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Bangkok, Thailand

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Asia's First Bioplastics Conference and Exhibition

International Conference and Exhibition on

Bioplastics - Technologies and Markets Towards the MDGs

Jointly Presented by:

Organized by the National Innovation Agency, Thailand

InnoBioPlast 2006 Strategic Partners:

Key Contributors:

Key Participants:

Programme and Abstracts

inno BioPlast 2006
Bangkok, Thailand

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Ministry of Science and Technology, Thailand

Jointly Presented by:

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National Metal and Materials Technology Center, Thailand

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Congratulatory Message from

H.E. Dr Pravich Rattanapian

Minister of Science and Technology, Thailand

The Ministry of Science and Technology, Thailand is proud to welcome delegates to InnoBioPlast 2006 to Bangkok. This is the first event of its kind in Asia, and is convened by the National Innovation Agency, Thailand, with the support of the United Nations Environment Programme.

The imperative to protect our environment and dwindling natural resources is underscored by the UN Millennium Development Goals (MDGs), agreed at the United Nations Millennium Summit in September 2000 and supported by nearly 190 countries around the world.

In this age of high oil prices and mounting concern over carbon emissions, bioplastics offer tremendous benefits over conventional materials- social, economic and environmental. Today, thanks to the fast pace of technological innovation, bioplastics are on the verge of leaving the niche areas they have till now occupied, and competing in mainstream markets-especially in applications such as packaging, electronics, automobiles and agriculture. The chemical and plastics industries have already invested heavily in these new technologies, and have high expectations of the new generations of bioplastics which are now competing successfully with conventional petroleum-based plastics. Clearly, emerging market opportunities for biodegradable and bio-based products hold great promise to implement the principles of sustainable development and contribute towards achieving the MDGs.

Recognizing that the road to sustainable development will be built on innovation, Thailand is gearing up for bioplastics. The Thai Government, in its newly-launched 10^{th} Social and Economic Development Plan, has prioritized green technologies including bioplastics and biofuels through a “New Wave Industry” programme, and the National Innovation Agency has been charged with developing a roadmap to foster bioplastics development in Thailand.

Although our bioplastics sector is still at a relatively early stage, Thailand offers important comparative advantages at production and industry levels, including ample and reliable supplies of bio-based feedstocks, excellent logistics, and ready access to strategic markets. In order to accelerate this development it will be important to generate a global awareness of Thailand's open-door policy towards businesses based upon renewable materials. Both technology transfer and foreign investment will be necessary for a thriving and sustainable bioplastics industry here in Thailand.

InnoBioPlast 2006 is delighted to welcome some of the world's foremost authorities in bioplastics – from Asia, USA and Europe, as well as Thailand's own research and business community. InnoBioPlast 2006 aims to highlight the role that bioplastics can and will play in contributing to environmental protection and the agricultural sector in both developed and developing countries. The event brings together key players in the global research and business communities, regulators and environmental organizations in order to share the latest technological breakthroughs, promote equitable regulatory frameworks and facilitate new partnerships and incentives to expand the industry.With such distinguished participation, I am confident that InnoBioPlast 2006 will succeed in its goals to highlight the issues and offer solutions, to educate, and to present new opportunities for partnerships in research and business.

On behalf of the Ministry of Science and Technology as well as the National Innovation Agency, I would like to express my sincere thanks to all sponsoring companies and exhibitors for your kind support. Most of all, we thank all speakers and distinguished delegates from Thailand and around the world for your participation.

I wish you a successful conference as well as a pleasant and productive stay here in Thailand.

Sincerely,

P. Rattanapian

H.E. Dr Pravich Rattanapian
Minister of Science and Technology

Foreword

Distinguished participant,

The National Innovation Agency extends a sincere welcome to all speakers, delegates, and exhibitors to the InnoBioPlast 2006 Conference and Exhibition.

We are delighted to offer this forum to the global bioplastics community, in cooperation with the United Nations Environment Programme. The tremendous response to our Call for Papers and the impressive academic standard of papers submitted attests to the need for such a forum. Due to the full allocation of all speaking slots, we have attempted to accommodate a number of excellent additional submissions as poster papers, and these are included in this document. I look forward to all the presentations and a lively debate in the coming days.

The National Innovation Agency is an autonomous agency established in 2003 under the supervision of the Ministry of Science and Technology. NIA works at enterprise, sector and national level to achieve its mission to foster innovation and enhance national competitiveness. NIA is therefore proud to be invited to develop a national roadmap for bioplastics development in Thailand. We are working closely with other concerned agencies to provide an enabling framework to stimulate investment, technology transfer and human resource development to establish a viable, sustainable bioplastics sector.

We hope that InnoBioPlast 2006 will mark the beginning of a new phase in bioplastics development in Thailand. NIA stands ready to facilitate the establishment of new partnerships and joint ventures in research and business, so please do not hesitate to contact us if we can assist in any way. May I wish you all a fruitful conference.

Sincerely,

Supachai L.

Supachai Lorlowhakarn
Director, National Innovation Agency, Thailand

Contents

Message

Foreword

InnoBioPlast 2006: Conference Programme 8

Satellite Programme: MTEC- TU Graz Workshop 11

KEYNOTE SESSION

The role of innovation in addressing the Millennium Development Goals 12

Global review of bioplastics industry- framework conditions and future markets 14

Thailand's policies to promote bioplastics 15

GLOBAL OVERVIEW

Bioplastics – from research to market 17

Bioplastics research in Thailand 19

Recent development of biodegradable and biomass-based plastics in Japan. 20

ADVANCES IN RESEARCH

Neo-PLA as high-performance bio-based polymers 22

Surface modification of PLA and PHA films using photochemistry 24

Effect of maleic anhydride on biodegradable film of poly butylenes [adipate-co-terephthalate] blended with thermoplastic tapioca 25

Polyhydroxyalkanoates (PHA) and their production 27

Novel bio-based and biodegradable polyamide 4 29

Rheology and processing of bio-based copolymers and blends 31

Polyhydroxyalkanoates (PHAs): production, optimization and factors affecting PHA accumulation 32

INTERNATIONAL STANDARDS AND REGULATIONS

Compostable plastic regulatory framework 33

Biodegradability & compostability: What is the difference? Standards - impact on usage of biodegradable polymers 35

Downstream applications, products and markets

PURAC®: World-class lactic acid products focused toward PLA polymers 37
Highly functional bioplastics (PLA composites) used for electronic products 39
Medical applications for bioabsorbable polymers 41
Introduction of Toyo Ink biomass-based products 43
Injection moulding of bio-based synthetic materials 45
Transparent flexible polylactide resin compound Rikemaster-GPR-075 47
Bioplastics in the automobile sector in Asia 48
BIONOLLE – An approach to more environmentally-friendly green plastics 49
Ecoflex and renewable materials 50
Recent developments in polylactic acid: TERRAMAC® 51
Sony's vegetable-based plastics 53

Poster Presentations

Steam explosion of oil palm trunk for glucose and xylose production 54
Characterization and enzymatic degradation of microbial co-polyester P(3HB-co-3HV)s produced by metabolic reaction model-based system 55
Green packaging from starch 57
Ecofriendly, sustainable, revolutionary biodegradable green nanocomposites: opportunities and challenges 59
Transparent and flexible polylactide films 61
Chitosan cotton: a potential novel material for absorbable wound dressing 63
Bionanosphere for drug delivery system 65
Strain improvement and production of L (+)-lactic acid by polyurethane immobilized Rhizopus oryzae in airlift bioreactor 66
The potential use of degradable plastic bags in Kuwait and its environmental benefits 68
Improving PHB production rate from Alcaligenes eutrophus NCIMB 11599 by two stage fermentation 70

Day 1: Thursday 21 September

Opening session

08:00 - 09:00 **Registration**

09:00 - 10:00 **Opening ceremony - InnoMart / InnoBioPlast 2006**

- Report of the Permanent Secretary, Ministry of Science and Technology, Dr Saksit Tridech
- Opening address: Minister of Science and Technology H.E. Dr Pravich Rattanapian
- Welcome remarks: Mr Supachai Lorlowhakarn, Director, National Innovation Agency
- Welcome remarks: Mr Juergen Koch, Country Director, GTZ Thailand
- Welcome remarks: Dr Phietoon Trivijitkasem, Chairman, Thai Bioplastics Society, Federation of Thai Industries

10.00 - 10.05 NIA - GTZ MoU Signing Ceremony for Bioplastics Development in Thailand

10:05 - 10:30 *Break and opening of InnoMart / InnoBioPlast 2006 Exhibitions*

Keynote session

Moderator: *Dr Suwabun Chirachanchai, Petroleum and Petrochemical College, Chulalongkorn University*

10:30 - 11:00 **The role of innovation in addressing the Millennium Development Goals**
Mr Hiroshi Nishimiya, Deputy Regional Director, UNEP Asia-Pacific Region

11:00 - 11:30 **Global review of bioplastics industry-framework conditions and future markets**
Dr Jöran Reske, Vice Chairman, European Bioplastics, Berlin, Germany

11:30 - 12:00 **Thailand's policies to promote bioplastics**
Kh Arkhom Tempittayapaisith, Deputy Secretary General, National Economic and Social Development Board, Thailand

12:00 - 13:30 *Lunch*

Global overview

Moderator: *Dr Ittipol Jangchud, Faculty of Science, King Mongkut Innstitute of Technology Ladkrabang*

13:30 - 14:00 **Bioplastics: from research to market**
Prof Dr Ramani Narayan, Professor of Chemical Engineering & Materials Science, Department of Chemical Engineering & Materials Science, Michigan State University, USA

14:00 - 14:30 **Bioplastics research in Thailand**
Prof. Krisda Suchiva, Deputy Director, National Metal and Materials Technology Center (MTEC), Thailand

14:30 - 15:00 **Recent development of biodegradable and biobased plastics in Japan, new identification and labelling system for biobased plastics in Japan**
Isao Inomata, Advisor, Biodegradable Plastics Society, Japan

15:00 - 15:15 *Break*

Advances in research

Moderator:	*Dr Ittipol Jangchud, Faculty of Science, King Mongkut Innstitute of Technology Ladkrabang*
15:15 - 15:45	**Neo-PLA as high-performance bio-based polymers** Prof Yoshiharu Kimura, Director, R&D Center for Biobased Materials, Kyoto Institute of Technology, Japan
15:45 - 16:15	**Surface modification of PLA and PHA films using photochemistry** Prof Douglas E Hirt, Center for Advanced Engineering Fibers and Films, Clemson University, USA
16:15 - 16:45	**Effect of maleic anhydride on biodegradeable film of polybutenes [adipate co-terephthalate] blended with thermoplastic tapioca** Dr Raffi Paramawati, Indonesian Center for Agricultural Engineering and Research and Development (ICAERD), Indonesia

Day 2: Friday 22 September

Advances in research (continued)

Moderator:	*Dr Nuttha Thongchul, Institute of Biotechnology and Genetic Engineering, Chulalongkorn University*
09.00 - 09:30	**Polyhydroxyalkanoates (PHAs) and their production** Prof Gerhart Braunegg, University of Technology Graz, Austria
09.30 - 10:00	**Novel bio-based and biodegradable polyamide 4** Dr Sei-ichi Aiba, Group Leader, Bio-based Group, National Institute of Advanced Industrial Science and Technology (AIST), Japan
10.00 - 10:30	**Rheology and processing of bio-based copolymers and blends** Prof Graham M Harrison, Associate Professor, Department of Chemical Engineering, Clemson University, USA
10:30 - 10:45	*Break*
10:45 - 11:15	**Polyhydroxyalkanoates (PHAs), biodegradable plastic production, optimization and factors affecting PHA accumulation** Dr Songsri Kulpreecha, Department of Microbiology, Faculty of Science, Chulalongkorn University, Thailand

International standards and regulations

Moderator:	*Dr Nuttha Thongchul, Institute of Biotechnology and Genetic Engineering, Chulalongkorn University*
11:15 - 11:45	**Compostable plastic regulatory framework** Dr Glenn R Johnston, Manager-Global Regulatory Affairs, NatureWorks LLC, USA
11:45 - 12:15	**Biodegradability & compostability: what is the difference? Standards-impact on usage of biodegradable polymers** Bruno De Wilde, Organic Waste Systems NV, Gent, Belgium
12:15 - 13:30	*Lunch*

DOWNSTREAM APPLICATIONS, PRODUCTS AND MARKETS

Moderator:	*Dr Rath Pichyangkura, Faculty of Science, Chulalongkorn University*
13:30 - 14:00	**PURAC®: World class lactic acid products focussed towards PLA polymers** Arno van de Ven, PURAC Co Ltd, Netherlands
14:00 - 14:30	**Using bioplastics in electronic products in Japan, and developing high-performance PLA/kenaf composites** Dr Masatoshi Iji, Fundamental and Environment Research Laboratories, NEC Corporation, Japan
14:30 - 15:00	**Medical applications for bioabsorbable polymers** Prof Yoshito Ikada, Nara Medical University, and Dr Masakazu Suzuki, Research Centre, Gunze Limited, Japan
15:00 - 15:15	*Break*
15:15 - 15:45	**Biomass-based biodegradeable inks for packaging** Hideki Yasuda and Hideyuki Takeuchi, Toyo Ink Manufacturing Co., Ltd., Japan
15:45 - 16:15	**Injection moulding for bio-based synthetic materials** Dr Andreas Marek, Fraunhofer ICT, Germany
16:15 - 16:45	**Advances in compounding with bioplastics** Ikuo Okoshi, Material R&D Center, Riken Technos Corporation, Japan

Day 3: Saturday 23 September

DOWNSTREAM APPLICATIONS, PRODUCTS AND MARKETS (continued)

Moderator:	*Dr Patchanita Vatakul, Faculty of Science, Chulalongkorn University*
9:00 - 9:30	**Bioplastics in the automobile sector in Asia** Katsuhiko Nakajima, Manager, Advanced Materials Development Section, Toyota Motor Co., Japan
9:30 - 10:00	***BIONOLLE*: An approach to more environmentally-friendly green plastics** Dr Yasushi Ichikawa and Tatsuya Mizukoshi, Showa Highpolymer Co., Ltd., Japan
10:00 - 10:30	**Ecoflex and renewable materials** Dr Dietmar Heufel, Head of Global Business Management (Ecoflex / Ecovio / Styroflex), BASF AG, Germany
10:30 - 10:45	*Break*
10:45 - 11:15	**Recent developments in polylactic acid: TERRAMAC®** Dr Shigemitsu Murase, Terramac Business Development Department, Unitika Ltd, Japan
11:15 - 11:45	**Sony's vegetable-based plastics** Hiroyuki Mori, Environmental Affairs Department, Sony Corporation, Japan

Closing Ceremony

11:45 - 12:00 **Closing address**
H.E. Dr Pravich Rattanapian, Minister of Science and Technology, Thailand

Day 3: Saturday 23 September

Satellite Programme

MTEC- TU Graz Workshop On Development Of Environmentally Friendly Degradable Plastics From Renewable Resources In Thailand

Hosted by MTEC-UNIDO/ICS/NIA and TU Graz, Austria

09:00 - 09:20	**Introduction to environmentally degradable polymers** Dr Krisda Suchiva, MTEC, Thailand
09:00 - 09:50	**From renewable resources to products: definition of raw materials** Prof Gerhart Braunegg, TU Graz, Austria
09:50 - 10:20	**General problems of renewable based materials** Dr Michael Narodoslawsky, TU Graz, Austria
10:20 - 10:40	*Break*
10:40 - 11:10	**Basics of biotechnological production** Prof Gerhart Braunegg, TU Graz, Austria
11:10 - 11:40	**Life cycle analysis and assessment** Dr Michael Narodoslawsky, TU Graz, Austria
11:40 - 12:10	**Technical and economic aspects of cleaner production** Dr Hans Schnitzer, TU Graz
12:10 - 13:30	*Lunch*
13:30 - 14:00	**Process network optimization** Dr Michael Narodoslawsky, TU Graz, Austria
14:00 - 14:30	**EDPs in Brazil: a report** Prof Gerhart Braunegg, TU Graz, Austria
14:30 - 15:00	**Agro-based zero-emission systems** Dr Hans Schnitzer, TU Graz
15:00 - 15:20	*Break*
15:20 - 15:40	**Raw materials available in Thailand** Dr Pawadee Methacanon, MTEC
15:40 - 16:00	**Standard testing for polymer biodegradability in Thailand** Dr Thanawadee Leejarkpai, MTEC
16:00 - 17:00	**Discussion and conclusion**

The Role of Innovation in Addressing the Millennium Development Goals

Hiroshi Nishimiya
Deputy Regional Director, UNEP Regional Office for Asia and the Pacific
Email: nishimiya@un.org

Hiroshi Nishimiya obtained his BA in Forestry from Kyoto Prefectural University in 1978. After graduation, he joined the Nature Conservation Bureau of the Environment Agency, which has now become the Ministry of Environment. He was stationed at several national parks all over Japan until 1986 when he moved to the United Nations Bureau under the Ministry of Foreign Affairs. He served as First Secretary at the Embassy of Japan in Brazil for three years during 1992-1995.

In 1999, he was dispatched to Cambodia as an expert of Japan International Cooperation Agency (JICA) and worked as a Senior Advisor to the Minister of Environment for two years. He came back to Japan in 2001 when he became Director of the Environmental Partnership Office under the Ministry of the Environment.

From October 2005, he was seconded from the Japanese Government to serve as the Deputy Regional Director of the United Nations Environment Programme, Regional Office for Asia and the Pacific (UNEP ROAP) in Bangkok. His main focus is on sustainable consumption, cleaner production, 3R (Reduce, Reuse, and Recycle), and waste management.

UNEP's 23rd Governing Council meeting held in 2005 focused on three goals - MDG 1, 3, and 7. Goal 1, poverty and hunger, has become the central focus from Rio then on to the WSSD in 2002 and it is the basis of UNEP's motto. On Goal 3, gender and empowerment of women have some of the strongest links to environment in the delivery of the MDGs. Goal 7, environmental sustainability, is the foundation upon which achieving all the other MDGs must be built. MDG 7 calls upon countries to integrate the principles of sustainable development into national policies and programmes, and reverse the loss of environmental resources. This Goal 7 is the central niche for UNEP's work for the last 34 years.

To achieve MDG 7, rapid development of effort to counteract rapid changes in environment particularly in Asia, is needed. Much of the environmental change is attributed to unsustainable patterns of development that contribute to pollution problems. In Asia, the demand for primary energy doubles every 12 years. By 2010, Asia would require nearly 25 million barrels of oil per day. Over 70 percent of this is to be imported from other regions. The world oil reserves are depleting. At the current rate of consumption, oil would last for about 40 years, natural gas would last for about 56 years, and coal would last for about 197 years. Scientists predict that developing countries' economies will be squeezed after oil production declines by 2037. After this, meeting the energy demand will be a challenge for the developing countries in the region. Our forecast is that there will be a societal change from the petro-society to the bio-society and "Innovation" will play an important role to this change.

At present there have been several initiatives such as 3R, Circular Economy, and Green Growth that are being promoted in the region in order to support effective implementation of MDG. The role of innovation would be to develop new tools to support these initiatives, which would lead to achievement of goals defined under MDG.

3R: 3R has an aim to minimize waste by focusing primarily on "reduce," followed by "reuse" and then "recycle". **Circular Economy (CE):** CE focuses on resource-use efficiency, which integrates cleaner production and industrial ecology in a broader system encompassing industrial firms, networks or chains of firms, eco-industrial parks, and regional infrastructure to support resource optimization. **Green Growth**: "Green Growth" is a paradigm that focuses on reducing the increasing environmental pressure arising from economic growth, thus enabling economic growth to reduce the poverty of the current generation while maintaining the carrying capacity for future generations.

Global Review of Bioplastics Industry - Framework Conditions and Future Markets

J ran Reske
Vice Chairman, Regulatory & Environmental Affairs),
European Bioplastics, Berlin, Germany
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J ran Reske is currently Vice Chair of European Bioplastics, the association of the bioplastics industry in Europe, and carries responsibility for standardization, certification, legislation and environmental affairs. He chairs the certification committee for compostable plastic products at DIN CERTCO, and is a member of several standardization working groups at DIN, CEN, ASTM and ISO. He is also Project Manager for the waste management of compostable packaging at ISD Interseroh Dienstleistungs GmbH (Cologne, Germany)

Prior to joining European Bioplastics Dr Reske was from 1996 to 1998 Coordinator of the government-funded project “Development of the Legislative and Technical Framework for the Composting of Bioplastics”. From 1998 to 1999 he was engaged in product development at MAFO GmbH, a converter of bioplastics (PLA, Starch, PHA).

This contribution will give an overview over the key producers and some big users of bioplastics. Their motivation for the support of the innovation – with a focus on the question of resources - and their marketing approaches will be addressed. Consumers’ responses add to the picture. Several examples from European countries will be described, selected cases from Asia, Australia and the USA will complete the overview. Reference will be made also to some examples of legal support in single countries and in general to the legal and technical frameworks which have been developed in the different economic realms – pointing especially to the global cooperation concerning the certification of bioplastics.

Packaging and agricultural applications have been the most important markets for bioplastic products so far, whereas fibres or housings made from bioplastics are good examples for recently growing market shares. An outlook on opportunities and possible ways ahead will conclude this contribution.

Keywords: bioplastics, outlook, global markets

Thailand's Policies to Promote Bioplastics

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Arkhom Termpittayapaisith is Deputy Secretary-General at the National Economic and Social Development Board (NESDB). He also serves as its Chief Information Officer, and Chief Parliamentary and Liaison Officer (CPLO).

Prior to 2003 he served in a number of senior level roles at NESDB, including Assistant Secretary-General, Policy and Plan Analyst (Senior Expert in Planning), Director of the Economic Analysis and Projection Division, and Chief of the Technical Planning Section, Economic Analysis and Projection Division.

From 1979 to 1981 he served in the NESDB's Industrial Planning Section, Economic Projects Division, before moving in 1982 to the Input-Output Section, National Accounts Division.

Kh Arkhom served as Senior Executive at the Civil Servant Commission and has also played key roles in both private and public sectors, as follows:

- Secretariat to Cabinet's Screening Committee on Economic (2001-Present)
- Thailand's Delegate for IMF Article IV Consultation
- Joint Working Group for Annual Budget Formulation
- Economic Committee, Thai Chamber of Commerce (1998-Present)
- Export Tax Refund Committee, Ministry of Finance (1998-Present)
- Prime Minister Operation Center Committee (2002-Present)
- Board Member of Mass Rapid Transit Authority of Thailand (2002-Present)
- Board Member of TOT Corporation Public Company Limited (2002-Present)
- Board Member Adviser of Government Savings Bank (2002-Present)
- The Electricity Regulatory Board (2005-Presnet)
- AOT Board of Directors (2006-Present)

Kh Arkhom obtained his BA.in Economics from Thammasat University in 1977, and was awarded an MA.in Development Economics at Williams College, USA in 1983.

At present, the global plastic consumption is more than 200 million tons a year and is growing at a rate above 5%. Although plastic products are convenient and cheap, the fact that many of the applications are for the products with a single time use in a life-cycle of even as short as few minutes, resulting in tremendous litters everyday. In the past, the reclamation and recycling of the plastic waste under the standardization were proposed, the economically viability, however, obstructs the implementation. Combining the current situation of the crude oil price and the realization of the finite petroleum resources with this environmental issue, the biodegradable plastics have introduced their own opportunity as alternatives to petroleum-based plastics.

During the past decade, the successfulness of the biodegradable plastic technologies has motivated the rapid growth in the market. In EU, the shares of the specific biodegradable products such as packaging and agricultural films are remarkable and already reached one percent of the total plastic products. The current global production capacity for biodegradable materials is approximately 300,000 tons and it is estimated that total will be as high as 550,000 tons in 2008.

Thailand is a biomass-rich country where our production capacity of agricultural raw materials such as rice, cassava, and sugar cane is ranking at the top in the world market. In addition, value creation of agricultural products is one of conceptual development for the Tenth National Economic and Social Development Plan (2007-2010). The plastics industry and business of the country is another supportive factor to initiate the new wave biodegradable plastic industries as evidenced from its export value record of as high as US$1.5 billion in 2003. In addition, Thailand also has its own potential of the technology development as the universities and research institutes have started the researches in this field.

According to the global situation and Thailand's strengths, the National Economic Restructuring Subcommittee has endorsed the development of biodegradable plastic industry to be under the Industrial Economic Restructuring Project in order to promote this industry intensively. The ultimate goal in the next 15 years is that Thailand will be one of the regional principal leaders in the biodegradable plastic industry. To achieve the goal, Thailand is placing its policies to promote the initial phase in the first 5 years with the "National Roadmap of the Development of Biodegradable plastics Industry" starting from 2007 to achieve related technologies, industries, investment and market share, which will lead to the business models for over 5,000 million baht economic value.

The Roadmap proposes the concrete strategies on 1. Sufficient supply of raw materials. 2. Development and invention of technology, 3. Innovation of industry and business. 4. Establishment of supportive infrastructure. With the integrated actions and cooperation of government private sectors and academy, the biodegradable plastic industry is prospected to be one of the strengthen new wave industries and businesses in the next five years in Thailand.

Keywords: bioplastics policy, Thailand, national plan

Bioplastics – from Research to Market

Ramani Narayan
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Email: narayan@msu.edu

Ramani Narayan is professor of chemical and biochemical engineering at the Department of Chemical Engineering and Materials Science at Michigan State University in East Lansing, Mich., a position he has held since 1990.

In addition to his professorship at Michigan State, Narayan served as director of the Biomaterials Program at MBI International and as MBI distinguished professor of chemical and biochemical engineering. His first academic appointment was as group leader and research professor of the Renewable Resources Engineering Laboratory at Purdue University. He holds a Ph.D. in organic chemistry (biopolymers) from Bombay University.

Since 1989, Narayan has been an active member of ASTM Committee D20 on Plastics, receiving the committee's William N Findley and Outstanding Achievement Awards. He is the current chairman of subcommittees D20.92 on Terminology and D20.96 on Degradable Plastics and Biobased Products. He serves as US technical expert and representative to the Working Group on Degradable Plastics of International Organization for Standardization (ISO) Technical Committee 61 on Plastics, and convener of Working Group 1, Subcommittee 1 on Terminology. He is also a member of ASTM Committees D10 on Packaging and E02 on Terminology.

In addition to ASTM International, Narayan is a member of the American Chemical Society, the American Institute of Chemical Engineers, the Society of Plastic Engineers, and the American Society of Engineering Educators.

Bioplastics based on annually renewable agricultural and biomass feedstocks can form the basis for a portfolio of sustainable products that is an environmentally preferable, green alternative to current materials based exclusively on petroleum feedstocks. These bioplastic materials offer value in the sustainability/life-cycle equation by being part of the biological carbon cycle, especially as it relates to carbon-based polymeric materials. This global carbon cycle vis-à-vis managing carbon efficiently and in an environmentally responsible manner will be discussed. Identification and quantification of biobased content uses radioactive C-14 signature and forms the basis for the mandated procurement of biobased products by the US Government. Biopolymers are generally capable of being utilized by living matter (biodegraded), and so can be disposed in safe and ecologically sound ways through disposal processes (waste management) like composting, soil application, and biological wastewater treatment. Single use, short-life, disposable products can be engineered to be biobased and biodegradable. The need for such products to be fully biodegradable in a defined time frame in the selected disposal infrastructure as opposed to degradable or partially biodegradable will be reviewed. Metrics and Standards for measuring biodegradability and biobased content will be presented.

Two basic routes are possible for the manufacture of biobased and biodegradable plastics. Direct extraction from biomass yields a series of natural polymer materials cellulose, starch, fibers, and vegetable oils that form the platform on which polymer materials and products can be developed. Alternatively, the renewable resources/biomass feedstock can be hydrolyzed to bio-monomers, which can be transformed by fermentation or chemical or hybrid processes to polymer materials, for example biomonomers can be microbially transformed to biopolymers like the polyhydroxyalkanoates or fermented to lactic acid and then polymerized to poly(lactic acid). Surfactants, detergents, adhesives, and water-soluble polymers can be engineered from biomass feedstocks. Vegetable oils provide a platform for chemical transformation to lubricants, polyesters, urethane foams, unsaturated polyester resin composites etc.

In this presentation, we review all the above new developments and rationale in designing and engineering bioplastics.

Keywords: bioplastics, standards, biodegradability, synthesis, design

Bioplastics Research in Thailand

Krisda Suchiva

Deputy Director, National Metal and Materials Technology Center (MTEC), Thailand

Krisda Suchiva is the Deputy Director of the National Metal and Materials Technology Center (MTEC). He directs research programmes in polymers and biomedical materials, including biodegradable polymers (BPs), at MTEC.

He has been working in collaboration with ICS-UNIDO on environmentally degradable plastics (EDPs) since 2001, trying to promote EDPs or bioplastics in Thailand. His interests include the production of bioplastics in Thailand based on cassava starch. Dr Krisda is also the President of the Polymer Society (Thailand).

ABSTRACT NOT AVAILABLE

Recent Development of Biodegradable and Biomass-Based Plastics in Japan

(New Identification and Labeling System for Biomass-Based Plastic Products by BPS)

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Isao Inomata obtained his Masters degree in engineering, specializing in industrial chemistry in 1969 at Tokyo University of Tokyo, Japan. After that he worked during 29 years at Mitsubishi Chemical Corp. mainly in planning and business development of various petrochemical products. From 1989 tot 2006 he worked in Mitsubishi Plastics,0Inc., responsible for business development work of polylactic acid film and sheets.

From April 1st 2006 Isao Inomata has worked as an Adviser to the Biodegradable Plastics Society of Japan.

The Biodegradable Plastics Society, Japan (BPS) was established in 1989 and, with more than 200 company members, has been making efforts to promote the recognition and the business development of Biodegradable Plastics products in Japan. BPS started the "GreenPla Identification and Labeling system" from 2000 and we have already certified about 800 biodegradable plastics products in Japan.

Because of the recent big pressure to address the global warming phenomena as mentioned in the Kyoto Protocol, many companies from various business sectors in Japan pay strong concern about the Biomass-based Plastics as the key material to establish the sustainable society in future. Especially because of recent rapid improvement of the technology how to utilize the biomass-based plastics in various application along with the constant price increase of raw material crude oil for plastics, many companies see the possibility to utilize that as the replacement of petroleum-based plastics.

The Biodegradable plastics Society (BPS) recognizes these movements clearly and started to promote the recognition and the business development of the biomass-based plastics in addition to Biodegradable plastics from 2003. From July 1st 2006 BPS started "BiomassPla" Identification and Labeling System for Biomass-based Plastic Product.

We examined the criteria for certifying biomass-based plastics products, and we defined a minimum biomass-based ratio requirement for the "BiomassPla" mark labeling in the biomass-based plastic products at min. 25 wt%.

Keywords: *GreenPla*, *BiomassPla*, bioplastics, labelling standards, certification

Neo-PLA as High-Performance Bio-Based Polymers

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Yoshiharu Kimura took his PhD. degree from Kyoto University in 1976. After doing postdoctoral work at the University of Iowa, he was appointed Assistant Professor of Fiber Chemistry at Kyoto Institute of Technology (KIT) in 1981. He became an Associate Professor of Polymer Science and Engineering in 1985, and Professor in 1990. He is now holding two additional posts of director at R&D Center for Biobased Materials and Center for Fiber and Textile Science of KIT. In 1998, he received the Award of the Society of Fiber Science and Technology, Japan for his research activity related with fiber science.

He has been working on biodegradable polymers for more than 25 years and is now admitted as a pioneer of the field. His current research is mainly related with new polymer systems utilizing polylactides and their copolymers. His research interests also include biomedical applications of biodegradable polymers and development of inorganic polymers. He has published more than 200 papers and has been the author or co-author of 20 books. He is currently a member of the International Advisory Board of “Macromolecular Bioscience” and an associate editor of “Polymer International”.

He also serves as a vice director of Advanced Software Technology & Mechatronics Research Institute of Kyoto (ASTEM RI) to encourage the university-industry cooperative research activities in various technological fields.

The polymers having developed as biodegradable polymers are now divided into three categories: (1) bioabsorbable polymers for biomedical use, (2) biodegradable plastics that can be assimilated in natural environment, and (3) bio-based polymers synthesized from renewable natural resources. Polymeric materials falling into the third category are convinced to be superior to the conventional petroleum-based polymers in reducing the emission of carbon dioxide into the global environment. It is therefore less important whether the bio-based polymers should be bio-degradable or not, although many of them ought to show biodegradable nature. This may be because the structural requirements both for biodegradable polymers and bio-based polymers are quite common in the principal aspect. Namely, the both polymers are preferably made up of natural products so that their starting materials can be derived from atmospheric carbon dioxide in a sustainable manner and their breakdown products can easily be metabolized by microorganisms.

Among the bio-based, biodegradable polymers, poly(L-lactide) (PLLA) has been paid an immediate attention. It can be synthesized by polymerization of a metabolite, L-lactic acid that can be manufactured by fermentation. Although PLLA exhibits a broad range of physico-chemical properties, its thermal and mechanical properties are not sufficient for use as ordinary structural materials. For improving these inferior properties, a stereocomplex form consisting of PLLA and its enantiomer poly(D-lactide) (PDLA) has high potential because of showing high melting nature (230 °C). It can be formed by simple polymer blend of PLLA and PDLA or more easily with stereoblock polylactides (sb-PLA) which are PLLA/PDLA block copolymers. These novel PLA polymers with high performance are named as "*Neo-PLA*". They can provide a wide range of properties that have never be attained with single PLLA, whilst retaining the sustainability or bio-based nature for which both monomers L- and D-lactic acids are manufactured from starch by fermentation.

Key words: Neo-PLA, biodegradeable, polymers, polylactide, bioabsorbable

Surface Modification of PLA and PHA Films Using Photochemistry

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Doug Hirt is currently Associate Professor of Chemical and Biomolecular Engineering at Clemson University. He received his BS (1982) and MS (1984) degrees in chemical engineering from Virginia Tech and his PhD in chemical engineering from Princeton University in 1989. From 1989-90, he held a position as a National Academy of Sciences/National Research Council Research Associate at NASA's Langley Research Center working in the area of polymer composites. He then began his teaching career at Clemson in 1990.

For the past 12 years, Doug has conducted research in the area of surface modification of polymer films and is currently Deputy Director of Clemson's NSF Engineering Research Center for Advanced Engineering Fibers and Films.

PLA and PHA are two very promising biomaterials being extensively used in medical and pharmaceutical fields. However, their hydrophobic surfaces limit their use in many biomedical applications. We used UV-assisted photografting in ethanol to grow hydrophilic polymers (e.g., poly(acrylic acid) and polyacrylamide) from the surfaces of PLA, PHA, and PLA/PHA blend films. The modified surfaces were characterized using water contact angle goniometry and ATR-FTIR spectroscopy, while toughness, Young's modulus, % elongation at break, % crystallinity, and tensile strength of unmodified and surface-modified films were also studied.

The penetration of monomers into the bulk of the surface-modified films was characterized using FTIR microspectroscopy. Microtomed sections of the surface modified films were placed in a diamond compression cell to perform the FTIR microspectroscopic analyses. Significant monomer penetration into the bulk of the surface modified films was observed, and certain mechanical properties were affected. The photografting was then conducted in water instead of ethanol and demonstrated favorable surface properties (enhanced wettability) without significantly affecting the bulk properties.

Key words: PLA, PHA, photochemistry, photografting, biopolymers

Effect of Maleic Anhydride on Biodegradable Film of Poly Butylenes [Adipate-co-Terephthalate] Blended with Thermoplastic Tapioca

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Raffi Paramawati is a senior researcher at the Indonesian Center for Agricultural Engineering Research and Development (ICAERD) – Indonesian Agency for Agricultural Research and Development (IAARD), Ministry of Agriculture (MOA).

Dr Paramawati received her BS degree in agricultural technology at the University of Gadjah Mada, Yogyakarta, in 1981, and an MSc in post-harvest technology at Bogor University of Agriculture, 1998. She continued her research at Bogor and was awarded a PhD in food science and technology in 2001.

She was made a UNU-Kirin Research Fellow at the National Food Research Institute (NFRI), Tsukuba, Japan, from 1999-2000, before entering the postdoctoral research program at Michigan State University (MSU), East Lansing – USA, from 2005-200. 6Her research Interests include biobased-biodegradable packaging, technology-based food safety, and horticulture process engineering.

Specific research topics include synthesis of PLA derived from indigenous starch waste to produce environmentally friendly packaging; biodegradable film packaging made of zein by biopolymer formation, and extension of shelf life of minimally processed-edible coated salacca finger stored in modified atmosphere at low temperature.

This study focuses on the effect of maleic anhydride (MA) on the functional properties of films made from polybutylene adipate-co-terephthalate (PBAT) blended with maleated thermoplastic starch (MTPS) of tapioca. Tapioca was plasticized with 30% glycerol by reactive extrusion process and added with 2, 3 and 4 % MA to form MTPS. Grafting ability was determined by soxhlet extraction method, and thermal analysis was measured by differential scanning calorimeter (DSC). MA has played an important role to initiate grafting between two polymers. Amount of 30%

of MTPS was grafted onto 70% PBAT and cast by single extruder casting machine to form films. Mechanical and barrier properties as well as surface image of films were investigated. The mechanical behavior of PBAT-MTPS graft films were compared to that of PBAT film without any additives. PBAT-MTPS graft copolymer displayed higher elongation and young modulus values than PBAT film but achieved slightly lower tensile strength values. The effect of maleic anhydride on barrier properties and surface image are also demonstrated.

Key words: biodegadable film, maleic anhydride, polybutylenes [Adipate-co-terephthalate], tapioca

Polyhydroxyalkanoates (PHA) and Their Production

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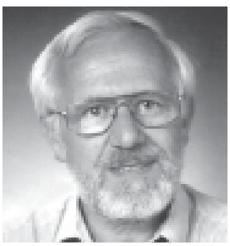

Gerhart Braunegg is a world-renowned authority on fermentation technology involving prokaryotic and eukaryotic microorganisms in aerobic and anaerobic processes, process design and process development. He has 25 years of experience in the field of environmentally degradable plastics, particularly in fermentation technology for plant cell cultures, and production of fine chemicals from renewable resources. Since Sept 1985, he has led the working group Applied Physiology working group at the Institute of Biotechnology, Graz University of Technology

Prof Braunegg is a member of the Senate of Graz University of Technology.

He is also a member of the international expert team “Environmentally Degradable Polymers and Plastics”, ICS-UNIDO, Trieste, Italy, and holds a seat on the Executive Board of the European Society of Environmentally Degradable Polymers.

He is an invited Professor at Ecole Polytechnique Montr al, Canada, Dept. G nie Chimique and has produced over 260 written and oral publications and peer-reviewed academic papers. Prof. Braunegg was awarded the Prize of the Styrian Provincial Government for Safe Technical Utilization of Meat/Bone Meal in 2001.

Since the year 2000 the price for mineral oil has more than doubled, and the price per barrel is now near to 70$ US. In the same time world production and consumption of polymeric materials from mineral oils has exceeded 200 million tons per year, and is still rising. On this background production of polymers via “White Biotechnology” based on renewable substrates is of increasing interest. By such technologies as well diols as dicarboxylic acids can be produced, that later on can be converted to polyesters, or polymers can be produced directly with the help of numerous microorganisms.

Polyhydroxyalkanoates (PHAs) are biodegradable polyesters that are stored intracellular when growth of the producing bacteria is limited by essential nutritional compounds like the nitrogen or phosphate source of the medium. Under such conditions PHA content in the cells can increase to more than 80% of the cell dry weight formed, and the quality of the polyesters formed can be influenced by feeding precursors for synthesis of copolyesters or terpolyesters.. A drawback for this development is the fact that PHAs are still more expensive than conventional plastics. Biotechnological polymer production occurs in aerobic processes, therefore only about 50% of the main carbon sources, and even a lower percentage of the precursors used for production of co-polyesters end up in the products wanted. To overcome this problem, cheap carbon and nitrogen sources for microbial growth and PHA synthesis are needed to lower the production costs. Such sources are available as agricultural waste and surplus materials, like glycerol liquid phase (GLP) from the biodiesel production process used as a cheap carbon source, or meat and bone meal used as nitrogen source after hydrolysis.

Both cheap carbon and cheap nitrogen sources are available from agricultural waste and surplus materials, and make a substantial contribution for minimizing PHA production costs. In tropical countries a variety of different carbon sources (e.g. molasses, starch, and palm oil) is available in high quantities for sustainable process development. For biopolymer production in Europe, and possibly as well in the USA, the situation differs due to the rather restricted availability of defined cheap carbon sources. Here, beside raw glycerol (GLP), substrates like cheese-whey or hydrolyzate of cellulose, might be of interest.

According to the results of our work, the biotechnological utilization of agricultural surplus products, whey and GLP, as cheap carbon sources for production of the high price product PHA is possible. Together with the application of hydrolyzed meat and bone meal that has been proved by the authors to be a suitable complex nitrogen- and phosphorus source, production costs can be minimized considerably. Because of totally different molecular masses depending on the substrate (high M*w* on whey hexoses, low M*w* on GLP), a broad spectrum of biopolyesters with different properties are available starting from surplus products as raw materials. The production of 3-hydroxyvalerate 3-HV in a constant amount from both cheap substrates makes the process economically even more interesting and improve the product qualities.

Based on the kinetics of microbial growth and product formation determined in fermentation experiments, processes for industrial PHA production can be developed and optimized. Examples for process development from different raw materials will be shown and discussed.

Keywords: polyhydroxyalkanoates, production

Novel Bio-Based and Biodegradable Polyamide 4

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Sei-ichi Aiba graduated in 1976 from the department of Industrial Chemistry, Faculty of Engineering, Tokyo University of Agriculture and Technology, Japan. He obtained his MS in 1978 and in 1994 was awarded a PhD from Tokyo University of Agriculture and Technology, Japan for a thesis entitled "Characterization of chitosan and its application to functional materials"

From 1978-2001 he held the post of Research Chemist at the Agency of Industrial Science and Technology, Japan, he joined the National Institute of Advanced Industrial Science and Technology (AIST), Japan. Dr Aiba has since specialized in research into bio-based and biodegradable polymers. He is also an authority on chitin and chitosan, its chemical modification, enzymatic hydrolysis, and application to functional materials and bioactive compounds.

He is the author or co-author of more than 50 scientific articles.

In general polyamides (nylon) have excellent thermal and mechanical properties but it is known to be non-biodegradable in the natural environment. One of polyamides, polyamide 4, is a linear polymer of ã-aminobutyric acid (GABA). It has also excellent properties based on its high melting point (265°C). Unlike other polyamides, it can be biodegraded in activated sludge as we reported. From these properties, polyamide 4 becomes a new attractive biodegradable material. Furthermore polyamide 4 has the possibility as a novel bio-based polymer because it is synthesized from 2-pyrrolidone, a lactam of GABA, and GABA can be made from glutamate. A glutamate fermentation system using biomass has been already developed. Our objective is development of a new recycling system of novel bio-based and biodegradable polyamide 4.

In this study, we report the following subjects; (1) Syntheses of a series of polyamide 4 with branched structures in order to improve their properties. The branched polyamide 4 has high tensile strength. (2) Isolation of polyamide 4 degrading bacteria from activated sludge. These were identified as Pseudomonas sp. strain ND-10 and 11. From the detection of GABA as an intermediate product it was suggested that the bacteria degraded polyamide 4 by hydrolysis of amide bonds. (3) Development of glutamate decarboxylase (GAD) derived from *Archaea, Pyrococcus horikoshii*. We cloned the GAD gene and prepared recombinant GAD in E.coli. It catalyzes the decarboxylation reaction of glutamate to produce GABA at high temperature (>95°C).

Keywords: polyamide, biodegradeable, bio-based, GABA, *pseudomonas*

Rheology and Processing of Bio-Based Copolymers and Blends

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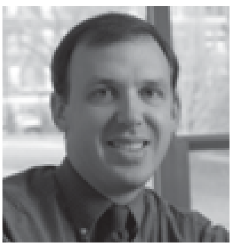

Graham Harrison is an Associate Professor in the Department of Chemical and Biomolecular Engineering at Clemson University in South Carolina, USA. He earned a PhD in 1997 from UCSB and performed post-doctoral work at the University of Melbourne. His research interests include bio-based polymers, extensional rheology, and film casting.

Bio-derived polymers show great promise for a wide range of commodity polymer applications. These polymers come from renewable feedstocks, can demonstrate similar mechanical properties to existing materials, and can offer opportunities for degradation after use. Two specific materials that are available are poly(lactic acid) (PLA) and the polyhydroxyalkanoate (PHA) family of co-polymers. In this work, we investigate the shear and extensional flow behaviors of these bio-derived polymers. In addition to the pure polymers, two PHA-PLA blends (10 & 20% PHA by mass) are studied. Dynamic oscillatory experiments were performed on the four materials at typical processing temperatures. Extensional viscosity measurements were made at strain rates up to 10 s^{-1}. The extensional viscosity of the PHA reaches a plateau value consistent with Trouton's Rule, where as PLA demonstrates strain-hardening behavior. The PHA-PLA blends are strain-hardening. Based upon the pure polymer results, both the shear and elongational rheology were fitted to power law models for polymer blend rheology, with consistent parameters observed in both geometries. The degradation of the materials, at typical processing conditions, is also investigated. The degradation kinetics are obtained from transient rheological tests coupled with a random chain scission model. Based upon the rheological results, formulations for fiber and film formation are determined. Mechanical testing is performed on the processed materials.

Key words: rheology, biopolymers, blends, PHA, PLA

Polyhydroxyalkanoates (PHAs): Production, Optimization and Factors Affecting PHA Accumulation

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Songsri Kulpreecha obtained her BSc (Hons) degree in Botany and MSc degree in Microbiology from Chulalongkorn University, Thailand.

In 1980, she attended a one year UNESCO training course in the field of Microbiology and Biotechnology in Japan. She received a Dr Eng degree in Fermentation Technology in 1986 from Osaka University, Japan.

Since returning to Thailand, Dr Songsri has conducted her research at the Department of Microbiology, Faculty of Science, Chulalongkorn University. Her research interest is microbial technology related to production of useful metabolites from microorganisms. She is the author and co-author of more than 30 scientific articles.

Since 1990 she has been actively conducting research on microbial production of PHAs, biodegradable plastics, and other aspects that aim at the economic feasibility and development of biopolymers for downstream applications.

PHAs are synthesized and intracellularly accumulated in bacterial cells as storage materials under unbalanced growth condition. Strategies are being developed to achieve conditions for efficient production of PHAs. Several factors need to be considered in the optimization of PHAs production e.g. using renewable resources as medium component, culture condition and cultivation method. *Ralstonia eutropha* and *Bacillus megaterium* were selected for our research work. Some physical and mechanical properties of the PHAs films produced by *R.eutropha* and *B. megaterium* were examined.

Keywords: PHAs, production, optimization, *Ralstonia eutropha*, *Bacillus megaterium*

Compostable Plastic Regulatory Framework

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Glenn Johnston is Manager - Global Regulatory Affairs for NatureWorks LLC, and has over 18 years of experience in the global regulatory arena. He has extensive experience with food contact legislation (FDA, EU, JHOSPA, KFDA, MERCOSUR, etc), chemical legislation (TSCA, EINECS, DSL, METI, KCL, and AICS), and composting legislation (Green PLA, BPS, DIN CERTCO, BPI, and ABA).

Glenn manages product stewardship issues, integrating it with global influences regarding toxicology, environmental, and safety. He has worked with industry groups in Japan (JHOSPA), Taiwan (EBPA), U.S. (BPI) and EU (IBAW). Glenn currently sits on the executive board of the Society of Plastics and Industry Food, Drug, and Cosmetic Packaging Materials Committee (FDCPMC), SPI Materials Supplier Council, and is a delegate to ISO TC61, member of ASTM D20, and delegate to CEN TC249. He has published papers and given speeches on biodegradable polymers and their regulatory framework throughout the globe.

With any new packaging entering the global marketplace, requirements and standards abound. With the advent of biodegradable and compostable packaging, new avenues for landfill diversion exist for plastic packaging. No longer are physical recycling and thermal recycling your only options. The avenue of organic recycling is now open for business for compostable plastics. The question remains, how high are the barriers?

Any plastics end-of-life regulation should not impede the successful commercialization of new materials and materials technologies that offer significant sustainability benefits. As a general principle, regulation and legislation of plastics materials designed to address issues of biobased and biodegradable materials now emergent in the marketplace should not allow the “perfect” to be the enemy of the “good.”

This talk will attempt to address some of the definition confusion in the marketplace over biodegradable packaging. Then I will give an overview on some of the regulatory hurdles facing biodegradable packaging across the globe.

As with any regulatory approach, many routes lead to the same successful ending. Hopefully I will arm you with knowledge to make your path a success.

Key words: biodegradeable, plastic, compostable, recycling, regulation

Biodegradability & Compostability: What is the Difference? Standards - Impact on Usage of Biodegradable Polymers

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Bruno De Wilde obtained a MSc degree in agricultural engineering with a specialisation in Biotechnology in 1983 at the State University of Gent in Belgium. After that he worked during 1 year at the Laboratory of Microbial Ecology of the same university. From 1985 tot 1989 he was employed in an R&D project on rural energy through biogas production in Indonesia.

From June 1st 1989 Bruno De Wilde works at Organic Waste Systems in Gent, Belgium where he is the manager of the laboratory for biodegradation, composting and digestion testing and consulting. He is the author or co-author of about 30 scientific articles.

Mr De Wilde has for many years been actively involved in several standardisation committees such as ISO, CEN and DIN in the field of biodegradable and compostable materials.

Although various standardization working groups have been laboring for many years on the issues of biodegradability and compostability, some people often are still confused about what these terms really entail. Yet, the European norm EN 13432 as well as the comparable ASTM specifications D6400 and D6868 have strict procedures with clear criteria and have been used successfully for several years now. Based on this experience an ISO norm is in development.

This presentation starts with a discussion on the European norm EN 13432 on compostability of packaging. Compostable materials must meet certain requirements with regard to composition (mainly heavy metal limits). Full biodegradation is required within a period of 6 months. Also disintegration must be achieved according to strict limits for a test material at a maximum thickness (more than 90% of input material must pass 2 mm). Finally, compost quality is evaluated via physical-chemical analyses and plant toxicity tests. The various requirements are discussed in detail.

Further, a description is given of systems how this norm is put into practice (certification and logos); experiences obtained after 5 years of usage of this norm in various European countries; future outlook; a comparison with similar norms in North America and Japan and the situation regarding a globally, unanimously accepted (ISO) norm. The first part of the presentation ends with an overview of the acceptance of biodegradable packaging in industrial composting plants in various countries.

In a second part of the presentation other environments of disposal and use will be discussed. First of all, degradability in soil for products such as mulching film and body bags. Which tests should be used? What are the requirements for acceptance? What is the situation concerning standardization? Also the French AFNOR norm on biodegradability of mulching film will be presented. Further, also degradation in home composting conditions will be touched upon as well as requirements for degradability of plastics in water and the status of a norm on flushable products.

Key words: polymers, biodegradeable, compostable, standardization

PURAC : World-Class Lactic Acid Products Focused toward PLA Polymers

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Arno van de Ven joined PURAC in April 2006 as global director of the chemical and pharma business. He is has global responsibility for PLA.

Mr de Ven has extensive experience in a wide range of technical markets. He was global business manager at DSM Engineering Plastics for a number of years. He subsequently joined BF Goodrich as VP/GM of its Specialty Plastics Group. Most recently Mr de Ven worked for Ferro Corporation in the United States as global director of its additives division.

PURAC started lactic acid production about 70 years ago, and is currently building its 5th lactic acid plant in Thailand. Although lactic acid is already known since the times of Cleopatra, the industrial scale production of this versatile compound has only materialized over the last 50 years. Due to the developments in the bio-plastics PLA market the growth of lactic acid use is expected to accelerate in the coming years. In order to capitalize on this growth-opportunity there is a need to create focused production of lactic acid for PLA manufacturing.

For cost-effective production of PLA, the efficient conversion of carbohydrates into lactic acid and the efficient conversion of (purified) lactic acid into lactide are the most critical steps. Know-how of fermentation and purification processes is critical, while knowledge of the effects of critical impurities on the yield of lactide formation is also required for efficient conversion. Once a good quality lactide is available, the conversion to PLA is extremely efficient.

In order to allow for a full range of PLA grades and properties, not only PLLA, but also PDLA polymers are needed. Combinations of PLLA and PDLA can provide improved heat-resistance. Due to the extensive experience in lactic acid manufacturing PURAC is in a unique position to produce focused grades of L(+) and D(-) lactic acid.

PURAC is committed to making PLA a success through partnerships. This paper presents the state of the art lactic acid technology relative to industry standards, while also elaborating on a number of critical issues in the development of a healthy PLA industry.

Key words: lactic acid, PLA, bioplastics, biotechnology, fermentation

Highly Functional Bioplastics (PLA Composites) Used for Electronic Products

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Masatoshi Iji is a Research Fellow (Dr Eng) at the Fundamental and Environment Research Laboratories, NEC Corporation, Tsukuba, Japan. He completed his Masters degree at the Department of Environmental Chemistry and Engineering of Tokyo Institute of Technology (1980). He was awarded a Masters degree in 1980, and obtained his Doctorate in 2002.

In 1980 he joined Denki Kagaku Kogyo KK (Japan) and developed plastics used in electronic components in the central research laboratories.

In 1990, he joined NEC Cor and has been responsible to researching and developing environmental friendly plastics in the fundamental and environmental research laboratories. The plastics include safe flame-retarding plastics with no use of toxic flame retardants and biomass-based plastics, which are used in electronic products.

Dr Iji is the author or co-author of over 60 scientific and technical articles. He has received seven awards, including Researcher Award from the Japanese Ministry of Education, Culture, Sport, and Technology (2002) and the Outstanding Technical Paper Award of the IEMT/IMC Symposium (1999).

We have developed highly functional PLA composites used for electronic products to improve their environmental friendliness and provide them with0new valuable functions.

A heat resistant PLA compound containing the fiber of kenaf, which effectively fixates CO2, and other safe additives mainly made with biomass has been developed (the biomass content in the resin part: 90%). The PLA composite shows high heat resistance (HDT: 100 °C /1.8MPa), high impact strength (8KJ/m^2) and good moldability. We practically finished it in collaboration with Unitika LTD. and have started to use it in housing of a cellular phone from May 2006. To expand its use in various electronic products, we have developed a flame-retarding PLA with a special metal hydroxide as a safe flame retardant and will start to use it in housings of personal computers in 2007.

Furthermore, we have basically developed an intelligent PLA performing rewritable shape memory by introducing a thermo-reversible bond into the PLA structure to apply it to future electronic products. The bond, based on the Diels-Alder reaction, provides the PLA with excellent shape memory owning to its cross-linked structure below the bond-coupling temperature (100 °C). This enables it to be recycled by its melting form above the bond-decoupling temperature (150 °C). The PLA composite can be used to create free-style (wearable) mobile products, shapes of which users can reform easily.

NEC will replace petroleum- resourced plastics in their electronic products to these bioplastics more than 10% until 2010.

Key words: PLA, composite, kenaf, thermo-reversible, heat-resistant, electronic

Medical Applications for Bioabsorbable Polymers

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Yoshito Ikada graduated from the Faculty of Engineering, Kyoto University with BS (1958), MS (1960), and PhD degrees (Dr Eng) (1963) in polymer chemistry, and also received a PhD degree (Dr Med) (1984) from Kyoto University Medical School.

His numerous academic posts include Associate Professor of the Institute for Chemical Research, Kyoto University (1977-1981), Professor at the Research Center for Medical Polymers and Biomaterials, Kyoto University (1981-1990) and Director of the Center (1988-1990). From 1998 to 1999 he was Professor of the Institute for Frontier Medical Sciences, Kyoto University, and since 1999 has held the posts of Emeritus Professor of Kyoto University, Professor at the Faculty of Medical Engineering, Suzuka University of Medical Science, and Professor of the Department of Indoor Environmental Medicine, Nara Medical University.

He was awarded the Prize of the Japanese Society for Biomaterials in 1988 and was President of the Japanese Society for Biomaterials (1992-1996). Prof Ikada was Chairman of the National Project on Tissue Engineering implemented by the Japan Society for the Promotion of Science (JSPS) (1996- 2002).

Prof Ikada has published widely and is author of a number of authoritative works on polymers At the Nara Medical University, Japan, Prof. Ikada is interested in the surface chemistry of polymers, hydrogels, biocompatibility, medical devices, artificial organs, surgical applications of biodegradable materials, tissue engineering, and polymeric drug delivery systems.

Masakazu Suzuki graduated from the Faculty of Engineering, Kyoto University with BS (1979), MS (1981), and PhD degrees (Dr Eng) (1986) in polymer chemistry, Kyoto University.

In 1985 he joined Gunze Limited as a Researcher, and is now Corporate Officer and General Manager of the R&D Center.

Dr Suzuki is currently interested in medical devices, artificial organs, surgical applications of biodegradable materials, tissue engineering, biosensors, and healthy foods.

A wide variety of biodegradable polymers have been developed for use as absorbable medical devices in the past three decades, among them are polyglycolide (PGA) and polylactide (PLA). In addition, biodegradable polymers have become the focus of interest to concerns about accumulation of non-biodegradable plastics in the environment in recent years. This is a new generation of biodegradable polymers called bioplastics, green plastics, of environment-friendly plastics, whose components are derived entirely or almost entirely from renewable raw materials. These plastics can be made from abundant agricultural resources. They preserve non-renewable resources (petroleum, natural gas, and coal) and contribute little to the already burdensome problems of waste management.

This presentation does not focus on the bioplastics, but on absorbable polymers for medical user. In biomedical technology, biodegradable polymers are well established for use as absorbable sutures, wound dressing, fractured bone fixation devices, and drug delivery carriers. Current attention of biomedical investigators has been directed to the application of biodegradable polymers to the tissue engineering that aims at creating new biological tissues from patients' cells for repair of lost or devastated tissues and organs. The tissue engineering needs scaffolds that assist proliferation, differentiation and biosynthesis of cells. To fulfill the functions of a scaffold in the tissue engineering, the scaffold should be biodegradable, so that it does not disturb the tissue regeneration from the cells seeded onto the porous scaffold.

This lecture will present recent advances in biomedical applications of biodegradable polymers, especially in the field of tissue engineering.

Keywords: bioabsorbable polymers, polyglycolide, polylactide, biomedical, tissue engineering

Introduction of Toyo Ink Biomass-Based Products

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Hideki Yasuda obtained a bachelor's degree in materials science and engineering in 1990 at Shibaura Institute of Technology.

Hideki Yasuda joined Toyo Ink Manufacturing Co Ltd in Japan in 1990 where he was mainly involved in development of Gravure and Flexo ink for food packaging application and its acrylic and urethane resin.

At present Hideki Yasuda is the manager of the R&D division for development of biomass-ink. He is also in charge of developing solvent-based laminate ink and its urethane resin including water-based system.

Toyo Ink will introduce our biomass-based products 'NEXT' series and its performance.

NEXT GC is a cornstarch-based gravure ink. BD200 NEXT GC is a laminate ink with good adhesion and laminate properties for a variety of biodegradable substances. BD100 NEXT GC is a surface printing ink with good rub-proof and heat-seal resistance.

NEXT GP is a polylactic acid-based gravure ink. EB008 NEXT GP has good adhesion and laminate properties on a variety of biodegradable substances.

NEXT AD-P is a polylactic acid-based laminate adhesive. NEXT AD-P has good laminate bond strength on biodegradable substances and sealant.

NEXT OP-P is polylactic acid-based OP varnish. NEXT OP-C is cornstarch-based OP varnish. NEXT OP-P and NEXT OP-C have good gloss, rub proof and adhesion on variety of biodegradable substances.

NEXT HS-P is polylactic acid-based heat seal varnish. NEXT HS-P has good heat seal strength on biodegradable substances and sealant. NEXT GP, NEXT HS-P and NEXT OP-P were developed by a joint research programme between Toppan Printing Co., Ltd., Toyobo Co., Ltd. and Toyo Ink.

Keywords: biodegradeable ink

Injection Moulding of Bio-Based Synthetic Materials

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Andreas Marek is the manager of the Fraunhofer project group "sustainable mobility", which was newly founded in 2003 and has been involved with bioplastics since 1998.

He is currently responsible for leading projects in the field of processing properties, technical characterisation and recycling of biodegradable materials and those based on renewable raw materials. Research into natural fibre-reinforced plastics adds to his expertise and is another important area of his responsibility.

Andreas has published several scientific papers and given speeches in Europe and South America. He is certified consultant at the German Agency for Material Efficiency (DEMEA) and responsible for the "Franz-Patat-Zentrum", in which 15 working groups collaborate in joint polymer research programmes. Additionally he manages the international working group of plastic networks to support international knowledge management in the field.

The lecture centres on the processing of bio-degradable thermoplastics and synthetic materials made of renewable resources using the injection moulding process.

Bio-degradable materials can be manufactured out of different natural raw materials such as starch, sugar or cellulose. Depending on their suitability, the raw materials are either processed directly (starch, oils), chemically modified (cellulose diacetate) or converted to the desired chemical structure by means of fermentation (lactic acid, PHB/V). If the natural raw material as source material on its own does not exhibit sufficiently well-suited properties with regard to processing, bio-degradable synthetic polymers can also be added.

At present, a number of bio-degradable polymers are being manufactured on a large scale and are ready for marketing. Apart from these, there are numerous types of bioplastics which are still in the development phase, the properties of which are being continuously optimised. For this reason, a current market overview of this group of materials is provided in this paper. Following on from this, the processing parameters and the properties of the bioplastics during processing are described in detail. Finally, comprehensive research regarding the properties rounds off this investigation. In cooperation with the internet portal www.bioplastics24.com, current results will be published online.

In addition, current test runs with regard to natural fibre-reinforced synthetic materials are presented in the paper. Once again, bio-plastics in the form of matrix polymers are the focus of the study.

The advantages of natural fibre composite materials rest in their improved recycling properties and the low weight of potential components. In addition, the paper demonstrates that the density of these new materials can be further reduced through the use of chemical foaming agents.

Key words: injection moulding, bioplastics, biodegradable

Transparent Flexible Polylactide Resin Compound Rikemaster-GPR-075

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Ikuo Okoshi obtained a bachelor's degree in engineering in 1994 at the Polymer Chemistry Laboratory, Sophia University, in Japan.

Having spent two years with Riken Technos Corp, Mr Okoshi was seconded from 1996 to 1999 to the Riken Institute of Physical and Chemical Research, where he studied the structure of biodegradable polyester at the polymer chemistry laboratory.

As a research engineer, since 1999 Mr Okoshi has researched and developed bio-based plastic compounds and antistatic plastic compounds at Riken Technos Corp.

In collaboration with Osaka University, Riken Vitamin has developed a new technology which enables the control of crystal size polylactide resin in nano order.

Polylactide resin, considered as a rigid plastic, is a crystalline resin. When it is softened by compounding with plasticizer, it results in a lower glass transition point (Tg). As for softened polylactide resin which is near room temperature. When Tg is lowered, crystallization slowly occurs and results in the alteration of certain properties, including degradation of transparency and an increase in modulus (=hardening).

Riken Vitamin has developed a plasticizer matching the compatibility of polylactic acid and applied this technology to enable control of crystal size in nano order to sustain the transparency of polylactide resin. The plasticizer has also succeeded in providing softening as well.

This transparent flexible polylactide resin compound (Rikemaster-GPR-075) based on this technology will be developed into applications which require transparency such as wrapping film and agricultural film.

Key words: polylactide resin, plasticizer, compounding

Bioplastics in the Automobile Sector in Asia

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Katsuhiko Nakajima graduated from the Faculty of Science and Technology, Department of Applied Chemistry, Keio University Japan. He has experienced in R&D Frontier Field which involving in the development of Polymer materials for 17 years. At present, he is the Project Manager at Material Engineering Division 3, Toyota Motor Corporation, Japan

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ABSTRACT NOT AVAILABLE

BIONOLLE – An Approach to More Environmentally-Friendly Green Plastics

Yasushi Ichikawa
Showa Highpolymer Co., Ltd., Japan

Yasushi Ichikawa obtained a Masters degree in material systems engineering with a specialization in polymer structures and properties in 1990 at Tokyo University of Agriculture and Technology in Japan.

From 1990 to 2001 he worked at Showa Denko KK in Kawasaki, Japan where he studied the properties and processabilities of polyolefin and biodegradable polymers. He obtained a PhD in material engineering with a specialization in structures and properties of aliphatic polyesters in 1999 at Tokyo University of Agriculture and Technology in Japan.

Since April 2001 Yasushi Ichikawa works at Showa Highpolymer Co Ltd in Hyogo, Japan where he is senior researcher for developing the biodegradable polyester Bionolle .

"BIONOLLE" is an example of a green plastic material which is commercially produced by Showa Highpolymer. *BIONOLLE* is an aliphatic polyester and has superior processability similar to polyethylene. *BIONOLLE* is one of the most suitable materials to process films used for agricultural purposes, shopping bags, compost bags and so on.

Showa Highpolymer has succeeded in producing a compound of *BIONOLLE* and starch which is not only similar to homogeneous *BIONOLLE* in its principal properties, but is also an environmentally friendly material. The latest achievements on this issue are reported, along with Life Cycle Analysis (LCA) results.

Keywords: green plastics, life cycle analysis, *Bionolle*

Ecoflex and Renewable Materials

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Dietmar Heufel obtained his MBA degree, specializing in Marketing and Operations Research at the University of Cologne, Germany.

After his studies he worked for 4 years at Blendax Company, Mainz where he developed Latin American export markets for cosmetic articles.

He has more than seven years experience in marketing and sales for audio and video cassettes at BASF AG, Ludwigshafen.

He continued as Marketing Manager for Polystyrene, developing export markets in particular for injection moulding applications. After that he was Business Manager for Polystyrene in Europe.

Dietmar has headed the global business unit “Biodegradable Polymers” at BASF AG, Germany for six years, and since May 2006 has served as board member of European Bioplastics.

Foreseeing a major trend in biodegradable products, BASF has introduced *Ecoflex* as one of the first and now most successful biodegradable plastics available. Its key features are:

- 100% biodegradable
- fulfils all of the international requirements for composting plastics
- approved for food contract
- properties similar to enhanced LDPE
- performance enhancer to all polymers made from natural resources.

Because of the unique properties of Ecoflex, BASF has developed a new product called *Ecovio*, which contains Ecoflex and 45% NatureWorks PLA. This product is mainly designed for flexible packaging and gives superior mechanical properties equivalent to HDPE film.

The presentation also provides market figures for biodegradable polymers and future trends.

Key words: *Ecoflex*, *Ecovio*, biodegradeable, polymers

Recent Developments in Polylactic Acid: TERRAMAC

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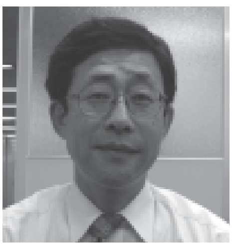

Shigemitsu Murase obtained his MSc degree in Engineering, specializing in polymer chemistry, in 1977 at Kyoto University in Japan. On graduation he joined Unitika Co Ltd. He obtained his Doctorate in Engineering at Kyoto University in 1997, and from 2000 to 2005, he was Visiting Professor in Tokyo University of Agriculture and Technology.

Since 2005, Shigemitsu Murase has served as General Manager of Terramac Business Development at Unitika Ltd.

In recent years, poly(lactic acid) (PLA) has been attracting much attention due to the increasing demand for non-fossil based raw material. The raw material of PLA is obtained from starch or tapioca in vegetables, such as potato, corn, cassava and so on. Thus, PLA has been highlighted as a green plastic whose monomer comes from renewable resources in agricultural materials that are grown annually, from the view point of prevention of both fossil resources exhaustion and global warming by increase in CO_2. Also many people take notice of PLA in terms of environmental protection because PLA is hydrolysable, biodegradable and compostable.

We show the profile of PLA as the most potential material amongst the biodegradable polymers, in respect of manufacture, mechanical properties, applications, and degradation behaviors in both natural environment and composting conditions. However, PLA is not without its problems. Heat stability and durability are somewhat inferior to general-purpose polymers. Unitika improves these properties by using advanced technologies. Products from improved PLA, TERRAMAC™, are currently commercially available, such as films, sheets, resins for injection and foam sheet moldings, fibers, and non-wovens. We present the key performance features, and the potential applications of PLA, TERRAMAC™, products. The typical ones are high heat resistant and/or hydrolysis resistant compound resins for injection molding such as returnable food trays and housings for electronics devices, and compound resins for foam extrusion followed by thermoforming of single-use food dishes capable of hot-fill and microwave reheating.

Key words: PLA, *Terrramac*®, biodegradeable, compostable

Sony's Vegetable-Based Plastics

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Hiroyuki Mori obtained a MEng degree in Mechanical Engineering in 1986 at Waseda University in Tokyo, Japan. In 1986 he joined Sony Corporation in Japan, where he worked on product design and CAE. In 1999 he began work with Sony's R&D section for environmental technology, and was involved as a project leader in applying bioplastics to electronics products.

Sony recognizes importance of biomass materials from environmental point of view, and has been developing to apply bioplastics called "vegetable-based plastic" to our products. Sony applied it to packages at first in year 2000, then expanded its application to casings of electronic products, which have higher added value and higher potential quantity consumed.

In this conference I will introduce our history to apply biomass materials, why we pay attention to the bioplastics, what kind of material properties are needed for our products, what products are commercialized, remaining technical problems, and our expectation and future dream to the bioplastics.

Key words: bioplastics, biomass, vegetable-based

Steam Explosion of Oil Palm Trunk for Glucose and Xylose Production

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Vittaya Punsuvon obtained his MS In Chemical Technology from Chulalongkorn University, Thailand, and in 1994 was awarded a PhD in Wood Chemistry by Mississippi State University, USA.

After a spell as lecturer in chemistry at the Department of Chemistry, Kasetsart University, Bangkok, he took on an assignment as chemist with Thaipakerizing Company, Bangkok, In 2001 he returned to Kasetsart's Department of Chemistry as Associate Professor in Applied Chemistry.

He has published extensively, mainly in the areas of extraction processes for the pulp and paper industry, fractionation and determination of chemical composition of various feedstocks.

The fractionation of oil palm trunk was studied using auto hydrolysis pretreatment. The auto hydrolytic pretreatment was performed by steam explosion. Oil palm trunk chip was steamed at temperatures varying between 203 and 223 °C for 2-5 minutes. The steamed fiber was washed with hot water to yield a solution rich in hemicellulose-derived mono- and oligosaccharides. The effects of these steam pretreatment conditions were assessed by measuring monomers (glucose and xylose) and oligomers solubilization in hemicellulose solution and chemical components in fiber after steam explosion. Fiber and solution under condition that yielded optimal hemicellulose solubilization were further subjected to enzymatic hydrolysis, using a preparation of cellulase for fiber and acid hydrolysis for hemicellulose solution. The optimization of the pretreatment conditions led to the following results at a pretreatment severity of log(Ro) = 3.65, yield of glucose from fiber hydrolysis = 40% of the potential; yield of xylose from solution hydrolysis = 34.4% of the potential.

Keywords: steam explosion, oil palm trunk, enzymatic hydrolysis, glucose, xylose

Characterization and Enzymatic Degradation of Microbial Co-Polyester P(3HB-co-3HV)s Produced by Metabolic Reaction Model-Based System

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Suchada Chanprateep is a lecturer at the Department of Microbiology, Faculty of Science, Chulalongkorn University in Bangkok.

After obtaining her M.Sc. in Industrial Microbiology at Chulalongkorn University in 1993, she was awarded a PhD in Engineering in 2002 by the Department of Biotechnology, Graduate School of Engineering, Osaka University, Japan, with support by a Monbusho scholarship from the Japanese Government

Since then Dr Chanprateep has held several research fellowships, and from March 2004 to March 2005 she was a Postdoctoral Associate at the Cornell/Ludwig Institute for Cancer Research (LICR) partnership, Department of Food Science and Technology, Cornell University, Ithaca, USA. Her research there involved the development and establishment of recombinant DNA-based system for the production of therapeutic agents

From September, 1997 to September, 1998 she spent a year at the International Post-Graduate University in Microbiology and Biotechnology, Department of Biotechnology, Osaka University, and was supported by a UNESCO Fellowship, the Japanese Government, and the International Cell Research Organization

She has published her work in a number of scientific papers, mostly in collaboration with Japanese research collaborators, and presented extensively in international conferences.

The two types of poly(3-hydroxybutyrate-*co*-3-hydroxyvalerate)s [P(3HB-*co*-3HV)s] were produced by *Paracoccus denitrificans* ATCC17741 using two different feeding methods. The produced P(3HB-*co*-3HV)s were fractionated and the copolymer sequence distributions were analyzed by ^{1}H and ^{13}C NMR spectroscopy. It was found that the P(3HB-*co*-3HV) samples produced by conventional feeding method were statistically random copolymers. The sequence distributions of P(3HB-

co-3HV) samples produced by optimization method were different from random P(3HB-*co*-3HV)s. The thermal properties and melting behaviors were analyzed by differential scanning calorimetry (DSC). These results demonstrated that P(3HB-*co*-3HV) samples produced by optimization method are close in nature to P(3HB-*co*-3HV)s rich in long-sequence of block 3HB units, but less in 3HV random regions. The enzymatic degradation profile of P(3HB-*co*-3HV) films was investigated in the presence of 3-hydroxybutyrate depolymerase from *Pseudomonase lemoignei*. The degradation process was observed by monitoring the time-dependent change in the weight loss of copolymer films. The surface erosion of copolymer films was qualitatively monitored by scanning electron microscopy (SEM) and atomic force microscopy (AFM). The highest degradation rate of 2.6% per day was observed for random P(3HB-*co*-38%3HV) produced by conventional method. In comparison, the hydrolysis degradation rates of random P(3HB-*co*-3HV)s were about one time faster than those of P(3HB-*co*-3HV)s produced by optimization method.

Key words: P(3HB-*co*-3HV), characterization, DSC, SEM, AFM, degradation

Green Packaging from Starch

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Kishan Khemani (PhD., Western, Canada) is Chief Technical Officer of Plantic Technologies located in Melbourne, Australia. He has extensive R&D experience in R&D of materials, polymers, biopolymers and biomaterials.

Previously, Kishan worked as a scientist at IPOS at UCSB, where he collaborated with Prof Fred Wudl and Prof Alan Heegar (Nobel Prize, 2000), and as a project manager and R&D Coordinator at Eastman Kodak / Chemical Company, and as Director of the biodegradable polymer and materials research at EK Industries and its subsidiary EarthShell Corporation.

Kishan has over fifty scientific publications and twelve US patents. He has also organized three International Symposiums over the years. In 1997, he edited and published a book entitled, "Polymeric Foams - Science & Technology". Recently, in August 2006, he published another book entitled "Degradable Polymers and Materials – Principles & Practice".

Kishan has served on the board of the TPMF division of the SPE (1997-2000), and is a member of the technical program committee of the Polymer Chemistry division of the ACS. He is also a senior member of the Bio/Environmentally Degradable Polymer Society (BEPS).

Kishan graduated from Bhagalpur University, India with a First-Class-First in MSc, and spent over two years conducting research under a Government of India Research Fellowship at the Indian Institute of Technology, Kanpur, India.

Plantic Technologies Limited is at the forefront of an ongoing revolution in food packaging. Currently, Plantic® material is used in a rigid packaging tray application that is biodegradable and water dispersible, and is being used by leading chocolate manufacturers such as Cadbury's, Lindt and Nestle. These trays are made from the Australian grown renewable resource raw material, corn. Starch from the corn is first purified and chemically modified, then processed with other ingredients inside an extruder and extruded into large rolls of sheet that look and feel like plastic. The sheets can be produced in any color of choice and are easily thermoformed into trays of any shape and size.

Plantic's current research and development efforts are focused on developing future technology platforms that will introduce new product applications for starch based materials. For instance, we are developing water resistant grades of products for packaging applications. Furthermore, we have projects aimed at developing injection mouldable grades. Some of our efforts are also focused on using nanotechnology in the development of these and other new applications.

Keywords: food packaging, biodegradeable, renewable

Ecofriendly, Sustainable, Revolutionary Biodegradable Green Nanocomposites: Opportunities and Challenges

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Padmalochan L Nayak is President of the Biodegradable Polymer Society of India, Chairman of SPC Biotech, Hyderabad, India, and Director, Biodegradable Polymer Research Laboratory, Ravenshaw University, Cuttack, Orissa, India.

As a specialist in polymer science and technology, Prof Nayak has played a leading role in research into biodegradeable polymers for the last two decades and has published prolifically, with books, reviews and over 260 research papers on biodegradable plastics in international refereed journals during this period.

Prof. Nayak has held many senior academic posts in his distinguished career, including the following:

- Prof and Head of Chemistry Department, Ravenshaw University, Cuttack, India: 1982-1994
- JSPS Fellow, Kyoto University, Japan: 1975-1976
- Senior Visiting Fulbright Scholar, Northwestern University, USA: 1977-1979
- Director, Central Institute of Plastics Engineering & Technology, Bhubaneswar, India: 1986-1988
- Visiting Professor, Gunma University, Japan: 1992
- Distinguished Visiting Professor, University of Massachusetts, Lowell, USA: 1994-1996
- Distinguished Visiting Professor, MIT, USA: 1997
- Distinguished Scientist, Michigan Biotechnology Institute, USA: 1998
- Distinguished Professor, Michigan State University, USA: 1998-2000
- Director, Institute of Materials Science, Bhubaneswar, India: 2001-2002
- CSIR, Emeritus Scientist, Govt of India: 2002-2004
- UGC National Emeritus Fellow: 2004- 2006
- Distinguished Visiting Professor, Hanyang University, South Korea: 2006.

Prof Nayak is also a Founder Life Member of the Orissa Bigyan Academy, a Life Member of the Orissa Bigyan Prachar Samiti, Society of Polymer Science, India, the Radiation and Photochemistry Society, Indian Science Congress Association and the Orissa Chemical Society.

His research Interests include biodegradable polymers from agricultural feedstocks, biodegradable green nanocomposites, conducting polymers, polymers from renewable resources, enzyme mediated polymerization, fullerene polymers, thermal stable polymers, synthetic resins for biomedical applications, graft-copolymerization onto some natural and synthetic polymers, radiation polymerization, photopolymerization, solution properties of high polymers, and freeradical polymerization initiated by some metal and nonmetal ions.

He is currently Chairman of SPC Biotech, Hyderabad, India, which manufactures corn-based biodegradable PLA, based on his own technology.

Sustainability, industrial ecology, eco-efficiency, and green chemistry are new principles that are guiding the development of the next generation of plastic and other products and processes. The new products have to be designed and engineered from “conception to reincarnation” incorporating a holistic “life cycle thinking approach”. Ecofriendly, biodegradable polymers in combination with nanotechnology are poised to create major breakthrough in plastic and polymer industries. The bio-based economy is challenging to agriculture, forestry, academic, society, and industry to develop and commercialize agro-based new materials with a “cradle to grave” concept. The extremely high price of petroleum and growing environmental problems are some of the driving forces in looking towards renewable-source based plastics to meet the challenges. The new biodegradable materials like polylactic acid (PLA), polyhydroxy alkanoates (PHAs), cellulosic plastics, starch and soy protein plastics are moving towards the main stream. Bio-based materials require value-added products through nanotechnology. Emerging nano reinforcements include nano clays, ultra-fine titanium dioxide and carbon nanotubes. Recently nano clays have been extensively used to modify the properties of agro-based green polymers. Some of the challenges in developing green nanocomposites include modification (blending/toughening), organo-modification of nano-particles, and appropriate processing through injection molding or extrusion-blow molding or cast films. The recent advancement of nano-biocomposites will be highlighted and their use in packaging, consumer products, electronic, and automotive parts will be discussed.

Keywords: PHA, PLA, nanocomposites, organi-modification, green packaging

Transparent and flexible polylactide films

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Amornrat Lertworasirikul is a lecturer at the Department of Materials Engineering, Faculty of Engineering, Kasetsart University, Bangkok, Thailand. She also holds the post of Visiting Lecturer at the Chemistry Program, Faculty of Science and Technology, Phranakhon Rajabhat University, and was until recently Assistant Professor of the Handai Frontier Research Center, Department of Applied Chemistry, Faculty of Engineering, Osaka University, Osaka, Japan.

Having graduated with a BS (Material Science) from Chulalongkorn University Bangkok, Thailand in March 1997, she continued her studies, obtaining a MS (Polymer Science) degree from the Petroleum and Petrochemical College, Chulalongkorn University, Thailand, In May 1999, and a D Eng (Biotechnology) degree from the Tokyo University of Agriculture and Technology in March 2004.

Her main teaching experience include materials science for engineers, materials processing laboratory, and general chemistry. Her research interests include functional polymers and biopolymers, and the crystal structures of polymers. She has published a number of peer-reviewed scientific papers, mostly in the areas of bio-based PLA films, and the determination of the molecular and crystal structures of chitosan and related compounds.

Interrelated problems of depletion of fossil resources and proliferation of global climate-changing emissions, pollutants and solid wastes prompted an increase in development of polylactide, biodegradable polymer which originates from renewable resources such as corn and rice. However, its inherent brittle nature is a major obstacle to competing with other petroleum-based plastics. Blending the polymer with low molecular weight compound is a practical way to overcome this problem. While the brittleness is improved, an increase of chain mobility and the consequent decrease of glass transition temperature of the blend lead to crystallization of the polymer even at room temperature. Flexibility and transparency of the blend get worse with the passing of time because of the crystallization proceeding. Here, non-crystalline polylactide (poly(DL-lactide)) was incorporated into blending system of semi-crystalline polylactide (poly(L-lactide)) and diglycerol

tetraacetate (DGTA). Crystallization of the blend was suppressed on condition that poly(DL-lactide) was included. Transparency of the films increased as a result of reduction in crystallinity and crystal size. Transparent and flexible films were obtained even when they were subjected to annealing at 60 °C for 1 hour.

Keywords: polylactide, transparent films

Chitosan Cotton: A Potential Novel Material for Absorbable Wound Dressing

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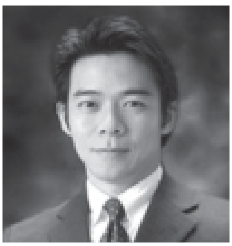

Suwabun Chirachanchai is Deputy Director of Research Affairs at the Petroleum and Petrochemical College, Chulalongkorn University. He is also Vice Center-Head at the Center for Chitin-Chitosan Biomaterials, Chulalongkorn University, and serves as External Expertise for the Processing Technology Program, School of Environment, Resources and Development, Asian Institute of Technology.

He has held several academic positions at the college, including Assistant Professor, Assistant Director for Research Affairs, and Lecturer. He as also served as a Visiting Lecturer at the Department of Chemical Engineering, Thammasart University, Bangkok, and the Department of Chemical Engineering, Khon Kaen University, Thailand. In 2004 he served as Visiting Professor at the Venture Business Laboratory, Hiroshima University, Japan. His teaching courses include polymer technology, composite materials, and advanced polymers at Bachelor and Masters levels.

He is the recipient of a number of prestigious academic awards, including the Science and Technology Research Grant Award, Toray Science Foundation (2003), the Overseas Research Grant Award, Asahi Glass Foundation (2003). He is a Hitachi Fellowship Scholar from Hitachi Scholarship Foundation (1995-Present), and also was Visiting Scientist Scholar from Japan Society of Scientific Promotion (JSPS) in 1999.

Prof Chirachanchai has since 2002 served on the Editorial Board of the Journal of Scientific Research, Chulalongkorn University,

He is a member of the Thai Academy of Science and Technology Foundation, the Chitin Chitosan Center of Excellence (Thailand), Japan Chemical Society, Japan Polymer Society, American Chemical Society, Chitin-Chitosan Society of Japan, Material Research Society Japan, and the Material Research Society USA.

He received his education at Osaka University and was awarded a PhD in Applied Fine Chemistry (Functional Polymers) in 1995. His research interests are controlled molecular recognition and inclusion compounds, biopolymers, chitin-chitosan, functional polymers, biodegradable polymers, nanomaterials, polymer modifications, polymer characterization, and polymer electrolyte membrane fuel cells.

He is author or co-author of over 22 peer-reviewed publications in refereed academic journals.

Absorbable wound dressing material requires not only the biocompatibility, biodegradability, non-toxicity but also the unique physico-chemical properties, such as the softness, high water absorption ability, and long water retaining time. Although chitin-chitosan satisfies the biorelated properties, the facts that chitosan does not melt and dissolves only in acids obstruct the processing of practical product. Up to now, challenges of chitosan for wound dressing, such as films, gels, fibers, etc. have been actively done.[1-3] However, the simple preparations with the uses of acid solvents and dialdehyde crosslinkers are always in the argument for the safety. Recently, we succeeded in preparing chitosan nanoscaffold by deacetylating chitin whisker.[4] In this work, we show a novel approach to conjugate chitosan with disaccharide molecules in an organic solvent free system.[5] The material obtained exhibits the soft cotton-like appearance whereas the morphology observed by TEM confirms the fine scaffold in mesoporous in nano-sized network. The chitosan cotton is a good candidate material to further develop for the absorbable scaled wound dressing.

Keywords: chitin, Whisker, chitosan, nanoscaffold, tissue engineering, lactose, maltose

Bionanosphere for Drug Delivery System

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For decades, drug delivery systems have been developed to achieve the effective drug administration in certain time and amount including the toxicity or the side-effects of drugs reduction, the increase of drug absorption, and the release performance improvement. Liposome and antibodies satisfy for being drug carriers as they can be taken up by macrophages, however, the disadvantages on the extravasations, in which the liposome moves from the blood vessel into tissue where it's not wanted, and the similarity of the receptors between the tumor cells and normal cells, obstruct the practically clipped at the tumor tissue. As chitosan shows its advantages on the bio-related properties, recently, we have succeeded in developing nanosphere for encapsulating the drugs and this brings the potential material for drug delivery system. The bionanospheres are formed in the sizes of 200-300 nm soon after the chitosan was conjugated with hydrophobic and hydrophilic groups. Here, we demonstrated our unique chitosan bionanospheres preparation and the effective drug incorporation.

Keywords: chitosan, nanosphere, drug delivery

Strain Improvement and Production of L (+)-Lactic Acid by Polyurethane Immobilized *Rhizopus oryzae* in Airlift Bioreactor

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His main research interests include microbial utilization of agricultural products and wastes, solid-state fermentation, microbial enzymes and fermentation technology, and the biodiversity of Actinomycetes. His current research work includes hydrolase enzymes from microorganisms, lactic acid production from starch by *Rhizopus oryzae,* and diversity of rare Actinomycetes and their application.

Prof Kitpreechavanich was awarded a Doctor of Engineering degree in Fermentation Technology by Hiroshima University, Japan in 1986, and has since authored or co-authored over 44 peer-reviewed papers in respected journals.

One hundred twenty three isolates of ultraviolet induction mutants at 0.001-0.07 % survival from a parent strain of *Rhizopus oryzae* DMKU 12 were screened for over production of lactic acid under slow shaking condition at 100 rpm. Five mutant strains were able to produce L (+)-lactic acid higher than parent strain on the media using glucose and liquefied cassava starch. Among these strains, *R. oryzae* KPS 106 gave the highest L (+)-lactic acid production, in a range of 97-102 g/l, which was corresponded to the highest specific activity of lactate dehydrogenase of crude cell extract. The production of L (+)-lactic acid by immobilized *R. oryzae* KPS106 on polyurethane sponge were investigated in 600 ml airlift bioreactor. It was found that inoculum prepared by 24 h culture of 2 x 10^7 spore/ml with 20 ml of 2.2 x 2.5 x 2.5 cm^3 polyurethane sponge in preculture consisted of 50 g/l and 5 g/l of yeast extract gave higher lactic acid compared to use spore suspension as directly inoculum. Cultivation of polyurethane sponge immobilized *R. oryzae* KPS106 at 35°C, 2.5 vvm of aeration rate and adjusted to pH 6.0 with ammonia produced

83.8g/l of lactic acid with Yp/s 0.74 was obtained after 72 h cultivation. Efficiency on lactic acid production using glucose by repetitive of polyurethane sponge immobilized *R. oryzae* KPS 106 was decreased. Eighty g/l of lactic acid with Yp/s of 0.70 was obtained in the first batch, whereas 70.8 g/l with Yp/s of 0.69 was obtained by the second batch culture. In addition of, average of 77.0 g/l of lactic acid with Yp/s of 0.82 was obtained from enzymatic saccharified cassava starch by 3 repeated batch cultures without declining efficiency in lactic acid production.

Keywords: strain improvement, lactic acid, polyurethane-immobilized, *Rhizopus oryzae*, bioreactor

The Potential Use of Degradable Plastic Bags in Kuwait and Its Environmental Benefits

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Dr Ali served as a member in several national consultative committees where she contributed to the establishment of guidelines and standards for “handling and Disposal of Chemical Wastes in Kuwait” and “Water Quality Standards of Kuwait Marine Environment” undertaken by Kuwait Environment Public Authority.

Dr Ali is the author or co-author of about 30 scientific articles and technical reports in areas of specialization and has given many presentations in international meetings worldwide.

Plastics are fast growing segment of waste stream in Kuwait. It is estimated that non degradable plastic material composes 13 percent of solid waste composition in Kuwait (Al-Muzaini and Beg 2002). Currently, the vast majority of solid waste produced in Kuwait is disposed to landfill. Very little waste currently disposed of in Kuwait undergoes alternative waste recycling or treatment (The Environment Strategy of Kuwait 2002).

Given the increasing future demand for more landfills to accommodate the generated waste in Kuwait coupled with increased public environmental awareness to minimize the associated environmental impacts of landfills, alternate solutions have been sought to dispose the rapidly accumulating waste in a environmentally friendly way. Among these solutions for plastic waste, the use of biodegradable plastics has been receiving greater attention over the past decade. However, in order to commercialize the use of biodegradable plastics in Kuwait, Standards and test methods that specifically applied to degradable plastics needs to be developed and make available as reference for the regulatory authorities in Kuwait.

Driven by the above reasons, the Kuwait Municipality the responsible authority for waste collection and disposal is working with Kuwait Institute for Scientific Research to investigate and ensure the safe introduction of biodegradable plastic bags to replace the current non-degradable plastic bags in Kuwaiti market and to propose related standards and test methods taking into consideration Kuwait's climatic and environmental conditions. This paper discusses aspects related to the potential use of biodegradable plastics in Kuwait and its associated environmental benefits.

Keywords: biodegradeable plastics, disposal, standards

Improving PHB Production Rate from Alcaligenes Eutrophus NCIMB 11599 by Two Stage Fermentation

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The objective of this present work is to study the application of two-stage fermentation for improving the Poly-β-Hydroxybutyrate (PHB) production rate by *Alcaligenes eutrophus* NCIMB 11599 using glucose as carbon source. In the first fermentor, the bacteria were grown to the maximum by chemostat in enriching medium. Then, it was stimulated to synthesize PHB in the second fermentor by fed-batch fermentation under unbalance medium condition. It was found that the dilution rate of the first stage at 0.10 h^{-1} could give 14.526 g/l of PHB or 33.25% (PHB/cell dry weight) in the second fermentor. In comparison with fed-batch fermentation, the two-stage fermentation gave similar PHB production rate at 2-cycle of fed-batch operation (100 hours) and gave higher production rate when the operation was more than 100 hours.

Keywords: fermentation, PHB, *Alcaligenes eutrrophus*