the forest product industry to focus on the necessity of self-sufficiency and the development of adhesives from natural or renewable raw material. A process, which converted the lignocellulosic materials into panel boards without using of synthetic resin binders, has been developed and patented by Shen in the mid eighties [1]. Studies on manufacturing process of binderless board have been conducted for years. Considering that no synthetic adhesive was applied, the bonding performance of binderless boards was greatly affected by the chemical changes of materials during manufacturing process. It was believed that degradation of hemicelluloses during steam and heat treatments play an important role in the self-bonding of binderless boards [1]. However, the self-bonding mechanism during steam and heat treatments has not been completely elucidated so far.

In recent years, non-wood lignocellulosic materials have been considered to produce various composite products. These resources are abundantly available in many countries; including residues from annual growth plants [2]. In general, physical and chemical characteristic and structures of non-wood lignocellulosic materials are different from those of wood. Non-wood lignocellulosic materials, which are usually rich in hemicelluloses, are supposed to be potential materials for binderless boards production [3][4][5].

The objective of this study was to investigate the chemical changes of non-wood lignocellulosic material during steam-injection pressing and hot-pressing treatments, in order to characterize the self-bonding of binderless boards. Kenaf (*Hibiscus cannabinus* L.) core and sugarcane (*Sugarcane officinarum* L.) bagasse were used as raw materials of binderless particleboard. The raw materials and its boards were analyzed for extractives, holocellulose, cellulose, and lignin. The neutral sugar composition of the water-soluble fraction was determined using an alditol-acetate method, while the lignin was analyzed using pyrolysis coupled to gas-chromatography-mass spectrometry (Py-GC-MS). Furthermore, the effects of chemical changes on the self-bonding performance and dimensional stability of binderless boards were discussed. Considering the chemical characteristics of non-wood materials were different from those of wood, it was necessary to discuss the role of cinnamic acids during steam and heat treatments.

Chemical analysis of kenaf core binderless particleboards showed that hemicelluloses, lignin and cellulose were significantly degraded during steam treatment. The partial degradation of those chemical components by mild steam-injection treatment increased the bonding performance (see Fig.1) and dimensional stability of the binderless board. Neutral sugar composition of water-soluble polysaccharide from hot-pressed boards was relatively similar with that of untreated kenaf core. In addition, analysis of lignin showed that syringyl/guaiacyl (S/G) ratio of hot-pressed board was not significantly different with that of untreated kenaf core. Compared with steam-injection pressing, the conventional hot pressing caused a lower degree of degradation of chemical components [6]. The hot-pressed kenaf core binderless board showed poor bonding performance. These results indicated that even though the hot pressing treatments also caused degradation of chemical components, but not to a significant degree to improve their binding ability. Similar trends to the kenaf core were observed for bagasse binderless boards [7].

Cinnamic acids, as postulated for cell wall of grasses/non-wood lignocellulosic materials, were identified by Py-GC-MS analysis with presence of tetra methyl ammonium hydroxide (TMAH) as methylating agent. The ratio of S/G and cinnamic acids/guaiacyl (C/G) decreased with an increase in pressing time and steam-pressure, indicating the modification and degradation of lignin has occurred [8]. The results showed that some parts of ester-linked cinnamic acids were cleaved due to the degradation of hemicelluloses and lignin during treatment. It was also found that there was correlation between decreasing of the C/G ratio and shear strength of binderless kenaf core composites [8]. In order to obtain the optimum conversion of chemical components, the proper control of high-pressure steam treatment became significant. In this study, the optimum bonding properties of kenaf core composites was obtained after steaming at 0.8-1 MPa for 10-15 min.

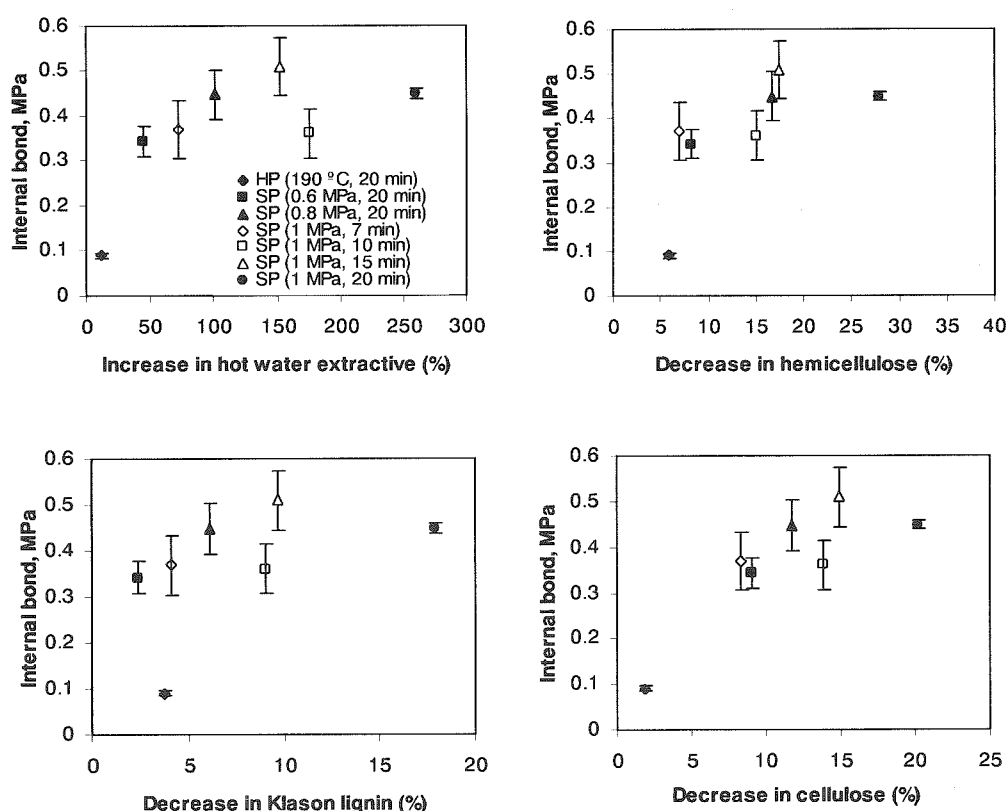


Fig. 1. The effect of chemical changes by steam and heat treatments on internal bond strength of kenaf core binderless boards. The corrected density of binderless boards was 0.5 g/cm³. HP, hot pressing; SP, steam-injection pressing

Thus, it was found that chemical components of non-wood materials degraded significantly in varying degree during steam and heat treatments. Not only hemicelluloses, other chemical components of non-wood materials were also degraded during treatments. The partial degradation of those chemical components by mild steam-injection treatments increased the mechanical properties of the binderless boards, and gave better quality than those made by hot-pressing treatments. In addition to three major components, the cinnamic acids also contributed in the self-bonding mechanism of non-wood lignocellulosic binderless boards.

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Development of kenaf binderless composite panels

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In recent years, effective utilization of fast-growing non-wood lignocellulosic materials and agro-wastes has been of great interest owing to a drastic fall in forest resources. Among the nonwood lignocellulosic materials, kenaf (*Hibiscus cannabinus* L.) has attracted special interest because of its rapid growing speed. Kenaf is an annual plant. The stalk contains two different types of fiber, an outer "bast" and an inner "core". The bast fiber provides high strength and can be converted into a high-performance oriented MDF [1], it is also a potential overlay material for making kenaf composite panel, while the kenaf core is extremely light in weight with the density around 0.15g/cm^3 , which is a good material for low-density board [2].

Synthetic binders are usually used for wood-based panel production. They are not only expensive, but also derived from non-renewable petro resources. Efforts have been done to develop binderless boards by using steam-explosion or high-temperature hot-pressing processed [3][4]. But the binderless board with high densities can usually be produced. Kenaf core is not only very light in weight, but also rich in hemicelluloses which may act as a binder when making board. It seems to be a good possibility for producing binderless boards using kenaf core.

The main objective of this study is to develop binderless (no binder) boards with relatively low density by using kenaf as raw material, including 3 main portions: Development of binderless particleboard from kenaf core using steam-injection pressing method; reinforce binderless particleboard with bast fiber-woven sheets; and development of binderless fiberboard from kenaf core using conventional dry-process fiberboard manufacturing.

Binderless particleboards were developed from kenaf core using steam-injection pressing [5][6]. The effects of board density, steam pressure and treatment time on the properties of the board were evaluated. The target board densities were relatively low, ranged from $0.10\text{--}0.70\text{ g/cm}^3$. The properties of the boards increased linearly with increasing board density (Fig.1). Steam pressure and treatment time also affected the board properties. The bending strength and internal bond (IB) strength were improved with increasing steam pressure. A long steam treatment time contributed to low thickness swelling (TS) values and thus better dimensional stability. The appropriate steam pressure was 1.0 MPa, and the treatment time was 10-15 min. The properties for 0.55 g/cm^3 density boards under optimum conditions were: modulus of rupture (MOR) 12.6 MPa, modulus of elasticity (MOE) 2.5 GPa, IB 0.49 MPa, TS 7.5% and wet MOR 2.4 MPa. Compared with the requirement of JIS 5908, 1994 for particleboard, kenaf binderless boards showed excellent IB strength but relatively low durability. The thermal conductivity of the low-density kenaf binderless particleboards showed values similar to those of insulation material (i.e., rock wool). The boards with densities of $0.15\text{--}0.20\text{ g/cm}^3$ are promising building materials for thermal insulation applications.

In order to improve the bending strength of low-density kenaf binderless particleboard, kenaf composite panel, that is, binderless particleboard reinforced with kenaf bast-fiber woven sheets was manufactured [7]. Compared with single-layer binderless particleboard, the bending strengths in dry and wet conditions, and the dimensional stability in the plane direction of composite panels were improved. The kenaf composite panel with a density of 0.45 g/cm^3 gave the properties of: dry MOR 14.5 MPa, dry MOE 2.1 GPa, wet MOR 2.8 MPa, IB 0.27 MPa, TS 13.9%, and linear expansion (LE) 0.23%. During binderless particleboard manufacturing, steam treatment (0.6-1.0 MPa) could cause significant change of chemical components of kenaf core, and self-bonding was achieved among particles [8].

Binderless fiberboards from kenaf core were manufactured using conventional dry-process fiberboard manufacturing without any other special treatment. Kenaf chips were converted into fibers and then hot pressed into fiberboards. The effect of steam pressure (0.4-0.8 MPa) and cooking time (10-30 min) in the refining process, fiber moisture content (MC) (10%, 30%), hot pressing time (3-10 min) on the board properties were investigated. Chemical analysis of fibers and binderless fiberboards was also done to investigate the changes of chemical components during board manufacturing process. The results showed that kenaf core binderless fiberboards manufactured with high steam pressure and long cooking time during the refining process had high IB strength, low TS, but low bending strength values. The binderless fiberboards made from 30% MC fibers showed better mechanical and dimensional properties than those from air-dried fibers. At a density of 0.5 g/cm^3 , binderless fiberboard with the refining condition of

0.8MPa/20min recorded: MOR 12MPa, MOE 1.7GPa, IB 0.43MPa, TS 12.1% under the optimum board manufacturing conditions. These values are similar to that of binderless particleboard at the same density level. However, the manufacturing process of binderless fiberboard is simpler and can easily be applied to commercial production at present time.

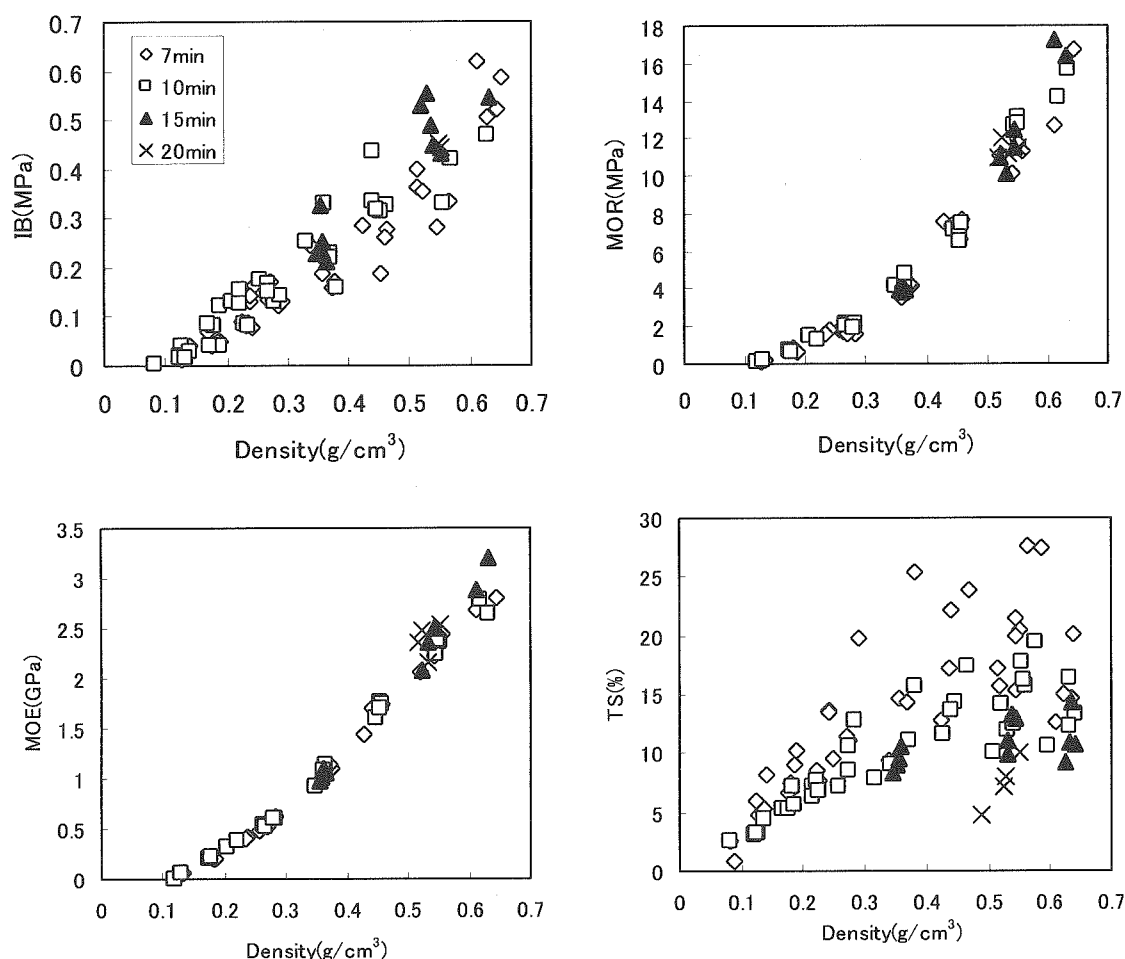


Fig.1. Effect of board density and steam treatment time on the properties of kenaf binderless particleboard. Steam pressure was 1.0MPa

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Studies on a Selective White Rot Fungus, *Ceriporiopsis subvermispora*: Production of Ceriporic Acids and Lignin Biodegradation of Wood for Methane Fermentation

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**Transcriptional analysis of recombinant coryneform bacteria in ethanol production process from wood biomass;
Effect of fermentation inhibitors**

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Bioethanol is recognized as an environmentally friendly and acceptable substitute for petroleum and an additive to petrol [1]. Wood biomass, which is renewable and non-competitive with food supplies, is attractive feedstock for bioethanol production [2].

Microorganisms such as recombinant *E. coli* and several yeast species have been utilized as ethanol producers. In such cases, ethanol production was accompanied by cell-growth; therefore the production rate was low and the energy loss for growth was considerable. RITE, Research Institute of Innovative Technology for the Earth, reported that coryneform bacteria produce valuable materials without growth under oxygen deprivation conditions. The recombinant coryneform bacteria producing ethanol from carbohydrates were constructed by introduction of two heterologous genes.

A problem associated with efficient conversion of wood biomass to ethanol is that a broad range of compounds which inhibit the fermenting microorganisms are liberated or formed along with the saccharides during wood hydrolysis. Inhibitors of fermentation include furan derivatives, such as furfural and 5-hydroxymethylfurfural (5-HMF), low-molecular-mass aliphatic acids, such as acetic acid and levulinic acid, and phenolic compounds [3]. The mechanism of fermentation inhibition has not been elucidated.

Although various studies to improve the methods of hydrolysis have been carried out, formation of fermentation inhibitors is inevitable in any case to a greater or lesser extent. Several papers described detoxification systems for wood hydrolysates, such as use of ion-exchange resins, treatment with activated charcoal, and over-liming [4][5][6]. Any detoxification system increases the cost of the whole process, therefore genetic manipulation of ethanol producers to improve their robustness to such inhibitors is expected. For the first step to construct efficient ethanol producers from wood biomass, it is important to investigate the inhibitory mechanism at the gene expression level.

In the present study, first ethanol producing coryneform bacteria were constructed, and the ethanol production rates were determined to select the best producer. Beech wood chips were pretreated with ethanolysis and hydrolyzed with Meicelase. The resulting soluble fraction (SF) was added to the ethanol producing reaction and the aerobic culture to evaluate the effects of fermentation inhibitors. The ethanol production rates decreased as the concentrations of SF increased. The effects of the inhibitors were also analyzed at the gene expression level with DNA microarray. Secondly potential fermentation inhibitors in SF were identified. Six potential inhibitors were detected by GC/MS. Thirdly each identified potential inhibitor was added to the ethanol producing reaction and the aerobic culture to evaluate the effects. DNA microarray analysis was also carried out.

This master thesis reports the effects of fermentation inhibitors derived from wood on ethanol producers at the whole genome expression level.

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**A selective lignin-degrading fungus, *Ceriporiopsis subvermispora*
produces extracellular polar lipids**

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A selective lignin-degrading basidiomycete, *Ceriporiopsis subvermispora* is able to degrade lignin in wood without intensive damage of cellulose. During wood decay by this fungus, extensive delignification is observed without the penetration of extracellular enzymes into the wood cell wall regions [1]. This indicates that *C. subvermispora* has unknown delignification systems catalyzed by low molecular weight metabolites. We demonstrated that *C. subvermispora* produced saturated and unsaturated free fatty acids during wood decay. We also isolated a series of novel alkylitaconates (ceriporic acids) that inhibit cellulose degradation by the Fenton reaction [2,3]. However, our knowledge on hydrophilic metabolites produced by *C. subvermispora* is still limited. Therefore, the present study is aimed at isolating key polar metabolites that are able to interact with hydrophobic substances like lignin and lipids.

C. subvermispora was cultured in a SDW medium at 28°C for 6 weeks. Polar metabolites were purified from the culture fluid of *C. subvermispora* by extraction with ethanol and acetone. The extracts were analyzed by thin-layer chromatography (TLC) using chloroform/acetone/methanol/acetic acid/water = 9/4/4/2/1 as a developing solvent. As a result, polar metabolites with *R_f* values, 0.58-0.87 were separated. Then, the extracts were further purified by solid phase extraction and reversed-phase high performance liquid chromatography (HPLC). The purified polar lipids were analyzed by liquid chromatography/electrospray ionization mass spectrometry (LC/ESI-MS) and detected deprotonated molecules of the metabolites.

These polar lipids have both hydrophilic and lipophilic moiety in a molecule. Therefore, these metabolites may play a central role in the selective lignin degradation by interacting with hydrophobic metabolites and lignin during wood decay.

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**Isolation and characterization of *gpd* gene from selective lignin degrading fungus,
*Ceriporiopsis subvermispora***

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White rot fungi are known to degrade plant cell wall lignin and also various aromatic pollutants. Intensive research has been done to make use of their special function for a novel carbon recycle system and also bioremediation of polluted environments, which contribute for development of a sustainable society. Especially, a selective white rot basidiomycete, *Ceriporiopsis subvermispora* is a promising microorganism effective as a biocatalyst to degrade lignin in industrial processes, including pulp and paper manufacture, and conversion of lignocellulosic biomass to various compounds. However, there is no report on development of DNA-mediated transformation system in this fungus. Transformation techniques are valuable tools for not only molecular biological analysis of the selective lignin degrading system but also strain improvement of desired catalytic phenotype.

Glyceraldehyde-3-phosphate dehydrogenase (GPD) is a key enzyme in glycolysis and gluconeogenesis. It is highly and constitutively expressed and, in higher eukaryotes, GPD protein comprises up to 5% of the soluble cellular protein. From this property the *gpd* promoter has been used to drive recombinant genes in various microorganisms. In this study, I attempted to obtain a novel transformation vector using *gpd* promoter cloned from *C. subvermispora*.

C. subvermispora strain ATCC 90466 were used throughout this work. Genomic DNA was extracted from mycelium cultured on YMPG liquid medium (0.2% Yeast extract, 1% Malt extract, 0.2% Bactotryptone, 1% glucose 0.1% L-asparagine and 0.1% MgSO₄), using the CTAB method. DNA fragments covering 1.3-kb promoter and terminator sequences were amplified using TaKaRa LA PCR *in vitro* cloning kit. Nucleotide sequence of the cloned fragments were determined and characterized, suggesting that *C. subvermispora gpd* gene encodes a 337-aa protein. Presence of six introns was predicted and the deduced amino acid sequence of *C. subvermispora gpd* gene showed high similarity to those of other basidiomycetes. Actual transcription from *gpd* was confirmed using RT-PCR technique and the expression was controlled by glucose in the medium.

Transforming vector plasmids were designed to contain the promoter and terminator sequences from *gpd* combined to a heterologous drug resistant marker gene, hygromycin B phosphotransferase (*hph*). Two recombinant plasmids, with or without the first intron, were constructed, since Logones *et al.* reported that introns enhanced expression of *ABH1* in *Schizophyllum commune* [1].

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Characterization of *Carthamus tinctorius* cinnamyl alcohol dehydrogenase

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Cinnamyl alcohols are the immediate monomeric precursors of lignin, lignans and related compounds, and biosynthesized from phenylalanine through the cinnamate/monolignol pathway. The last step of the pathway which gives rise to cinnamyl alcohols are catalyzed by cinnamyl alcohol dehydrogenase (CAD). The pathway has been characterized well in relation to lignin biosynthesis and many CAD cDNAs from various plant species have so far been cloned and characterized. However, nothing is known about the physiological route among many possible parallel routes of the cinnamate/monolignol pathway, and no CAD genes which are involved in lignan biosynthesis have been identified. *Carthamus tinctorius* is a good plant material for comparative studies of lignan and lignin biosynthesis, because its maturing seeds produce significant amounts of both lignans and lignin. In this study, cDNAs encoding *Carthamus* CADs were cloned and their recombinant enzymes were characterized biochemically.

Promoter analyses of light responsive prenyltransferases involved in naphthoquinone

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Shikonin, a red naphthoquinone derivative, is a secondary metabolite that specifically occurs in boraginaceous plants, and is the active principle of the medicinal plant *Lithospermum erythrorhizon*. Since this compound and its derivatives exhibit anti-bacterial activity, their functions as phytoalexins have also been reported. The biosynthesis of shikonin includes a key prenylation step catalyzed by geranyl diphosphate (GPP): 4-hydroxybenzoate (4HB) 3-geranyltransferase; i. e., coupling of the shikimate and mevalonate pathways. This enzyme plays a critical role in the regulation of shikonin biosynthesis in cell cultures of *L. erythrorhizon*, i. e., up- and down-regulation of this enzyme activity directly affects the production of shikonin. The enzyme activity is strongly suppressed by light irradiation, ammonium ion, and the synthetic auxin 2,4-dichlorophenoxyacetic acid (2,4-D), whereas this activity is enhanced with the addition of oligogalacturonide (OG) and methyl jasmonate (MJ) to the medium. It has also been reported using a partially purified enzyme that this protein is ER membrane-bound and shows strict substrate specificity for geranyl (C₁₀) diphosphate for the chain-length of the prenyl donor, which is in clear contrast to the mitochondrial polyprenyltransferase for ubiquinone biosynthesis.

In our previous study, two cDNAs of geranyltransferase from *L. erythrorhizon* were isolated, which were designated LePGT-1 and LePGT-2 [1]. Their gene expressions were regulated in the same manner as observed on the enzyme activity level, suggesting that this biosynthetic step was regulated at gene expression level. In expression analyses of LePGT-1 and LePGT-2 in *Lithospermum* cell cultures, no clear difference between LePGT-1 and LePGT-2 was observed. However, they showed different enzymatic properties, e.g. Km value, which suggested that they have different physiological roles in plant.

In this study, I have isolated the promoter regions of LePGT-1 and -2 by TAIL-PCR and prepared GUS reporter constructs using these promoters, with which model plants, such as tobacco and Arabidopsis, were transformed to analyze their promoter activities. The detailed analyses revealed that both promoters are very active in root tissues of both heterologous host plants, but the regulation on promoter activity strongly depends on the host plant species. I also introduced the promoter-GUS construct into cultured *Lithospermum* cells, the homologous host, by particle bombardment method to find the *cis*-element responsible for the negative regulation on the gene expression by light.

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Cloning and Functional Analyses of Water Channels from a Conifer Stem

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Trees play an important role to control CO₂ in the atmosphere because the wood is the most abundant biomass on the earth. Water is essential for the assimilation of carbon dioxide, and trees over ten meters in height need to pull water and ions up to the leaves in their crowns. Most widely accepted theory how to pull water up to their crown is so-called cohesion theory (Zimmermann 1983). According to the theory, cohesive strength of water can maintain in a meta-stable water column beyond 10 meters in height under substantial hydrostatic tension, which is driven by transpiration of water from leaves. However, metastable state is vulnerable to cavitation in xylem (Tyree and Sperry, 1989). Refilling of embolized conduits requires that water enters the embolized tracheids while pressurizing the gas phase until it is forced back into solution.

The sap ascent has long been considered as a process simply physical and no living cell involved. However, a conifer wood consists of tracheids, or water conduits, which are always connected with a living cell, or ray parenchyma cells, on their radial walls. Considering the topological location of the living cells in the xylem, they are probably involved in the water refilling in the conifer stems, into an embolized area (Canny, M. J., 1997), which may reduce hydrostatic tension in the xylem conduits. Only a little molecular basis has been reported in the water conduit through the living cells in the xylem (Kuroda 2000). Aquaporins are known as a water channel or the other solute, and universally distributed in organisms. Here, the study was focused the molecule located in a conifer xylem trunk.

So far no functional aquaporin was reported in the wood trunks, especially in mature secondary xylem in spite of abundant aquaporin fragments in trunk EST libraries. Thus, the trunk of a 22-year-old Japanese red pine (*Pinus densiflora*) was used for the mRNA source. In the RT-PCR cloning, primers were designed by using a few hypothetical contig sequences, which were connected EST sequences in the genus *Pinus* by using a soft ware. The KOD plusTM amplified products were ligated into a vector, pT7Blue-2. Finally, three different clones have obtained with full coding sequences in the mature xylem. They are assigned as a member of Plasma membrane Intrinsic Proteins, two PIP1s and a PIP2. Xylem PIP1 had two isoforms that is distinct from only a base or one amino acid residue. They are probably on a homologous chromosome. On the contrary, xylem PIP1 was different in 3'-UTR from the other PIP1, which has also cloned separately from the seedlings. In 5'RACE, one of the isolated clones was mainly expressed in the xylem. All of the cloned PIPs contain six putative membrane-spanning regions. A conserved motif NPA is located in loop B and E. A deduced phosphorylation site is also found in the clones. The sequence analyses clearly show that the cloned PIPs are an aquaporin. The cloned PIP1 and PIP2 were respectively transcribed *in vitro* after subcloning into an expression vector pTNTTM, which carries a 5'β-globin leader sequence and a poly(A) tail. The obtained mRNAs with pol(A) tail were respectively micro-injected into *Xenopus* oocytes and measured water transport by analyzing the volume changes in response to the hyper- and hypotonic solutions. The cloned PIPs were demonstrated water transport in response to the osmolarity.

Together with these findings, functional aquaporins are first demonstrated in the mature xylem. The living cells in the xylem, which was the RNA source in this study, only consist of ray and epithelial cells. The latter surrounds resin canal and produces hydrophobic isoprenoids. Thus, the aquaporin probably functional in the ray cells participating water ascent of the xylem conduit.

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Development of a Data Analysis System for GPS Occultation Measurements

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GPS (Global Positioning System) occultation is useful to monitor the global distribution of humidity, temperature and electron density perturbations. This technique is based on the principle of satellite-to-satellite limb sounding. By receiving GPS radio wave which passes through the atmosphere with a receiver onboard a low Earth orbiting (LEO) satellite, refractivity profile can be obtained. With objective of the dense observations in the equatorial region, RISH (Research Institute for Sustainable Humanosphere) plans to perform GPS occultation experiment on the Brazilian LEO satellite named EQUARS (Equatorial Atmospheric Research Satellite) to be launched in 2007. The data obtained from EQUARS can be applied into the operational numerical weather prediction (NWP) in Japanese Meteorological Agency. For this application the real-time processing is required.

In this study, we have developed the data analysis system for retrieving the atmospheric parameters from GPS occultation data obtained by LEO satellites. The system consists of data collection and reduction part, positioning and orbit determination part, excess phase delay calibration part, and retrieval part. Data needed for the analysis are acquired in data collection and reduction part. The position and velocity vectors of GPS and LEO satellite are derived in positioning and orbit determination part. In excess phase delay calibration part, phase delay due to the atmosphere is obtained. In retrieval part bending angle of the ray path is calculated, and atmospheric parameters such as refractive index, temperature, and pressure are derived at the end.

We also improved the atmospheric retrieval procedure. To solve the problems of the bending angle collection method which was previously used, we developed the improved collection method, and verify its effect by comparing with other data. Moreover, we estimated the total analysis time of the data analysis system and evaluated the possibility of operational application of EQUARS data to NWP.

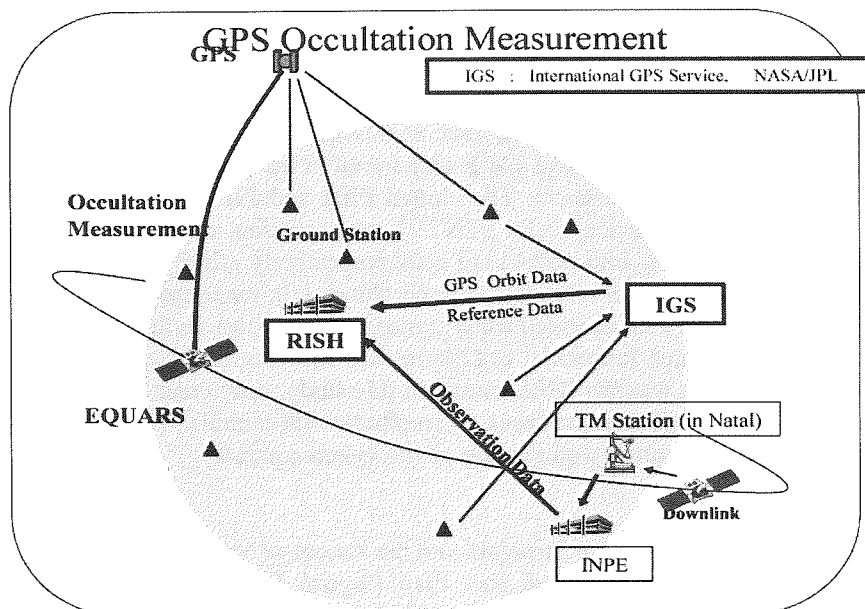


Fig. 1. Schematic diagram showing the communication of GPS occultation and ground reference data.

Development of a growth-ring analysis technique for tropical trees

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Although the equatorial atmosphere plays a key role in global climate change, its behavior has not been clarified yet, because long-term ground-based meteorological observations are scarce so far. Growth-ring analysis of tropical trees (dendroclimatology) seems to be a promising technique for reconstructing climate variations. Because precipitation is one of the most significant factors affecting tree growth in the tropics, a growth ring is formed in a tropical forest, having a clear annual dry season when hardwood shed their leaves.

In this study we conducted a survey trip in Indonesia in order to collect various tree samples, and finally selected teak (*Tectona grandis*) and sungkai (*Peronema canescens*) for our growth ring analysis. There are only a few reports on dendroclimatology in Indonesia except a pioneering study using teak by H. P. Berlage (1931) and a follow-on researches by G. C. Jacoby and R. D. D'Arrigo (1989-90, 1994). This study applies image processing to analysis of growth ring in a transverse section, and aims at developing an automatic analysis system which enables us to process a large amount of samples taken from, for example, a teak plantation. Firstly a digital camera and scanner are employed to take pictures of tree's transverse section, then, characteristics of growth ring are investigated by adopting image-processing techniques. We estimated tree growth rate from an increment of growth ring area. This is better than the growth ring width, because transverse section of a tropical tree do not normally appear concentric, but are significantly deformed depending on radial directions. We demonstrated the effectiveness of this technique by applying it to teaks from Kertsono, east Java. Consequently, a strong correlation is observed among increments of different transverse sections from the same tree, and also between increments of different trees sampled in a nearby area. This indicates that tropical tree rings could contain meaningful signals about the environment, such as precipitation, drought, etc.

In addition, we analyzed teak and sungkai samples collected from several locations in Indonesia: sungkai from Lampung (southern Sumatra) and Serang; teak from Indramayu. Their tree growth rate is compared with total annual precipitation (May to April), which showed a good correlation especially in the sungkai from Lampung. The tree-ring analysis system developed in our study will, we hope, greatly contribute to the development of dendroclimatology in the tropics..

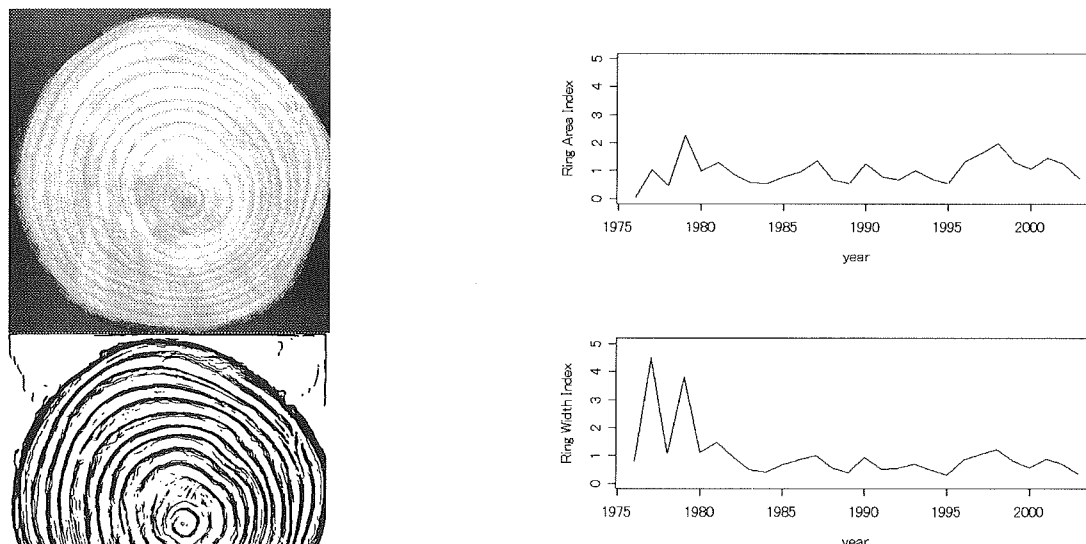


Fig. 2. Comparison between the year-to-year ring area variation as a new technique (top) and the ring width variation as a traditional method (bottom).

Fig. 1 Original sungkai image (top) and processed image with a differential filter (bottom).

Water vapor variation around the tropical tropopause during the CEPEX campaignKazunari Koishi*Laboratory of atmospheric environmental information analysis, RISH, Kyoto University*

Understanding water vapor variation in the atmospheric system is important to grasp the climate conditions of our planet. To estimate the radiative and chemical effects on the climate change, we have to clarify factors contributing to water vapor variation around the tropical tropopause region where water vapor acts as a very sensitive minor constituent. Because water vapor content at the tropopause is about 4 to 5 order less than that at the surface, the tropical tropopause region is supposed to be one of the data sparse areas where we cannot get the routine observation data. Recently, many researches using models and satellite data have actively discussed about the cause of controlling the stratospheric water vapor content. However, there are many uncertainties in the models and satellite data so that none of interpretation explains all the observational facts synthetically. Thus, in this study we use data from the NOAA water vapor sonde that has little estimation error owing to its measurement principle. Then we focus on how the large scale circulation field and the water vapor variation are connected with each other. The water vapor, ozone and meteorological sonde data used in this study were obtained from the campaign called CEPEX (Central Equatorial Pacific Experiment). ECMWF 40 year reanalysis (ERA40) wind and temperature data, NOAA OLR (outgoing long-wave radiation) and UARS/MLS water vapor mixing ratio were also used for investigating the large-scale circulation features.

A mean water vapor mixing ratio observed on a voyage during the CEPEX campaign was about 1.9 ppmv at 16.5 km where the cold point tropopause lies, and it was about 3.3 ppmv when observations were done on Christmas Island where the voyage ended up. The mean difference with 1.4 ppmv is quite large in comparison with the standard stratospheric water vapor content. In the former case on a voyage the water vapor content at the tropopause level shows a minimum mixing ratio, indicating that some significant mechanism should work to keep the water vapor less than the usual value. We tried to understand how this significant change in water vapor content depends on space or time variations of the circulation structure. By showing longitude-time sections of the ERA40 temperature and the NOAA OLR around the equatorial (5S to 5N) tropopause level we found that there appear cold regions often in the east of the low OLR and warm regions in the west of the low OLR during the northern winter time including the 20-day CEPEX observation period. The temporal change in the temperature was much more distinguished than the spatial gradient. We also found the temporal change in the MLS water vapor data in a longitude-time section. While seeing their relationships in the equatorial longitude-height sections averaged over the former half (7 to 17 March) and the latter half (20 to 26 March) of the observation period, we found there was cold anomaly distribution inclined eastward with increasing altitude in the east of the low OLR and wind divergence distribution around the cold anomaly. In this period, horizontal sections for the horizontal wind at 100 hPa showed anticyclonic gyres with cold anomalies over the western and central Pacific region, which is supposed to be a Rossby response due to the tropospheric heating. This observational evidence suggests that the coldest region enhanced by this response makes water vapor around the tropopause lower, which was first pointed out observationally by Eguchi and Shiotani [2004]. The same mechanism could be applied to water vapor decrease particularly during the former half of the CEPEX period. This is supposed to be caused by the intensification of the coldest region and the large-scale horizontal wind structure at the tropopause level. On the contrary during the latter half of the observation period, this large-scale circulation structure becomes weak, and comparatively warm region contains rather rich water vapor. Hence we can conclude that the disturbance around the tropopause level with a time scale of a few weeks is one of the most important factors controlling the temperature and horizontal wind field and consequently water vapor variations during the CEPEX period.

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Cirrus cloud variations near the tropical tropopause layer (TTL) inferred from the lidar measurement

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It has been recognized that cirrus clouds near the tropical tropopause where the air mass enters the stratosphere from the troposphere might be crucial to define the stratospheric water content through the dehydration process. The cirrus clouds around the tropical tropopause could also affect the heat balance with an increase of 1 K/day locally. It is important for the earth's radiation budget and the climate variability to investigate the global distribution of the cirrus clouds and their space-time variations. However, an observation of the cirrus clouds is very difficult since they are optically thin and appear at high altitude near the tropopause level. In this study using lidar observations performed onboard the research vessel "Mirai" and intensive radiosonde observations with every three hours we investigate the cirrus variations around the tropical tropopause layer (TTL) and clarify a relation between the ambient temperature and the occurrence of the cirrus clouds. The observation period is mostly for the northern winter season around December and for two years, 2001 and 2002.

We first investigated the temperature structure for the two years in relation to the cirrus clouds. In 2002 the temperature field shows a clear contrast between the former half of the observation period being warm and the latter half being cold, while in 2001 it is almost cold for the whole period. Then the cirrus cloud occurrence was investigated for the two years corresponding to the temperature structure. In 2002 the cirrus clouds appear at 10- 16 km height range in response to convective activity in the former half period, while they appear around 18 km where it is very cold in the latter half period. The observation evidence in the latter half is similar to that reported in a previous work by Winker and Trepte (1998). Based on observations for the polarization ratio and the backscatter coefficient, it is suggested that the particles are non-spherical and rather large, resulting that the cirrus clouds at 15- 18 km height range consist of cloud particles with ice nuclei.

Next we investigated the cirrus cloud occurrence and the ambient temperature at each altitude in the upper troposphere and around the tropopause (15- 18 km height range). In 2001 the cirrus clouds appear in the specific temperature range around the TTL. The appearance in the 15- 18 km height range tends to be high when the temperature is high, and it is about 10%. On the other hand in 2002 the appearance is rather variable with height and temperature, but it tends to be high where it is cold at high altitude. Overall appearance in the 15- 18 km height range is about 40% with higher occurrence in the colder temperature, which contradicts with the case in 2001.

As further investigation we saw the cirrus cloud and the ambient temperature for three selected periods and height ranges. During the first half when the tropopause is relatively warm the cirrus clouds appear at 15- 16.5 km where the background temperature is cold, which is similar to the result in 2001. During the latter half when the tropopause is relatively cold at 17- 18 km height range the cirrus clouds appear in the cold region. In addition we saw the cirrus clouds at 15- 16 km height range, which has no clear relation to the temperature. This study clearly demonstrated the different appearance of the cirrus clouds and their dependences on the temperature conditions in 2001 and 2002.

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Variation of the atmospheric angular momentum in the stratosphere and its relation to the ozone transport

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Since 1970s the satellite measurement has been successful in the atmospheric observations, and we acquired the global ozone distribution in the latter half of 1970s. Since then we have recognized the Antarctic ozone hole, and the distribution of ozone in the global scale has become one of the most important factors controlling the earth's climate. As the photochemical lifetime of ozone in the lower stratosphere is very long, the ozone distribution is highly affected by the atmospheric transport. As a result we need to know not only the ozone production/loss but also the effect of the transport to understand the global distribution of ozone.

The stratosphere has its nature of very stable stratification in vertical direction, as the atmosphere absorbs the sun's ultraviolet radiation in the upper stratosphere. In such a stratified region the atmospheric waves generated in the lower part of the atmosphere can propagate and affect the state of the general circulation. When these waves break under some conditions, it is expected from the atmospheric wave theory that they transfer wave momentum to the background flow. To describe this quantity we usually use one of the useful physical parameters called the E-P flux.

In this paper we investigate the angular momentum transferred from waves propagating in the atmosphere and its relation to the atmospheric angular momentum in the stratosphere. Two case studies were performed: one for the stratospheric sudden warming in the northern hemisphere, and the other for the poleward and downward shift of the westerly jet in the southern hemisphere. Though the time scales of these events are rather rapid in about a week, the atmospheric angular momentum for each case did not show such a rapid change but represents a part of the slow change of the whole stratosphere.

In the time scale of a month the vertical component of the E-P flux (F_z) and the change in the monthly mean stratospheric angular momentum was compared. We found that the stratospheric angular momentum is decreasing, as a result of the vertical transport of the negative angular momentum as indicated in F_z of both hemispheres. The correlation is strong during the winter in both hemispheres, representing the typical atmospheric conditions in the winter stratosphere. During the springtime in the northern hemisphere it is well known that the ozone amount is highly affected by the atmospheric condition and its interannual variability. Thus the change in the angular momentum during the winter was investigated in association with the ozone amount in the following spring, and we found that the two physical quantities are closely related with each other; when the decrease of the angular momentum is larger, the ozone amount during the spring is richer, and vice versa. In the southern hemisphere we see characteristic signatures similar to the northern hemisphere. Moreover in the southern hemisphere the atmospheric angular momentum can be used as an index of the strength of the polar vortex. It is suggested that the index also indicates how easy the heterogeneous reaction can be introduced on the polar stratospheric clouds (PSCs).

Relationship between low-latitude irregularities and background ionosphere with the Equatorial Atmosphere Radar

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Depletion of plasma density, or plasma bubbles, frequently grows in the nighttime equatorial F region. Plasma bubbles contain various scales of field-aligned irregularities (FAI). In this paper, we studied the background ionospheric condition for generation of plasma bubbles based on the data from the Equator Atmospheric Radar (EAR) [1] and ionosondes. Observations were conducted in March-April 2004 as a part of the first international observation campaign (CPEA-I), and in October-November 2004. National Institute of Information and Communications Technology operated three ionosondes located along the same geomagnetic meridian during these periods.

Comparing between the EAR and ionosonde observations, we confirmed that plasma bubbles were generated when the F layer was raised by the prereversal enhancement, and reached 400 km at Chumphon. We also found disappearance of E region FAI in the post sunset hours related to the rise of the F layer. Bottom height of FAI echoes agreed well with that of the F layer observed by the co-located Ionosonde (see Figure 1). Different height variation of the F layer observed with three ionosondes suggests that the vertical motion of the F layer should be controlled by the other factor, i.e. neutral wind, than the zonal electric field.

In order to determine spatial distribution of plasma bubbles, we investigated zonal drift velocity of plasma bubble from the EAR multi-beam observations. Zonal drift speed was about 140 m/s just after the sunset, and it gradually decreased by 10 m/s every one hour. On the assumption that plasma bubbles are generated just after the sunset and the drift speed decrease linearly, we estimated the generation region of plasma bubbles. We found that plasma bubbles which contain 3-m scale FAI echoes can appear was estimated as far as 2000 km west from the EAR. Large-scale distribution of plasma bubbles were estimated to show intermittently occurrences with spacings of 600-800 km. This scale may be related with the day-to-day variation of plasma bubbles.

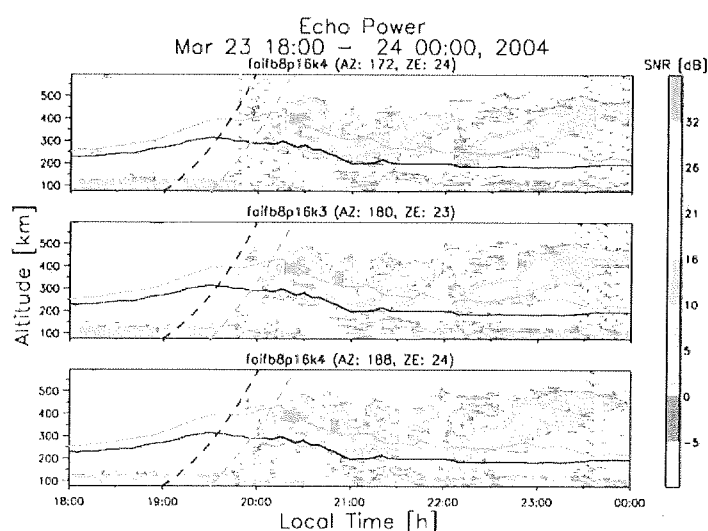


Figure 1: Time-height cross-section of FAI echoes observed with the EAR during 18-24 LT on March 23, 2004 and time variation of the bottom of F -layer.

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Observational study on convection at Sumatra Indonesia

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The Indonesian maritime continent is one of the regions where the most active convection occurs anywhere on the globe [1]. Sumatra is one of the largest islands in the Indonesian Maritime Continent. However, the formation process of convection over Sumatra has never been studied. In this paper, the convective activity over Sumatra and its relationship to large-scale disturbances are studied as the case study during October-December 2001. Tropical cirrus develops with deep convection in the troposphere plays an important role in the radiation processes [2]. However, the formation and maintain processes of cirrus are not still understood well. Formation of cirrus and its relationship to the vertical wind in the upper troposphere are studied using data derived from a VHF-band wind profiler (Equatorial Atmosphere Radar; EAR) [3], lidar, and radiosondes observed over Sumatra.

During 15 October-31 December 2001, deep convection over Sumatra occurred with three kinds of large-scale disturbances. These are (1) eastward-moving Super Cloud Clusters (SCCs), (2) circulation disturbance over the Indian Ocean, and (3) East-Asian cold surge. Deep convection over Sumatra was observed when six eastward-moving SCCs developed over the Indian Ocean passed over it. When low-level moist air in the Indian Ocean supplied to Sumatra by circulation disturbance, the convective activity induced by local circulation was strengthened. During the strong cold-surge events, large low-level northeasterly flow over the South China Sea caused the formation of low-level convergence over Sumatra. Deep convection formed in the cold-surge-induced convergence region.

During 5-9 May 2004, eastward-moving SCCs passed over Sumatra. Figure 1 shows time variations of vertical winds observed with the EAR averaged over 8-15 km. Updraft exceeding 5 cm/s prevailed in the upper troposphere while large-scale convective envelope existed over Sumatra. During 6-7 and 7-8 May, the cloud top of cirrus existed below the continuous downdraft (> 5 cm/s) region. Radiosonde results showed that 55-90 % of downdraft observed by the EAR can be explained by the northeasterly flow along the isentropic surface.

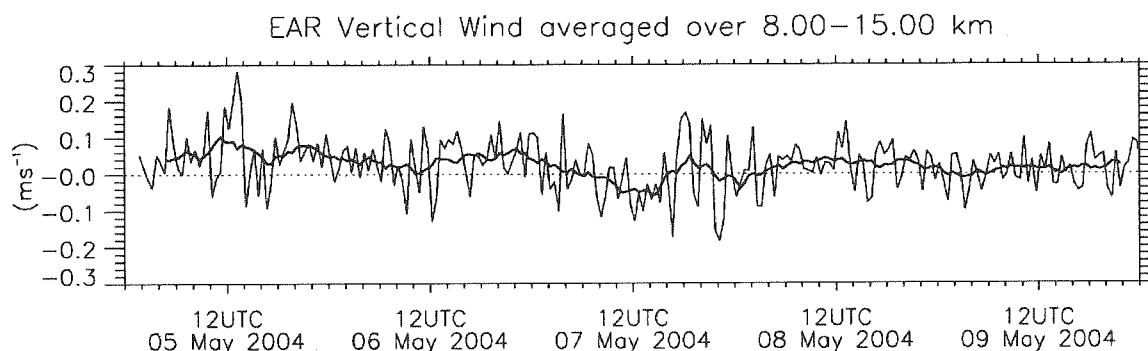


Figure 1: Time variations of vertical winds observed with the EAR averaged over 8-15 km during May 5-9, 2004.

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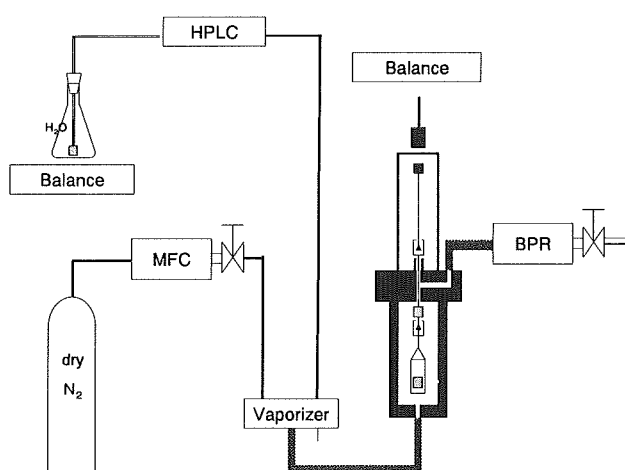
Moisture adsorption of wood at temperatures above 100°C

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Recently, wood working such as production of compressed wood, fixation of bent wood, or the dimensional stabilization of boards has been carried out using high temperature steam. In relation to this, we have been studying some physical properties of wood under high temperature steam and found that they were conspicuously different at different moisture contents. However, because it is difficult to measure the moisture content of wood under high temperature steam, we have used the relative humidity in the measuring atmosphere instead. In this paper, we will describe the equilibrium moisture content of wood under steam at relative humidity of 20 to 90% above 100°C, and clarify its effect on some physical properties of wood above 100°C.

The Figure below shows a schematic diagram of the measuring system. A HPLC pump and a Mass flow controller (MFC) are respectively used to control high pressure water and high pressure nitrogen. Water and nitrogen are mixed together in the vaporizer. Then the mixture is applied at an adjusted flow rate to achieve the desired partial steam pressure at a fixed temperature in the vicinity of a sample holder. The pressure of the system is controlled with BPR and the sample weights are measured with a magnetic suspension balance (RUBOTHERM Co.) .



As is shown in the figure, the balance at the top is separated from the sample portion at the bottom and the two parts are connected through magnetic force. This structure enables us to measure the sample weight accurately under high temperature and high pressure steam. The samples used in our experiments were sugi (*Cryptomeria japonica* D.Don) wood.

Figure: Schematic diagram of the measuring system

From the measurements above, we observed a linear relationship between the moisture content of the wood and temperature in the temperature range between 40 and 180°C at a fixed relative humidity of 20 to 90%. From this we could estimate the moisture content at any temperature and at any relative humidity. With increasing temperature, the shape of adsorption isotherm changed from type II to type III in BDDT classification¹⁾. Adsorption water was separated into hydrated water and dissolved water on the basis of the Hailwood-Horrobin theory²⁾. It was found that with increasing temperature the decreasing rate of hydrated water was large compared to that of dissolved water, and at 180°C only dissolved water was observed.

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Optically transparent composites reinforced with plant fiber-based nanofibers

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The plant cell wall consists of nanofibers 4 nm in width and thickness, called cellulose microfibrils. Because the nanofibers are bundles of semi-crystalline extended cellulose chains, the Young's modulus and tensile strength are as high as those of aramid fibers (trade name: Kevlar), a well-known high strength fiber, and surprisingly the thermal expansion in the axial direction is as small as that of quartz.

Recently, we demonstrated that cellulose microfibril bundles of 50 nm width produced by bacteria, could reinforce transparent resins without losing transparency [1]. The nanocomposites exhibited low thermal expansion, as good as can be found with silicon crystal, high strength comparable to that of soft steel, and ease of bending similar to that of plastics. Our findings engendered a new interest in cellulose microfibrils, the most abundant biomass resource on Earth, as a promising nanofiber for use in materials of the future. This study is a first example of a successful fibrillation of wood pulp fibers into nanofiber bundles, which are thin enough to work as well as bacterial cellulose in maintaining the transparency of resin[2].

The plant fiber is a cellulose microfibril bundle of micro order diameter. To produce optically transparent composites reinforced with plant fibers, it is necessary to fibrillate these fibers into nanofibers. The fibrillation of pulp fiber was attempted by two methods, a high-pressure homogenizer treatment and a grinder treatment. High-pressure homogenizer treated pulp exhibited a wider distribution of fiber width, from some microns to 50 ~ 100 nm. Thus, homogenizer-treated pulp slurry was subjected to a grinder treatment. With the increase in the number of passes, the bundles of homogenizer-treated pulp were further fibrillated, and 10 repetitions of the grinder treatment resulted in uniform nanofibers 50 ~ 100 nm wide.

Figure 1 shows the results of light transmittance measurements versus wavelength for the fiber/acrylic resin composite sheets and an acrylic resin sheet. At a 600 nm wavelength, grinder treated pulp/acrylic resin composite transmits 70% of the light, including surface reflection (Fresnel's reflection), at a fiber content as high as 70 wt%. When we compared the light transmittance against that of pure acrylic resin, we found that the degradation in light transmission due to the fibrillated pulp fiber network is only 20%. On the other hand, the light transmittance of homogenizer-treated pulp/acrylic resin sheet is 30% and the degradation is around 60% at a fiber content of 62 wt %.

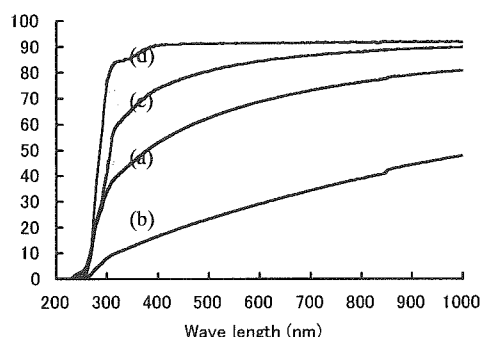


FIGURE 1 Regular light transmittance of (a) 45 μm -thick grinder-treated pulp/acrylic resin sheet, (b) 53 μm -thick high-pressure homogenizer-treated pulp/acrylic resin sheet, (c) 60 μm -thick bacteria cellulose/acrylic resin sheet, and (d) 40 μm -thick acrylic resin sheet

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Utilization of Compressed-Sugi Dowels as Joint Material in Timber Structures

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INTRODUCTION

Density of Sugi (Japanese Cedar: *Cryptomeria japonica* D.Don) is usually around 300 to 400 kg/m³ and such low density generally correlates to low mechanical properties. While low density implies that it can be easily compressed into high density material which might has a potential for becoming a strong materials.

The final purpose of this research is to create a high strength material by using low density, weak and not utilized Sugi material. As the first step of this research project, basic pull-out resistance of Sugi compressed dowels was evaluated to examine the potentials as the feature joint material in place of glued-in-hard wood dowels.

CONCEPT of COMPRESSED SUGI DOWEL JOINT

The basic concept of joint member is shown in Figure 1. It was expected that the end part of compressed dowel will be expanded once again into the shape of spindle by absorbing water and that by making use of this volume recovery some sort of pull-out resistance might be obtained.

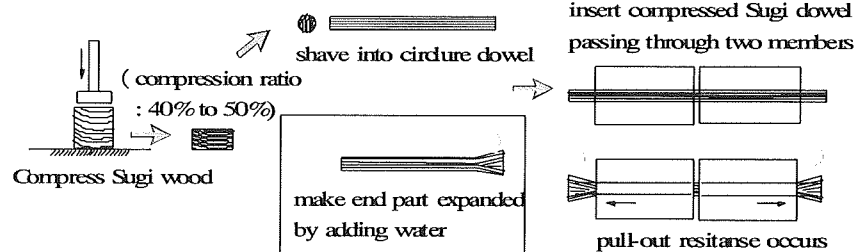


Figure 1. The basic concept of joint member using compressed Sugi dowel.

MATERIALS and METHODS

Dowel was made from compressed Sugi (Japanese cedar). Sugi was fully warmed at 105 degrees C within the press for 10 minutes. Target volume of compressed wood was 45% of the original one. Compressed square woods were shaved into dowels with 12mm in diameter. For evaluation of pull-out resistance, spruce glulam (105x105x105mm) was used as the main members. After processing 12mm lead hole in main members, a dowel was inserted until the end part coming out then water was applied to make the end part recover its shape. Pull-out tests were done as shown in Figure 2. The parameters set out in this experiment was the grain direction to that of dowel. We defined that L was parallel to the fiber direction, R is perpendicular to the fiber direction (radial direction), and T was tangential direction. The size of dowel was set to 'd'=12mm, and 'g' and 'D' were also parameters with experimental variation.

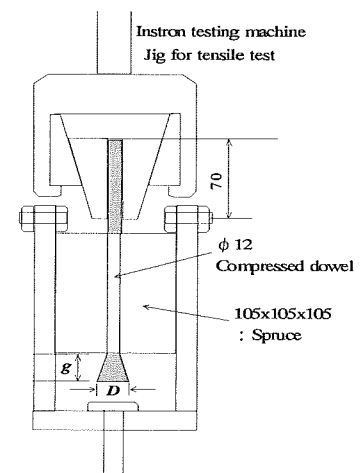


Figure 2 Pull-out test.

RESULTS and DISCUSSION

The relationship between P_{max} and expanded volume V with parameters of dowel directions is shown in Figure 3. It is likely to be proportional between P_{max} and the expansion volume. Moreover, there seemed to be strength anisotropy among dowel directions. R, T specimens were likely to have a higher pull-out resistance than that of L specimen. These relationships could be explained using the ratio of strength anisotropy of wood.

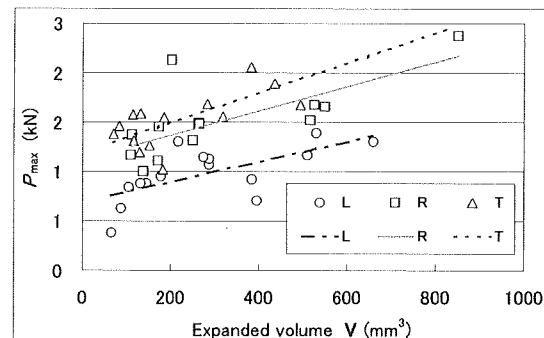


Figure3 P_{max} vs. expanded volume V .

Study on chip-type wave-particle correlator onboard spacecraft

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Wave-particle correlator (WPC) is a direct measurement system to observe the interactions between waves and particles, which exchange their energies in space plasma. Since space plasmas are collisionless, their kinetic energies are transported through plasma waves. It is important that we identify the wave-particle interaction process to know generation of plasma waves. However, it is difficult to study the interaction process by using the previous plasma instruments with low time resolutions in the order of milliseconds, since the wave-particle interaction occurs in such a short time as 1 μ s. The wave-particle correlator realizes the calculation of the correlation between observed wave phase and particles with high time resolution onboard spacecraft/rocket [1-3]. We proposed the new WPC system on the basis of the digital technology [4]. In the present paper, we designed and developed the prototype of this new WPC system (Fig. 1).

The developed new WPC system is the one-chip type wave-particle correlator. The algorithm of calculating correlations is programmed into one FPGA (Field Programmable Gate Array) chip. It realizes flexible observations as well as the high-speed processing. We designed 3-channels of digital filter (bandpass filter) with variable cut-off frequency and installed onto the FPGA. The filters limit the frequency bandwidth of the observed waveforms. The waveforms with limited frequency bandwidth are processed by the correlation calculation algorithm (see Fig. 2) in the FPGA. We can dynamically change the cut-off frequency of filters depending on the observed phenomena. In our algorithm, the correlation index (C) is calculated as following formula,

$$C = \int \text{sign}(E) \times f(v) dt$$

Further, we developed the algorithm for synchronizing particle data with filtered wave data.

Since measurements of plasma particles are operated independently of waveform measurements, this synchronous control is one of the most important parts of the present WPC system. To confirm our algorithm, we conducted the functional tests using the dummy waveform data which are input from the signal generator. The correlation of the dummy waveforms was calculated with the periodic pulses as dummy particle signals generated via a digital module in FPGA and we confirmed that our algorithm functions properly.

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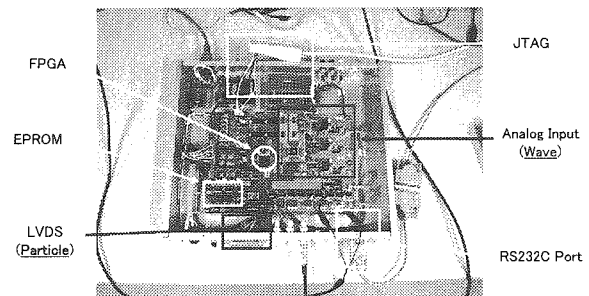


Fig 1: Test board for wave particle correlator.

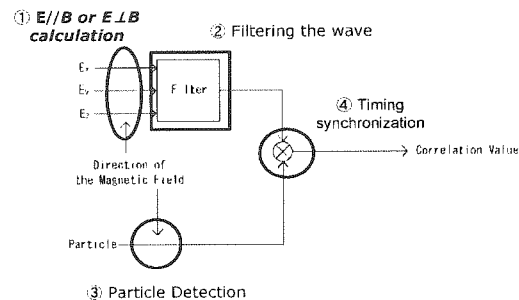


Fig 2: Block diagram of correlation calculation between waves and particles

Study on Direction of Arrival Estimation Method with Automatic Calibration System for Solar Power Station/Satellite

Masatoshi Matsumoto

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In Solar Power Station/Satellite (SPS), it is necessary to transmit microwave power generated in space to a rectenna site on Earth correctly by a beam control. The difference of characteristics in each pilot signal receiver, however, causes a serious error for the accurate detection of Direction of Arrival (DOA). Piece-to-piece variations of devices, secular changes, and failure of equipments are cited as main causes of the difference. We have been studying a method of estimating DOA with a self-calibration function, and it has turned out that DOA estimation is affected badly when the mean of phase errors which are added in passing through the receivers is not zero. In the present research, we have developed a DOA estimation method which is not influenced by such errors.

We study a DOA estimation method with an automatic phase calibration system for linear equispaced arrays, named PCLE method (Phase Calibration method for Linear Equispaced arrays). This method assumes that the sum of the differences of characteristics in receivers approaches 0. We show through numerical simulations that the PCLE method causes errors in estimation of the DOA if the sum is not 0 although this errors become negligible with data received by a lot of antennas.

Then, we have developed a new method, named PCLE-WS method (Phase Calibration method for Linear Equispaced arrays with double (W) pilot Signals). The PCLE-WS method is not necessary to assume that the sum of the phase differences from characteristics is 0. We show that PCLE-WS method well estimates the true DOA with data received by any number of antennas by both numerical simulations and demonstration experiments. Fig.2 shows experimental setup and experimental result of PCLE method. The α that leads true DOA physically is different from ideal parameter.

Finally, we suggest how we should apply these methods to SPS. We propose that the PCLE-WS method should be used for experimental types of SPS and the PCLE should be used for commercial types of SPS from a view point of the number of antennas.

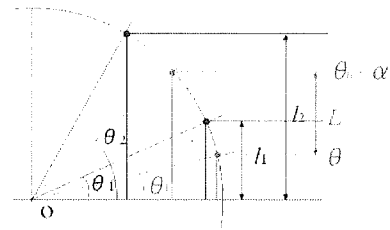
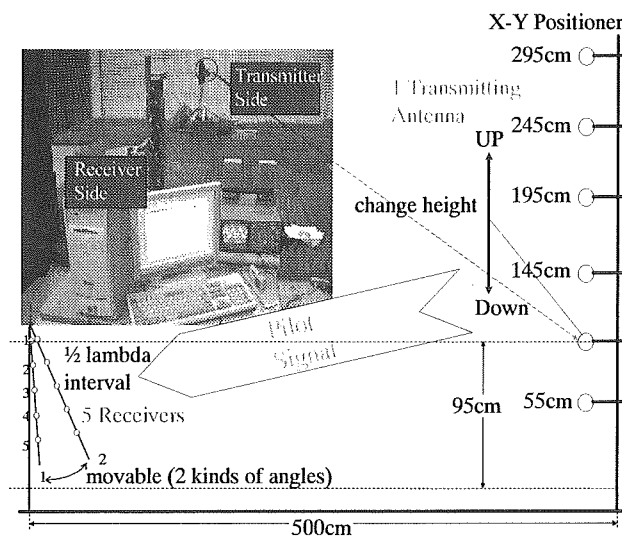


Fig. 1. There is a unique θ_0 which satisfy, $\sin \theta_1 - \sin \theta_2 = \sin(\theta_0 + \alpha) - \sin \theta_0$. α is assumed correct.



Receiver side pictures

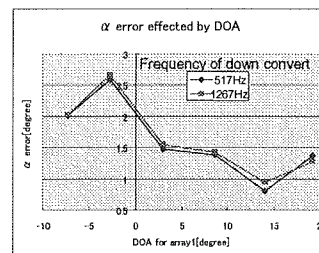
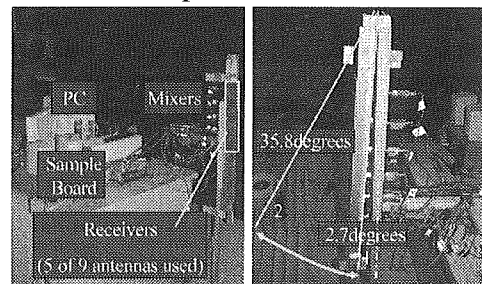


Fig.2 Experimental Setup and Experimental Result of PCLE method

Study on Microwave Power Transmission System with Active Integrated Antenna

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Development of Microwave Power Transmission (MPT) System with huge phased arrays (diameter: 1.0km~2.6km), very accurate beam control (less than 0.0001 degree), high overall efficiency and light weight is necessary to realize Space Solar Power System (SSPS) economically. To satisfy these requirements, a Phase Controlled Magnetron (PCM) is considered to be suitable for a microwave transmitter. The PCM, developed by our research group, takes advantages of high power, high DC-RF conversion efficiency, low cost, and light weight. A typical output power from the PCM is more than 300W, while an output power from one antenna element is less than 1W for SSPS parameters. Power dividers and phase shifters after the PCM output are necessary to satisfy SSPS parameters and it leads to disadvantages. The power dividers and the phase shifters are inserted after the high power microwave output, thus an insertion loss in these elements is critical for overall efficiency. Therefore, the loss following to the PCMs must be reduced to realize the PCM-based MPT system.

In this paper, a Slot-coupled Active Integrated Antenna (AIA) system is proposed as one of the solution of the MPT system for SSPS, which is composed of a waveguide slot as a power divider, an AIA as an active device part (a low-loss phase shifter / a high efficiency amplifier) and a planar antenna. By using an electromagnetic coupling between the AIA and the waveguide slots, thin and light AIA structure can be realized. One of the important factors of the slot-coupled AIA is a coupling factor of the electromagnetic coupling between microstrip lines and waveguide slots. In the study, improvement of the coupling factor is studied. By tuning the electromagnetic coupling structure and the waveguide dimensions, the coupling factor of more than 90% is achieved for 2-element model (Fig.1). Measurement results show good agreement with the electromagnetic simulations.

A design and a fabrication of an amplifier for the AIA part are also studied. In a design of the power amplifier integrated with AIA, the reduction in size is one of the important points to construct 2-dimensional, compact, and thin AIA array structure. From the view point of the device characteristics, good grounding, heat handling and output matching are also important to realize the stable high power output, and to avoid breakdown of the device. These key points are well examined and considered in the design. As a basic design, a compact amplifier with low-power HEMT is designed and fabricated. The operating point of class AB is chosen to improve the efficiency of the amplifier. Measured PAE (Power Added Efficiency) of the basic amplifier is 47% at 0dBm input power. As a next step, a drive-stage amplifier for a high-power AIA is designed and fabricated. Through the design and the fabrication, sufficient compactness is achieved and the operation as an amplifier is demonstrated (Fig.2).

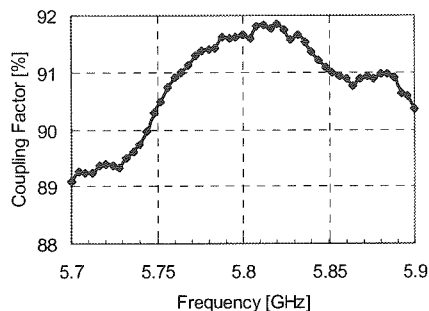
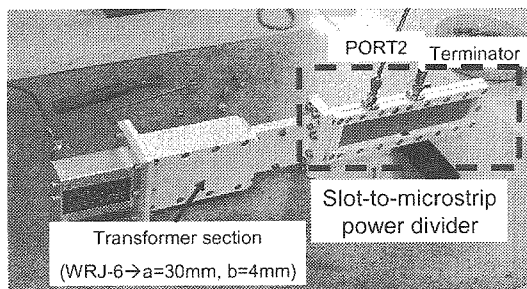


Fig. 1 Experimental Result of New Waveguide Power Divider

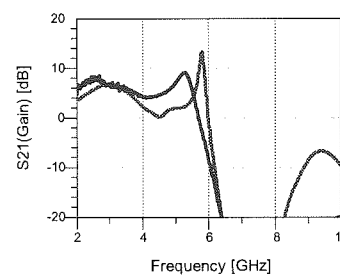
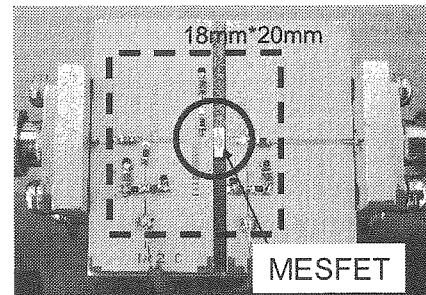


Fig.2 Experimental Results of AIA Power Amplifier (red line: simulated curve, blue line : measured curve)

Computer Experiments on Magnetrons with 3D Electromagnetic Particle Code

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The objectives of the current study are to analyze the electromagnetic interactions with the electrons drifting around the cathode in magnetrons [1] by performing 3D electromagnetic particle simulations [2]. It is very difficult to analyze theoretically the electron resonance with the electromagnetic field in the internal space bounded by complex shaped conductors of magnetrons. Therefore, we newly developed a 3D simulation code with electromagnetic particle model for the magnetron analysis. The simulation model is shown in Fig.1.

We analyzed the effects of the complex 3D internal structure of a magnetron on the microwave enhancement and electron behavior. We particularly examined the effects of end-hats and end-spaces attached on each side in the z-axis direction. We discussed the relations between the resonance frequencies and the axial structures of magnetrons by using an equivalent circuit. Fig.2 shows the temporal evolution of the spatial distribution of electrons in the interaction space. Just after we begin the emission of electrons from the cathode, emitted electrons gather

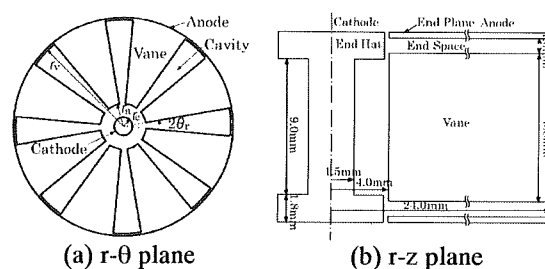


Figure1: 3D simulation model

around the cathode and form Brillouin flow. The density fluctuation of electrons gradually occurs in the θ direction, and the fluctuation of electrons grows and forms electron spoke. When the electron spoke is achieving the anode, the shape of the spoke starts to change. Electrons are gathered around the center of the z-direction and there is a space which no electrons exist around the each edge of the z-direction.

We also performed computer experiments with inhomogeneous magnetic field applied along the axis direction in the internal magnetron. Finally, we investigated the effects of the electron emission from the cathode on the microwave enhancement. We hired two models of electron emission from the cathode. One is the model in which a limited region for the electron emission is assumed on the cathode, and the other has emission shields around the cathode. In the first case, we observe the same microwave emission as observed in the case of uniform electron emission, although some electrons are diffused along the axis direction. In the second case, we could see the initial phase of electron bunching. However, it turned out that no intense microwave was enhanced. We conclude that the microwave emission can depend on the manner of electron emission from the cathode, which has to be examined by different parameters of electron emission as a future work.

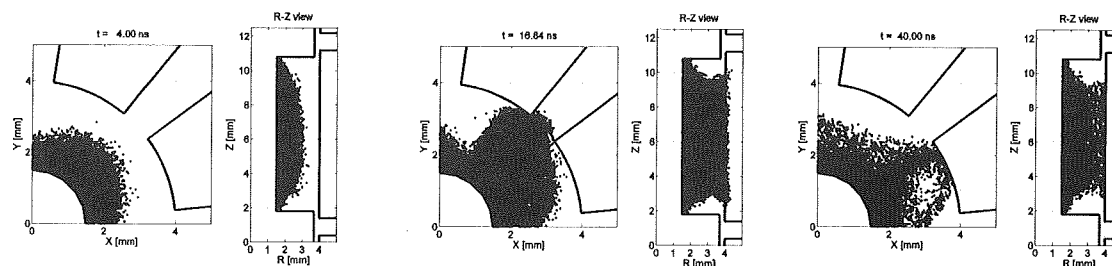


Figure 2: Electron distribution at different times

ACKNOWLEDGMENTS

Computation in the present study was performed with the KDK system of Research Institute for Sustainable Humanosphere (RISH) at Kyoto University as a collaborative research project.

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- [1] N. Kroll, The Unstrapped Resonant System, in *Microwave Magnetrons*, Edited by G. B. Collins, chap.2, McGraw-Hill Book Company Inc., New York, 1948.
- [2] H. Matsumoto, and Y. Omura, *Computer Space Plasma Physics: Simulation Techniques and Software*, Terra Scientific Publishing Co., Tokyo, 1993.

Observational study on generations of plasma waves In the low latitude boundary layer

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In space around the earth, the solar wind plasmas interact with earth's magnetic fields, and it results in forming the magnetosphere. The night side region of the magnetosphere is called as Magnetotail after the tail-like structure of magnetic field lines. The low latitude region of the magnetotail is filled with hot plasmas. Since the region is formed as a sheet-like structure, we call it plasma sheet. The origin of the plasma sheet plasmas is believed to be the solar wind. However, much difference of plasma temperatures in plasma sheet and solar wind suggest the existence of some thermalization processes in the interface region between the plasma sheet and solar wind. This interface region is called Low Latitude Boundary Layer (LLBL). The GEOTAIL spacecraft observed that the both plasmas of solar wind and of magnetosphere origins are mixed in the LLBL. Therefore the LLBL is a key region in the geophysics in the view point of the plasma transportation from the solar wind into the magnetosphere. Therefore, it is very important to investigate the wave-particle interactions taking place in the LLBL, because kinetic energies are transported via plasma waves in the collisionless plasmas such as space plasmas. In the present paper, we focus on generation of plasma waves in the LLBL based on GEOTAIL observation data.

In the day-side LLBL, the GEOTAIL observed the mixture of solar wind ions and magnetosphere ions as well as low energy electrons thermalized along ambient magnetic field. We examined the relation between plasma waves and particles, and found that ion acoustic waves are observed when low energy electrons are thermalized along the ambient magnetic field. We proposed the current driven type instability as the excitation mechanism of ion acoustic wave in the day-side LLBL. We also surveyed the night-side LLBL from the viewpoint of plasma wave generations. We performed statistical analyses of the spatial distribution of the observed plasma waves. The GEOTAIL data used for the statistical analyses are obtained from January 1995 to March 2004. The results show the existence of the electromagnetic waves with their frequencies below 100Hz. Further, we found that they have the interesting feature that the intensities of these waves have the dawn-dusk asymmetry (see Figures 1 and 2).

We examined these low-frequency electromagnetic waves and found that they are whistler mode waves. In order to make clear how the dawn-dusk asymmetry is formed, we examined propagation directions of whistler mode waves. Using the Means method, we found that whistler mode waves are emitted from the magnetic equator region to the high latitude direction along the ambient magnetic field. This means that the source region of whistler mode waves is on the magnetic equator. By consulting plasma particle data and liner dispersion analyses, we concluded they are generated due to the electron temperature anisotropy. The relation of this generation mechanism and the dawn-dusk asymmetry is still unclear. However, the identification of the whistler mode wave generation is very helpful for considering a model for the dawn-dusk asymmetry.

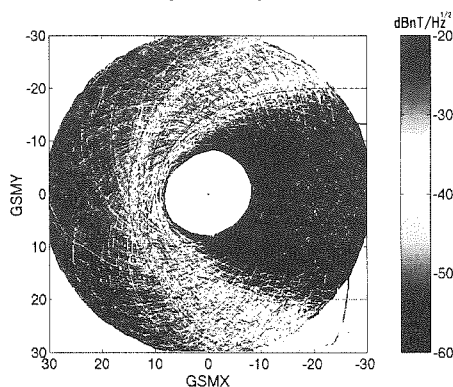


Figure 1: Spatial distributions of observed whistler mode waves.

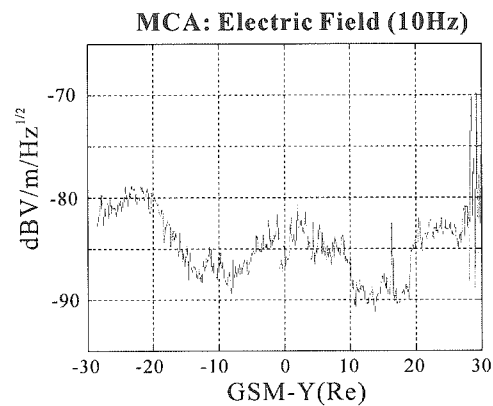


Figure 2: Dawn-dusk asymmetry of observed whistler waves. Electric field data of MCA 10Hz channel are used for the present statistical analyses.

Study on Parameter Optimization of Rectifying Circuit of Rectenna

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In Space Solar Power Satellite system (SPS), it is very important to develop the high RF-DC efficiency of rectennas that change microwave power into DC power. Since very huge rectenna is needed, we must make rectenna cheaply. So, we notice the substrate to mount a rectification circuit. In our research group, experimental examination on the height of substrate was carried out to solve the relation between RF-DC conversion efficiency and substrate parameters. Also in the rectification circuit that uses the glass epoxy ($\epsilon_r \sim 4.2$) substrate whose characteristic is generally considered to be bad, we have obtained about 63% RF-DC conversion efficiency that was comparatively high efficiency. So it is believed that a certain amount of selection nature in the parameter of the substrate is necessary for realization of efficient rectennas. So, even if we don't use the expensive substrate like Teflon that is used mainly, it can be assumed that high efficiency is kept by using a cheap substrate.

The purpose of this study is to carry out detailed analysis and evaluation about the substrate parameter dependency of the RF-DC conversion efficiency through simulations. In this study, the dependency was examined for 4 parameters (ϵ_r : relative permittivity, $\tan \delta$, h : substrate thickness, and t : conductor thickness).

When an ideal microstrip line is taken into consideration, there was no dependency on ϵ_r . But since the influence by a manufacture error became large relatively if ϵ_r became large when the error of actual line length and width was taken into consideration, the decline of RF-DC conversion efficiency became large. If $\tan \delta$ is 0.01 or less, high efficiency is maintainable. Even if the characteristic of the substrate is inferior to the expensive Teflon, high efficiency rectenna is realizable (Fig.1).

Next, we explain about the theoretical study of a rectifying circuit. In the past, we tried to develop a theory of the rectifying circuit. However, we can't realize how the rectifying circuit performs the RF-DC conversion in the high frequency band, especially the relation of the rectification and the circuit composition (the microstrip line between diode and output capacitance).

So, the purpose of this study is to clarify the theory of the rectifying circuit in the high frequency band. In this report, we derive the theoretical formula by taking the internal factors of a diode into consideration.

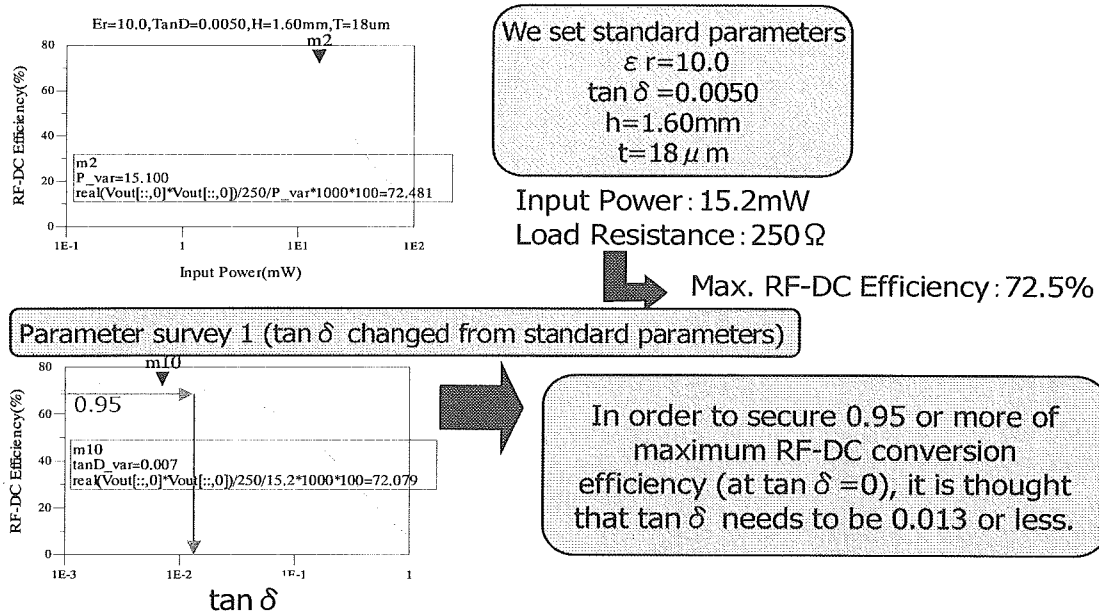


Fig. 1 Substrate parameter influence to RF-DC conversion efficiency in case of ideal microstrip lines

Synthesis and Functional Analysis of a Dicarboxylic Acid Produced by *Ceriporiopsis subvermispora*, Ceriporic acid B and its Analogue

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