

BIOGRAPHIES AND ABSTRACTS

7th International Conference on

WOODFIBER-PLASTIC

Composites (and other natural fibers)

May 19-20, 2003

Monona Terrace Community & Convention Center
Madison, Wisconsin, USA

Sponsored by the USDA Forest Service in cooperation with the American Chemical Society's Cellulose and Renewable Materials Division, University of Wisconsin's Polymer Engineering Center, University of Toronto, Materials & Manufacturing Ontario, and Forest Products Society.

Hosted by the USDA Forest Service, Forest Products Laboratory.

PLANNING COMMITTEE

Conference Chair

*Craig M. Clemons
Research General Engineer
Forest Products Laboratory
USDA Forest Service
Madison, Wisconsin, USA*



Dr. Craig M. Clemons is a Research General Engineer in the Performance-Designed Composites Group at the USDA Forest Products Laboratory (FPL) in Madison, Wisconsin. He received a B.S. degree in Chemical Engineering, an M.S. degree in Forestry, and a Ph.D. degree in Materials Science, all from the University of Wisconsin-Madison. For the past 12 years, he has worked at FPL developing composite materials from wood/paper fibers and thermoplastics. His areas of interest lay both in the materials science and processing technologies of these natural fiber-reinforced thermoplastics. Current areas of emphasis are processing-structure-property relationships, fungal durability, and impact performance of natural fiber-reinforced thermoplastics.

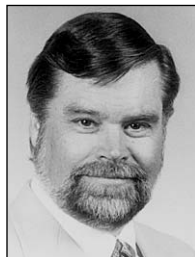
Committee Members & Session Moderators

*John J. Balatinecz
Professor Emeritus
Faculty of Forestry
University of Toronto
Toronto, Ontario, Canada*



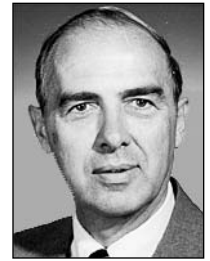
Dr. John J. Balatinecz is Professor Emeritus in the Faculty of Forestry at the University of Toronto, Toronto, Ontario, Canada. He received a B.S. degree in Forestry from the University of British Columbia, an M.S. degree in Forestry from the University of Washington, and a Ph.D. degree from the University of Toronto.

*Arthur B. Brauner
Executive Vice President
Forest Products Society
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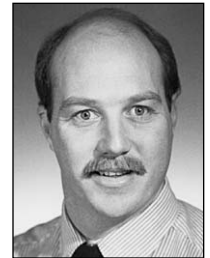
Arthur B. Brauner received B.S. and M.S. degrees in Wood Science and Technology from the University of Michigan. He has been Executive Vice President of the Forest Products Society since 1976. He came to the Society in 1968 as Editor of Publications and Director of the Society's computerized information retrieval system. Previously, he was on the staff of West Virginia University's School of Forestry as a Research Assistant and Assistant Professor.

*Daniel F. Caulfield
Research Chemist
Forest Products Laboratory
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Dr. Daniel F. Caulfield received a Ph.D. degree in Physical/Polymer Chemistry from the Polytechnic Institute of Brooklyn (now Polytechnic University of New York). He has been a Research Chemist at the USDA Forest Products Laboratory for over 30 years. His fields of research interest are structure/properties relationships in composites and paper. He has authored or coauthored over 75 technical articles, primarily in the area of moisture interaction with cellulose and paper. In 1982, he was elected as a Fellow in the International Academy of Wood Science.

*Robert H. Falk
Research Engineer
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USDA Forest Service
Madison, Wisconsin, USA*



Dr. Robert H. Falk is a Research Engineer at the USDA Forest Products Laboratory in Madison, Wisconsin. He performs research on the development of value-added building products from wood waste materials. This work includes the development of reuse options for salvaged lumber and timber as well as the development of composites from waste natural fibers and waste thermoplastics. In addition to developing a basic understanding of the engineering properties of these materials, Dr. Falk is active in helping develop the engineering property and engineering design standards necessary to facilitate their widespread use in construction applications. He is a professionally registered engineer and received a B.S. degree in Civil Engineering from California Polytechnic State University, an M.S. degree in Civil Engineering from Michigan Technological University, and a Ph.D. degree in Structural Engineering from Washington State University.

*Douglas J. Gardner
Professor/Program Leader
Advanced Engineered Wood
Composites Center
University of Maine
Orono, Maine, USA*



Dr. Douglas J. Gardner is Professor and Program Leader of Wood Science in the Department of Forest Management and the Advanced Engineered Wood Composites Center at the University of Maine. Prior to coming to Maine, he was Interim Director of the Institute of Wood Research (1997-1998) and Associate Professor at Michigan Technological University (1995-1998). He served on the wood science faculty at West Virginia University (1988-1994), and was post-doctoral research associate at Auburn University (1986-1988). Dr. Gardner's research, teaching, and service activities focus on polymer and interfacial science aspects of wood-polymer hybrid composite materials. He is also involved in research in the areas of adhesion and surface science, extruded wood-plastic composites, and the analysis of volatile organic compound emissions from wood composite processing. He has coauthored over 80 technical publications and 85 research presentations. Dr. Gardner is a member of the Forest Products Society, Society of Wood Science and Technology, Adhesion Society, and the American Chemical Society. He serves on the editorial advisory board of the *Journal of Adhesion Science and Technology*. He is a frequent contributing author and reviewer for the *Forest Products Journal*. He has been recognized for his work by receiving the 1992 Cahn Award, and

appears in the 4th Edition of Who's Who in Science and Engineering. He is an Honorary Member of the Union of Wood Processing Manufacturers of the Slovak Republic. He received a B.S. degree and Certificate of Advanced Study from the University of Maine, and a Ph.D. degree from Mississippi State University.

Rebecca E. Ibach
Research Chemist
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Dr. Rebecca E. Ibach is a Research Chemist in the Modified Lignocellulosic Materials Project at the USDA Forest Products Laboratory in Madison, Wisconsin. Her research is in chemically modifying solid wood and wood-based composites by lumen-filling and/or cell wall bonding chemistries to protect wood (from moisture, UV, and biological deterioration) and to improve its properties (i.e. mechanical, dimensional stability, and hardness). She received a B.S. degree from St. Norbert College in De Pere, Wisconsin, and a Ph.D. degree from the University of Wisconsin-Madison.

Laurent M. Matuana
Assistant Professor
Dept. of Forestry
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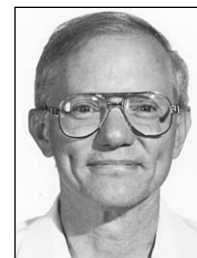
Dr. Laurent M. Matuana is an Assistant Professor in the Department of Forestry at Michigan State University in East Lansing, Michigan. His responsibilities include teaching and research. He received B.S. and M.S. degrees from the University of Laval, Quebec, Canada, and a Ph.D. degree from the University of Toronto, Ontario, Canada.

Kristiina Oksman
Professor
Dept. of Machine Design & Materials Technology
Norwegian University of Science & Technology
Trondheim, Norway



Dr. Kristiina Oksman is a Professor in the Department of Machine Design and Materials Technology, Norwegian University of Science and Technology in Trondheim, Norway. She is responsible for teaching and research on wood and natural fiber composites, nano-composites, and materials from renewable resources. Current research projects include nano-composites from renewable raw materials, wood fiber composites with improved durability, and cellulose fiber as reinforcement in polyolefins. She received an M.S. degree in Material Science and Engineering and a Ph.D. degree from Luleå University of Technology, Sweden. Previously, she worked as the Project Manager of Natural Fibre Composites with the Swedish Institute of Composites in Piteå, Sweden.

Roger M. Rowell
Research Chemist/Project Leader
Forest Products Laboratory
USDA Forest Service
Madison, Wisconsin, USA



Dr. Roger M. Rowell is a Research Chemist and Project Leader at the USDA Forest Products Laboratory in Madison, Wisconsin. He is also a Professor in the Department of Forestry, the Department of Biological Systems Engineering, and the Engineering Research Center for Plasma-Aided Manufacturing at the University of Wisconsin-Madison. His research interests include carbohydrate synthesis, chemical modification of lignocellulosics for property enhanced composites, materials science of natural fibers, composites from sustainable agro-resources, cold plasma modification of carbohydrate polymers, and fiber/thermoplastic composites. Previously, he was a United Nations Development Project Mission Leader for composites in India; Guest Scholar at Kyoto University, Kyoto, Japan; Guest Research Fellow at Forest Research, Rotorua, New Zealand; Guest Professor at the University College of North Wales, Bangor, United Kingdom; a National Science Foundation Exchange Professor at the Wood Research Institute, Kyoto University, Uji, Japan; and a Guest Professor at Beijing Forestry University, Beijing, China. He received a B.S. degree in Chemistry/Math from Southwestern College, and M.S. and Ph.D. degrees in Biochemistry from Purdue University. He is the author of over 300 publications, has edited 9 books, and holds 22 patents.

Anand R. Sanadi
Research Scientist
Forest Products Laboratory
USDA Forest Service
Madison, Wisconsin, USA



Dr. Anand R. Sanadi has worked in research in the area of natural fiber composites for over 10 years, and research in composites for over 15 years. He is the chief inventor of the process to produce highly filled natural fiber composites, where fiber loadings of over 80% by weight is possible. His interests include structure-property relationships in polymers and composites, and adhesion and interfaces in non-similar materials. Previously, he was an Assistant Scientist in the Department of Biological Systems Engineering at the University of Wisconsin-Madison. He received a Bachelor's degree in Textile Technology from the Indian Institute of Technology, an M.S. degree in Chemical Engineering from the University of Toronto, and a Ph.D. degree in Engineering Science from Washington State University.

Nicole M. Stark
Chemical Engineer
Forest Products Laboratory
USDA Forest Service
Madison, Wisconsin, USA



Nicole M. Stark is a scientist in the Performance-Engineered Composites Group at the USDA Forest Products Laboratory (FPL) in Madison, Wisconsin. She received a B.S. degree in Chemical Engineering and an M.S. degree in Mechanical Engineering from the University of Wisconsin-Madison. She is currently working towards her Ph.D. at Michigan Technological University. Nicole has been involved with the research and development of natural fiber/thermoplastic composites for 8 years. Her research focus has been to examine the influence of raw materials on mechanical properties and she is currently working towards a fundamental understanding of the photodegradation of these composites.

Jerrold E. Winandy
Project Leader
USDA Forest Service
Forest Products Laboratory
Madison, Wisconsin, USA



Dr. Jerrold E. Winandy is Project Leader of the Performance-Engineered Composites Group at the USDA Forest Products Laboratory (FPL) in Madison, Wisconsin. They are responsible for developing new and improved composites from wood and other non-wood fiber sources using thermoset, thermoplastic, inorganic, and other naturally-derived binders. He is also an Adjunct Professor in the Department of Wood and Paper Science at the University of Minnesota. He received B.S. and M.S. degrees from Purdue University, and a Ph.D. degree from Oregon State University. His personal research has historically dealt primarily with the modeling effects of chemical, thermal, and biological agents on the engineering properties on wood and wood composites. More recently, his work has begun to study serviceability/durability issues for wood-based composites.

Session Speakers & Poster Presenters

Donald A. Bender
Professor/Director
Wood Materials & Engineering Lab.
Washington State University
Pullman, Washington, USA

Dr. Donald A. Bender is Director of the Wood Materials and Engineering Laboratory and Professor of Civil Engineering at Washington State University. He has taught courses and conducted research on wood engineering for 20 years. He has researched the performance of glulam timbers and wood trusses, developed design methods for post-frame timber structures, and developed nondestructive evaluation techniques for wood materials. Dr. Bender is a technical advisor to numerous industry trade associations, and is active in the American Society of Civil Engineers, American Society of Testing and Materials, and the Society for Wood Science and Technology. He is a registered professional engineer and holds the Weyerhaeuser Distinguished Professorship at Washington State University. He received B.S. and M.S. degrees in Agricultural Engineering from Virginia Tech, and a Ph.D. degree in Agricultural Engineering from Purdue University.

Lars A. Berglund
Professor
Dept. of Fiber & Polymer Technology
Royal Institute of Technology (KTH)
Stockholm, Sweden

Dr. Lars A. Berglund is Professor of Wood and Wood Composites at the Royal Institute of Technology in Stockholm, Sweden. Previously, he was Professor of Composite Materials at Luleå University of Technology, Sweden. He received an M.S. degree in Polymer Science and Engineering from the University of Massachusetts, and a Ph.D. degree in Materials Science and Engineering from Linköping University, Sweden.

Gerard T. Caneba
Associate Professor
Dept. of Chemical Engineering
Michigan Technological University
Houghton, Michigan, USA

Dr. Gerald T. Caneba is an Associate Professor in the Department of Chemical Engineering at Michigan Technological University in Houghton, Michigan. He received a B.S. degree in Chemical Engineering from the University of Philippines, and M.S. and Ph.D.

degrees in Chemical Engineering from the University of California, Berkeley. He also attended a Summer Professional Program in "Microsystems: Mechanical, Biochemical, Optical" at the Massachusetts Institute of Technology. He holds several patents and is the author or coauthor of numerous refereed journal publications and proceedings. His awards and honors include winner of Best Academic Poster, sponsored by ACS Rubber Division (April, 1985); Filtration Society Fellowship (1983-1984); UNESCO Fellowship (1980-1982); Topnotcher - Chemical Engineering Professional Licensure Examination in the Philippines (1979); Who's Who in America (Science and Engineering) (1994); and Work in Nanotechnology selected by the Center for Nanoscale Materials of Argonne National Laboratory was presented to the *DOE Nanoscale Science Research Centers Workshop "Enabling the Nanoscience Revolution"* in Washington, D.C. on February 26-28, 2003, which was attended by government, academic, and industry leaders.

Ben Dawson-Andoh
Associate Professor
Division of Forestry
West Virginia University
Morgantown, West Virginia, USA

Dr. Ben Dawson-Andoh is an Associate Professor in the Division of Forestry at West Virginia University in Morgantown, West Virginia. His fields of specialization include wood microbiology, wood chemistry, wood and microbial biochemistry, wood biodeterioration and preservation, environmental impact of wood processing, application of biotechnology to manufacture of forest products. Previously, he was a Research Scientist at Forintek Canada Corporation in Ottawa and Quebec City, Canada. He received a Ph.D. degree from the University of British Columbia.

Bernard De Jéso
Professor, Organic Chemistry
Laboratoire de Chimie des Substances Végétales
Université Bordeaux I
Talence, France

Dr. Bernard De Jéso is a Professor of Organic Chemistry at the Laboratoire de Chimie des Substances Végétales, Université Bordeaux 1, Talence, France. His responsibilities include research, education, and administration. He received a Ph.D. degree in Organic Chemistry from the Université Bordeaux 1.

Nathan Deringer
Graduate Research Assistant
Dept. of Wood & Paper Science
University of Minnesota
St. Paul, Minnesota, USA

Nathan Deringer is a Graduate Research Assistant in the Department of Wood and Paper Science at the University of Minnesota in St. Paul, Minnesota. He is currently working on his thesis "Product Adoption by Intermediaries Within a Distribution Channel." He also has completed work on a project that dealt with the shear strength of OSB webbing in I-joists that were subjected to humidity cycling. He received a B.S. degree in Forestry Administration and Utilization from the University of Wisconsin-Stevens Point, and an M.S. degree in Forest Products Marketing from the University of Minnesota.

Peter Dylingowski
Manager, Biocides Lab, Plastic Additives
Rohm & Haas Company
Spring House, Pennsylvania, USA

For 25 years, Peter Dylingowski has been involved in Microbiology for Biocides in plastics, textile, wood, and adhesives at Ventron, Thiokol, Morton Thiokol, Morton International, and Rohm and Haas Companies, which are now all the same. His responsibilities have been efficacy testing of biocide formulas in traditional materials such as textiles, adhesives, and wood as well as newer applications such as various plastics with flexible PVC being the core market. He also gave technical support at National Technical Meetings to sales and marketing. Mr. Dylingowski also supported the biocides business as

Microbiology Lab Manager for Sales and Technical Service as well as Research Developmental Projects. He has developed new test methods for Biocide treated carpet and textiles and was Chair of the American Association of Textile Chemists and Colorists (AATCC) committee on microbiological methods. He received a B.A. degree in Biology from Salem State College, Salem, Massachusetts. Prior to his industrial microbiology days, he taught Biology at Manchester by the Sea, Massachusetts as well as a tour in the U.S. Army Medical Corp and Reserves. He is a senior member of the AATCC and Past Chair of Committee RA-31 Antimicrobial Activity. He also is a member of the American Society Testing Materials and Society for Industrial Microbiology.

Ana Espert
Ph.D. Student
Dept. of Fiber & Polymer Technology
Royal Institute of Technology (KTH)
Stockholm, Sweden

Ana Espert is a Ph.D. Student in the Department of Fiber and Polymer Technology at the Royal Institute of Technology in Stockholm, Sweden. Her responsibilities include coordination of a European Community research project, guidance of undergraduate training, and research studies. She received an M.S. degree in Chemical Engineering from the Universidad Politécnic in Valencia, Spain.

Omar Faruk
Scientific Staff
Institut für Werkstofftechnik, Kunststoff-und
Recyclingtechnik
Universität Kassel
Kassel, Germany

Omar Faruk completed his M.S. degree in Chemistry from the University of Chittagong, Bangladesh. After graduation, he joined the Bangladesh University of Engineering and Technology as a teaching assistant. With a DAAD (German Academic Exchange Service) scholarship, he went to the Institute for Material Science, Polymer and Recycling Technology at the University of Kassel, Germany under a research project (natural fiber and wood-reinforced composites) for 2 years. After completing the scholarship, he is currently working as a Scientific Staff member at the University of Kassel as well as working towards his Ph.D. degree.

E. Kristofer Gamstedt
Assistant Professor
Dept. of Solid Mechanics
Royal Institute of Technology (KTH)
Stockholm, Sweden

Dr. E. Kristofer Gamstedt is an Assistant Professor in the Department of Solid Mechanics at the Royal Institute of Technology in Stockholm, Sweden. His responsibilities include teaching and examination in undergraduate and graduate courses; conducting research on wood-fiber composites; and consultancy for the Swedish Pulp and Paper Research Institute. Previously, he was Senior Scientist and Post-Doctoral Fellow in the Materials Research Department at Risø National Laboratory in Denmark, and a Graduate (Ph.D.) Student in the Division of Polymer Engineering at Luleå University of Technology. He received an M.S. degree in Applied Physics and Electrical Engineering from Linköping Institute of Technology, and a Ph.D. degree in Polymer Engineering from Luleå University of Technology.

Piedad Gañán Rojo
Assistant Professor, Materials Engineering
Universidad Pontificia Bolivariana
Medellin, Columbia

Dr. Piedad Gañán Rojo is an Assistant Professor of Materials Engineering at Universidad Pontificia Bolivariana in Medellin, Columbia. His responsibilities include polymer and polymer composite materials research in the New Materials Group. He received a Chemical Engineering degree from Universidad Pontificia

Bolivariana, and a Ph.D. degree from Universidad del Pais Vasco, San Sebastian, Bosque Country, Spain.

Marek Gnatowski
Technical Director/President
Polymer Engineering Co., Ltd.
Burnaby, British Columbia, Canada

Dr. Marek Gnatowski is Technical Director and President of Polymer Engineering Company, Ltd. in Burnaby, British Columbia, Canada. His responsibilities include research in polymer chemistry (including polymer modification), technology and processing, relationship between polymer structure and properties, plastics recycling including biodegradable plastics, coating materials chemistry, technology and evaluation, organic technology, environmental problems, waste management and chemical grouting, and industrial slurry; materials testing; failure analysis including applications such as automotive, construction, aerospace, electronics, electrical, coatings, adhesives, packaging, consumer products, etc.; technical and legal consulting; adhesives and coatings formulation; plastics and rubber compounding; process design; scaling up process; collection and analysis of technical and marketing information; R&D management; supervising experimental work in plants and construction sites; and safety and hygiene for manufacturing and application procedures. He received an M.S. degree in Engineering and a Ph.D. degree from the Warsaw University of Technology, Warsaw, Poland.

Subba Rao Gurram
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Subba Rao Gurram is a Graduate Research Assistant in the Department of Agricultural and Biosystems Engineering at South Dakota State University in Brookings, South Dakota. He is currently working towards his M.S. degree in food and biomaterials processing. He has received a B.S. degree in Agricultural Engineering from APAU in Hyderabad, India.

John C. Hermanson
Research General Engineer
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Dr. John C. Hermanson is a Research General Engineer at the USDA Forest Products Laboratory in Madison, Wisconsin. His responsibilities include theoretical and experimental mechanics applied to utilizing wood- and other natural fiber-waste material in products for green building construction. Previously, he was a Research Scientist in the Wood Materials and Engineering Laboratory at Washington State University. He received B.S.C.E. and M.S.C.E. degrees from the University of Washington, and a Ph.D. degree from the University of Wisconsin-Madison.

Ryo Ikuto
Graduate Student
Faculty of Agriculture
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Nara-shi, Nara, Japan

Ryo Ikuto is a Graduate Student (manufacture of wood-plastic composites) in the Department of Agricultural Chemistry at Kin-ki Daigaku University, Nara-shi, Nara, Japan. He received a Bachelor of Agriculture degree from Kin-ki Daigaku University in 2002.

Rodney E. Jacobson
President
A-J Engineering Co., LLC
Madison, Wisconsin, USA

Rodney E. Jacobson is President of A-J Engineering Company, LLC in Madison, Wisconsin. He is also a Prime Contractor at the USDA Forest Products Laboratory. His primary research and development efforts include the use of cellulose as a reinforcement in nylons. Other R&D efforts include natural fiber-reinforced commodity thermoplastics and International consulting. Previously, he was a Materials Engineer at the USDA Forest Products Laboratory. He received B.S. and M.S. degrees in Material Science and Engineering from Washington State University.

James L. Julson
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Dr. James L. Julson is an Associate Professor in the Department of Agricultural and Biosystems Engineering at South Dakota State University in Brookings, South Dakota. His responsibilities include teaching and research. He received B.S. and M.S. degrees in Agricultural Engineering from South Dakota State University, and a Ph.D. degree in Engineering from the University of Nebraska-Lincoln.

Travis Keener
Product Development Representative
Eastman Chemical Company
Longview, Texas, USA

Travis Keener is a Product Development Representative at Eastman Chemical Company in Longview, Texas. He joined Eastman in 1994 as a co-op student. He has spent the last 3 years in the Technical Service and Product Development area of the Specialty Polymers Department. He received a B.S. degree in Chemical Engineering from Oklahoma State University.

Thomas Kelley
Business Manager
Dover Chemical Corporation
Dover, Ohio, USA

Kelley Thomas is Business Manager (chlorinated resins) at Dover Chemical Corporation in Dover, Ohio. Previously, he was General Manager at ICC Industries B.V.; Product Manager at Ferro Chemical, Keil Division; and Director of Marketing at Ferro Chemical S.A. He received a B.S. degree from the Florida Institute of Technology in Melbourne, Australia.

Takeyasu Kikuchi
Director
EIN Engineering Co., Ltd.
Tokyo, Japan

Takeyasu Kikuchi is Director of the EIN Engineering Company, Ltd. in Tokyo, Japan. Previously, he was Chief Researcher for the project of re-use of waste plastic (supported by the Ministry of Environment); Director of the Researchers' Association of the Wood Material with new function and performance (organized under the Ministry of Forest); member of "The Market Survey Committee for Woody Wastes in Works" (subsidized by the Government); Chief Researcher for development of applied technology of photocatalytic paper (subsidized by the Ministry of International Trade and Industry); Chief Researcher in purification technology of rivers, lakes, and marshes and the closed waters with the use of network blocks for growing aquatic plants, which utilizes recycled waste plastics (subsidized by the Ministry of Environment); Chief Researcher for joint development for wood-filled plastics for concrete mold application (with Chubu Regional Construction Bureau and Ministry of Construction); and member of "The Research Committee for Promotion of Reprocessing Waste Plastics in the Tohoku District" (established by Tohoku Regional Bureau of Economy, Trade and Industry).

Hyun-Joong Kim
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Dr. Hyun-Joong Kim is an Assistant Professor in the School of Biological Resources and Materials Engineering at Seoul National University in Suwon, South Korea. He received B.S. and M.S. degrees from Seoul National University, and a Ph.D. degree from the University of Tokyo. Previously, he was a Research Scientist in the Department of Materials Science and Engineering at the State University of New York at Stony Brook.

Alcides Lopes Leão
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Dr. Alcides Lopes Leão is a Professor at UNESP, College of Agricultural Sciences, São Paulo State University, Botucatu, Brazil. His responsibilities include Coordinator for the Laboratory of Solid Residues and Composites, FAO South American Representative for Flax, and Coordinator for several projects related to natural fiber application in the automotive industry. He received a Bachelor Agronomist degree and an M.S. degree in Energy in Agriculture from UNESP, and a Ph.D. degree from the University of Wisconsin-Madison.

Kaichang Li
Assistant Professor
Dept. of Wood Science & Engineering
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Corvallis, Oregon, USA

Dr. Kaichang Li is an Assistant Professor in the Department of Wood Science and Engineering at Oregon State University. His expertise includes biodegradation of lignin, enzymatic pulp bleaching, wood adhesives, and wood composites. His current programs include developing formaldehyde-free wood adhesives from renewable natural resources; investigating interphase chemistry of wood-plastic composites; investigating the mechanisms by which white-rot fungi degrade lignin, focusing on properties of laccase and its role in the fungal degradation of lignin; developing environmentally benign pulp bleaching techniques; investigating enzymatic deinking of recycled paper; and application of ionic liquids in the pulp and paper industry. He received B.S. and M.S. degrees from South China University of Technology, and a Ph.D. degree from Virginia Tech.

Mark J. Manning
Manager, Technical Development
U.S. Borax, Inc.
Valencia, California, USA

Dr. Mark J. Manning is Manager of Technical Development at U.S. Borax, Inc. in Valencia, California. He is responsible for technical and market development efforts in support of boron-based wood preservatives. More recently, his primary focus has been in the area of preservative treatments for engineered wood products. He is active in the technical subcommittees of the American Wood Preservers' Association and is a member of the International Research Group on Wood Preservation. He received a B.S. degree in Chemistry from Arizona State University, and a Ph.D. degree in Inorganic Chemistry from the University of California.

Jeanette Maurice
Graduate Research Assistant
Dept. of Forestry
Michigan State University
East Lansing, Michigan, USA

Jeanette Maurice is a Graduate Research Assistant in the Department of Forestry at Michigan State University in East Lansing, Michigan. Her responsibilities include executing necessary research projects that vary between individually driven or industry related. Her primary research deals with the freeze-thaw durability of wood-plastic composites and how different compositions of composites react to freeze-thaw actions. She received a Bachelor degree in Forestry from Michigan State University.

Manju Misra
Visiting Assistant Professor
Composite Materials & Structures Center
Michigan State University
East Lansing, Michigan, USA

Dr. Manju Misra is a Visiting Assistant Professor in the Composite Materials and Structures Center at Michigan State University in East Lansing, Michigan. He has 17 years of teaching experience in polymer science and chemistry, including polymer plastic processing technology and engineering to graduate, post-graduate, and post-graduate diploma students; 19 years of research experience in the field of polymer, biopolymer, natural fiber, bio-composites, blending, polymer processing, fiber-matrix adhesion, and polymer synthesis; and has successfully managed several research programs in the field of polymer and composites. He is the author or coauthor of 100+ publications and holds several patents. He received a B.S. (Honors in Chemistry) degree, an M.S. (Specialization: High Polymer Chemistry) degree, a M.Phil. (Polymer Chemistry) degree, and a Ph.D. (Polymer Chemistry) degree from Utkal University in Orisa, India.

Amar K. Mohanty
Visiting Associate Professor
Composite Materials & Structures Center
Michigan State University
East Lansing, Michigan, USA

Dr. Amar K. Mohanty is a Visiting Associate Professor in the Composite Materials and Structures Center at Michigan State University in East Lansing, Michigan. He has 10 years of teaching experience in polymer, spectroscopy, and organic and physical chemistry; 21 years of research experience in the field of polymer, biopolymer, reactive blending, polymer kinetics, graft-copolymerization, polymer synthesis, natural fiber, bio-composites, polymer processing, fiber-matrix adhesion, and polymer synthesis and nano-composites; and he has successfully managed and is presently managing/supervising several research programs in the field of polymers, fiber-reinforced composites and nano-composites. He is the author or coauthor of 100+ publications and holds several patents. He received a B.S. (Honors in Chemistry) degree, an M.S. (Chemistry) degree, and a Ph.D. (Chemistry) degree from Utkal University in Orisa, India.

Inaki Mondragon
Professor of Chemical Engineering
Materials & Technologies Group
University of the Basque Country
Donostia - San Sebastian, Spain

Inaki Mondragon is a Professor of Chemical Engineering and Head of the Materials and Technologies Group at the University of the Basque Country in Donostia - San Sebastian, Spain. He is also Vice Dean of R&D in the Esanela Ingeuena T. Industrial and Coordinator of the 'Network of Excellence' GREENCOMP presented to the 1st Call of the 6th Framework Program of the European Community (2003).

James Morton
Senior Partner
Principia Partners
Exton, Pennsylvania, USA

James Morton is a Senior Partner with Principia Partners, and has over 15 years of consulting experience in the chemicals and materials industries. He has conducted and directed numerous assignments on market and sales strategies, acquisition and divestiture analyses, and strategic business planning for global materials suppliers and leading fabricated component producers and OEMs. He has specialized in assisting clients with their market-entry planning, product repositioning, and pricing strategies. He has specialized in evaluating intermaterial and interprocess competition to assist clients with market entry planning, product repositioning, and pricing strategies. Prior to joining Principia, Mr. Morton was a Project Manager in the Market Assessment practice at Charles River Associates. He was also employed in the Advanced Materials and Plastics practices at Kline & Company. He began his consulting career in product liability litigation involving construction and industrial products. His work focused on investigating equipment and system failures in the medical and aerospace business. He is a recognized expert in metallurgy and has provided court testimonial expertise in several cases. He received a B.A. in Chemistry and Economics from Franklin & Marshall College, and also earned M.S. and P.E. degrees in Materials Science from Columbia University. He is a member of the Society of Automotive Engineers, Society of Plastics Engineers, and ASM International.

Friedrich Munder
Project Manager
Institute of Agricultural Engineering Bornim e.V.
Potsdam, Germany

Friedrich Munder is Project Manager at the Institute of Agricultural Engineering in Potsdam, Germany. He is responsible for new technologies and projects of growing, crop harvesting, and processing of natural fiber plants; R&D projects of machine design and development; and engineering, start up, and test operation of new processing facilities and the industrial application of natural fibers. He received Master's and Ph.D. degrees in Agricultural Engineering from the University of Rostock, Germany.

Byung-Dae Park
Adhesive Scientist
Dept. of Forest Products
Korea Forest Research Institute
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Dr. Byung-Dae Park is an Adhesive Scientist in the Department of Forest Products at Korea Forest Research Institute in Seoul, South Korea. His responsibilities include conducting research on the improvement of wood adhesive properties and developments of new adhesives for wood-based composite products. Current research work includes reduction of formaldehyde emission of UF resin-bonded particleboard, and UF resin modification with emulsified MDI resin. He received a B.S. degree from Chonnam National University, an M.S. degree from the University of Toronto, and a Ph.D. degree from Laval University.

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Dr. Chul B. Park is a Professor and Canada Research Chair in Advanced Polymer Processing Technologies and the Director of the Microcellular Plastics Manufacturing Laboratory, Department of Mechanical and Industrial Engineering, University of Toronto, Toronto, Ontario, Canada. His area of research includes the development of Novel microcellular processing technologies; analysis and control of cell nucleation, cell growth, and shaping; computational modeling of foaming; development of artificial wood; and measure-

ment and modeling of the thermophysical properties of polymer/supercritical fluids. He is a member of several professional affiliations, has organized conferences/seminars (Foam Seminar with JSPP-Kansai Branch and Professor M. Ohshima of Kyoto University; ASME RSC 2003, and PPS Regional Asia/Australia Meeting), has chaired or co-chaired several sessions, and has received numerous honors/awards. He is a reviewer for *Polymer Engineering and Science*, *Journal of Applied Polymer Science*, *Journal of Cellular Plastics*, *Cellular Polymers*, *Journal of Thermoplastic Composite Materials*, *Polymer Composites*, *Composite Science and Technology*, and *Industrial and Engineering Chemistry Research*. He received a B.S. degree in Mechanical Engineering from Seoul National University, an M.S. degree in Mechanical Engineering from the Korea Advanced Institute of Science and Technology, and a Ph.D. degree in Mechanical Engineering from the Massachusetts Institute of Technology.

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Michel Pétraud is a Research Engineer at the Centre d'Etude Structurale et d'Analyse des, Molécules Organiques, Université Bordeaux 1, Talence, France. His responsibilities include research in Nuclear Magnetic Resonance characterization of organic materials.

Tefu Qin
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Tefu Qin is an Assistant Professor in the Department of Wood Properties at the Research Institute of Wood Industry, Chinese Academy of Forestry, Beijing. His responsibilities include wood chemistry and wood/polymer research. The research field involves the composites of wood chemistry; and the chemical structure of wood, the extractive of wood, the surface modify of wood, and wood/polymer composite. He is the author or coauthor of 21 published research papers and a monograph book on Chinese plantation wood properties, which won the National Books Award and the First-Class State Excellence Scientific and Technical Books Award (1999). He was also awarded the First-Class Scientific and Technical Advancement Award of State Forestry Bureau (1998) and the Second-Class National Scientific and Technical Advancement Award of the Ministry of Science and Technology (1999). He received a B.S. degree in Chemistry.

Stephen L. Quarles
Wood Durability Advisor
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Dr. Stephen L. Quarles is a University of California (UC) Cooperative Extension Advisor in Wood Building Durability at the UC Forest Products Laboratory (UCFPL). He is responsible for development and implementation of the outreach and research program on durability issues related to the in-service performance of wood-frame structures and wood and wood-based products. His research is currently focused on the performance of exterior-use building materials and assemblies that are subjected to wildfire exposures, and since wildfire and moisture (rainfall) design features are often conflicting, developing an understanding of how to optimize the design of buildings located in the urban wildland interface. Dr. Quarles joined the UCFPL in 1985, and prior to accepting the Wood Durability Advisor position in the fall of 2000, was Head of the Wood Building Research Center and the Service to Industry Program (1992-2000), and was a member of the faculty at Berkeley (1985-1992). He worked at a particleboard plant in Southern Georgia, operated by Weyerhaeuser Company, initially through participation in a cooperative education program while an undergraduate, and then full-time from 1978 to 1980. He received a Ph.D. degree in Wood Science and Forest Products from the

University of Minnesota, and an undergraduate degree from Virginia Tech. He has published more than 50 articles in refereed and non-refereed outlets, and numerous technical reports.

Mohini Sain
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Dr. Mohini Sain is a Professional Engineer and holds a Doctorate degree in Chemical Engineering. Before joining academia, he worked approximately 8 years in industry in various capacities, including a consultant in Asia, Europe, and the United States. In 1997, he returned to academia and developed research programs in green composites, recycling, surface science of natural polymers, and more recently in coating, in collaboration with more than 30 industry partners. He is involved in several Network of Centre of Excellence programs and recently became the Group Leader of Natural Fiber Composites of the Canadian Network of Centre of Excellence for Automotive of the 21st Century and collaborates internationally in the paper and the natural composite fields. In the year 2001, he received the prestigious Industry-University Synergy Award from Conference Board Canada and NSERC for his excellence to transform research innovation into industrial practice. He is the author of 170+ technical publications in international journals and conferences and holds patents in paper recycling, composite, and fiber products. He is also the author of several book chapters. He is a member of diverse organizations including CPI, TAPPI, PAPTAC, MMO, and the Ontario Professional Engineers Association. He is also a member of advisory boards of industry and institutions.

Jean-Roch Schauder
Application Technology Development Specialist
ExxonMobil Chemical
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Dr. Jean-Roch Schauder is an Application Technology Development Specialist at ExxonMobil Chemical in Machelen, Belgium. His responsibilities include U.S. Application Technology Development for Exxelor Products, WW Application Technology Development for lube oil viscosity modifiers, and Plastomers Development. Previous responsibilities include WW Application Technology Development for Exxelor modifiers, ExxonMobil Chemical; Exxelor modifiers grades development and process support, ExxonMobil Chemical; EPDM grades development, ExxonMobil Chemical; and Research Assistant, Cambridge University. He received a Ph.D. degree in Organic Chemistry from FNDP, Namur, Belgium.

Stephen M. Shaler
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Advanced Engineered Wood Composites Center
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Dr. Stephen M. Shaler is Professor of Wood Science and Adjunct Professor of Chemical Engineering in the Department of Forest Management, and Assistant Director of the Advanced Engineered Wood Composites Center at the University of Maine, Orono, Maine. He has received several awards and has served on numerous committees. He is a Technical Reviewer for several publications including *Wood and Fiber Science Forest Products Journal*, *TAPPI*, and *Modeling and Simulation in Materials Science and Engineering*. He is the author or coauthor of numerous publications and presentations. He is a member of the Society of Wood Science and Technology, Forest Products Society, Pulp and Paper Association of Canada, and International Society for Optical Engineering. He received a B.S. degree in Wood Science and Technology and an M.S. degree in Wood Engineering from Colorado State University, and a Ph.D. degree in Forest Resources from Pennsylvania State University.

William D. Sigworth
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Crompton Corp.
Middlebury, Connecticut, USA

Dr. William D. Sigworth received his Ph.D. from Case-Western Reserve University and joined Crompton Corporation's predecessor, Uniroyal, Inc. at their Research Center in Wayne, New Jersey in 1970. He is currently responsible for new product and applications development in the the Polymer Modifiers Group. His work in this area has led to new opportunities in the areas of wood and natural fiber-filled plastics as well as polypropylene nano-composites. In previous assignments, he served in the Technical Service department of the Trilene® liquid polymers business where he was instrumental in developing products for the telecommunications, sealants, and rubber industries. He has also worked on the development of Royalene® polymers with improved heat resistance, elucidating the effects of oxidate degradation on long-term tire performance, and determining the mechanisms of air loss in tires. Dr. Sigworth has been active in corporate safety programs and currently serves on the Steering Committee of the STAR behavioral based safety program.

Jungil Son
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Advanced Engineered Wood Composites Center
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Dr. Jungil Son is a Post-Doctoral Research Associate in the Advanced Engineered Wood Composites Center at the University of Maine in Orono, Maine. He is involved with research in several project areas. Previously, he was a Post-Doctoral Research Associate at Seoul National University and a Researcher at the Forestry Research Institute of South Korea. He received his B.S., M.S., and Ph.D. degrees from Seoul National University in Suwon, South Korea.

Wayne (Weining) Song
President
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Dr. Wayne (Weining) Song is President of Futuresoft Technologies (Beijing) Company, Ltd. (FTI). His responsibilities include managing and developing Chinese markets for FTI's turn-key wood-plastic composite systems; new development in polymer nano-composite and other high end co-extrusion systems; and coordinating FTI's international marketing in North America and Europe. He is also Director of Futuresoft Technologies Inc. in Toronto, Canada where he is in charge of North American marketing of wood-plastic technology and systems, especially profile dies and extrusion processing technology. He received a B.S. degree from Peking University-Beijing, a Master of Engineering degree from Tsinghua University-Beijing, and a Doctor of Philosophy degree from McMaster University, Hamilton, Canada.

Morwenna J. Spear
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Dr. Morwenna J. Spear is a Research Officer in the School of Agricultural and Forest Sciences at the University of Wales, Bangor, Gwynedd, United Kingdom. His responsibilities include research in wood preservation and chemical modification of wood and laboratory supervision of undergraduates and post-graduates. He received a B.S. degree in Forestry and Forest Products and a Ph.D. degree in Compatibilization of Natural Fibers from the University of Wales.

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Klaus Specht is a Ph.D. Student at the Institute for Materials Science, University of Kassel, Kassel, Germany. His responsibilities include research in the area of natural fiber-reinforced composites. He received two Graduate Engineer degrees from the University of Kassel.

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Dr. Volker E. Sperber is Senior Lecturer at the Institute for Materials Science, University of Kassel, Kassel, Germany. His responsibilities include lectures, organizing conferences, and consulting services for business development. Previously, he was Manager of New Developments at EWvK (a joint enterprise of BASF, Bayer, and Hoechst AG) for plastic development and recycling. He received a Diplomchemiker degree from the Universitaet des Saarlandes in Saarbruecken, Saarland, Germany, and a Dr. rer. nat degree from the Universitaet des Saarlandes, Saarbruecken, Saarland, Germany.

Brett C. Suddell
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Dr. Brett C. Suddell graduated from the University of Wales Swansea in 1996 with a degree in Materials Science and Engineering with honors. In 1998, he conducted research in ceramic matrix composites in aero engines as part of the Masters of Research degree (MRes) for Rolls Royce Plc. Continuing his sponsorship with Rolls Royce Plc., and obtained a Ph.D. in 2001. Since completing his Ph.D., Dr. Suddell has been working as a Research Officer in the Interdisciplinary Research Centre for Computer Aided Materials Engineering at the University of Wales Swansea working in the area of natural fiber composite materials. His work has included conducting a major world survey in the use of natural fibers within composite systems. He has been invited to write a book chapter on "The use of natural fiber composites within the automotive industry" by Michigan State University and also speak to the United Nations IGG forum on Hard Fibers in Brazil. Dr. Suddell was responsible, along with Professor John Evans, for setting up the Natural Fiber Composites Group within the IRC in 2001. He is also active within the Institute of Materials, Minerals, and Mining of the United Kingdom (formerly the Institute of Materials). He is Chair of the Younger Members Committee for the United Kingdom, which is responsible for 4,500 people in the materials sector under the age of 35. He has been responsible for increasing the profile of younger members within the Institute and the Younger Members Committee now has a reputation as being one of the most active and successful committees within the Institute. He is also responsible for setting up the prestigious Institute Silver Medal, which is awarded annually to a younger member. Dr. Suddell also holds positions on the Professional Policy Board, and an ex-officio position on the Institutes governing body - the Council. He has been invited to sit on the United Kingdom's Materials Strategy Commission and has been an active member of the Materials Congress executive since 1998. He is also Vice President of the South Wales Metallurgical Association. He has also been an invited judge at the National Lecture Competitions and the Science, Engineering, and Technology awards for Britain. He was also invited to be an External Advisory group member for the Engineering and Physical Science Research Council advising on issues relating to post-graduate students. He has been awarded the designatory letters AMIMMM. He has also been on the organizing committee

for four conferences (chairing two of these), organized two individual day sessions, and has opened one of the conferences in question.

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Dr. Masahiro Takatani is an Associate Professor in the Department of Agricultural Chemistry, Faculty of Agriculture, Kin-ki Daigaku University, Nara-shi, Nara, Japan. He is responsible for research in the manufacture of wood-plastic composites and adhesives for wood.

Divino Eterno Teixeira
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Dr. Divino Eterno Teixeira is a Wood Products Researcher at the Brazilian Institute of Environment in Brasilia. He is Head of a section on forest products research development. He is responsible for planning and executing research in woodfiber composites, wood thermoplastics, particleboard, and wood-cement composites. He is also a member of the Editorial Committee of four Journals on the subject of forestry and forest products. He received a B.S. degree in Forest Engineering (Wood Technology) from the University of Brasilia, and M.S. and Ph.D. degrees from the College of Forestry, Wildlife, and Range Sciences, University of Idaho. He also received a degree in Specialization in Forest Products from the Forestry and Forest Products Research Institute in Tsukuba, Ibaraki, Japan.

Robert J. Tichy
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Dr. Robert J. Tichy is a Research Engineer at the Wood Materials and Engineering Laboratory, Washington State University, Pullman, Washington. His research focus is on product and market development for the engineering use of wood-based products. Prior to joining Washington State University in 1992, he worked in the forest products industry where he held positions with the Western Wood Products Association as Manager of Engineering Research and Development; with Weyerhaeuser Company as Senior Engineer with the Engineered Systems and Products Group; and as President of Technology Management and Implementation, Inc. He received a B.S. degree in Wood Technology from the University of Illinois, an M.S. degree in Wood Engineering from Colorado State University, and a Ph.D. degree in Materials Science and Engineering from Washington State University.

Ken Tsuchibe
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Ken Tsuchibe is the Technical and Marketing Manager at Mitsubishi Rayon America in New York, New York. He received a Bachelor degree from the Department of Engineering at Tohoku University in Sendai, Miyagi-ken, Japan.

Praveen Tummala
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Michigan State University
East Lansing, Michigan, USA

Praveen Tummala is a Visiting Research Specialist in the Composite Materials and Structures Center at Michigan State University, East Lansing, Michigan. His responsibilities include the development and fabrication of bio-plastics for polymer matrix in eco-friendly bio-composites; fabrication of bio-composites from natural fibers and commer-

cial thermoplastics; and development of polymer nano-composites from nano-particles like clay and polymer matrices. He received a Bachelor of Technology degree from Andhra University in Vizag, Andhra Pradesh, India, and an M.S. degree from Michigan State University.

Lih-Sheng (Tom) Turng
Assistant Professor/Co-Director, Polymer
Engineering Center
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Madison, Wisconsin, USA

Dr. Lih-Sheng (Tom) Turng is an Assistant Professor in the Department of Mechanical Engineering, and Co-Director of the Polymer Engineering Center and its Industrial Consortium - a multi-university research site of NSF Industry/University Cooperative Research Center for Advanced Polymer and Composite Engineering. As Assistant Professor, his responsibilities include teaching and research in polymer processing with conventional and advanced processes, materials, and tools and directing sponsored research programs on microcellular injection molding and nano-composites. Before joining the University of Wisconsin-Madison, Dr. Turng was with C-MOLD, a company recognized for its advanced plastics CAE simulation packages. Dr. Turng is the lead author of the book "C-MOLD Design Guide - A Resource for Plastics Engineers," which covers process physics, material properties, design rules, troubleshooting, and judicious interpretation of simulation results for plastics design and manufacturing. He was also the Task Leader of C-MOLD KnowHow!, the first web-based Knowledge Management System specifically for the plastics industry. As a result of a team effort, C-MOLD KnowHow! won the 1999 Technology of the Year Award from *Industry Week* and the Best Product of 1999 in computer productivity tools category from *Design News*.

William T.Y. Tze
Ph.D. Candidate
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Orono, Maine, USA

William T.Y. Tze is a Ph.D. Candidate in the Department of Forest Management at the University of Maine, Orono, Maine. He performs his research in the Advanced Engineered Wood Composites Center and the Laboratory for Surface Science and Technology. His research focuses on physical and chemical characterization of wood and fiber surfaces, and evaluation of fiber/polymer interfacial bonding in composites. Other research experience includes pulping and bleaching studies of agricultural fibers and evaluation of sawing and woodworking properties of tropical wood. He is a member of the Forest Products Society, Society of Wood Science and Technology, and the American Chemical Society. He was the recipient of the International Tropical Timber Organization Fellowship in 1994. He performed his fellowship at the University of Reading and Oxford University in the United Kingdom, for enhancing his experience in managing statistical data and formulating research in forestry. He previously held positions as a Guest Researcher in the Polymers Division of the National Institute of Standards and Technology in Gaithersburg, Maryland; Graduate Research Assistant in the School of Forestry and Wood Products at Michigan Technological University; Wood Science and Utilization Research Officer in the Sepilok Forest Research Center of Malaysia; and Shift-in-Charge of the pulp and paper mill plant in Sabah Forest Industry, Malaysia. He received a Bachelor of Forestry Science (Wood Industry Concentration) degree from the Universiti Putra Malaysia, an M.S. degree in Forestry (Wood Science) from Michigan Technological University, and an Advanced Certificate in Pulp and Paper Management from the College of Engineering, University of Maine.

Steven A. Verhey
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Dr. Steven A. Verhey is a Research Assistant Professor in the School of Forest Resources and Environmental Science at Michigan Technological University in Houghton, Michigan. His responsibilities include research pertaining to the durability of wood-based composites; woodfiber-thermoplastic composites, in particular. He also has additional responsibilities for helping to promote and develop a new minor degree program in Engineered Wood Products. He received a B.S. degree in Chemistry from the University of Wisconsin-Stevens Point, and an M.S. degree in Chemistry (Polymer Chemistry) and Ph.D. degree in Forest Science from Michigan Technological University.

Michael P. Wolcott
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Dr. Michael P. Wolcott is an Associate Professor in the Department of Civil and Environmental Engineering, and Research Director at the Wood Materials and Engineering Laboratory, Washington State University, Pullman, Washington. Previously, he was an Assistant Professor of Wood Science at West Virginia University. He received several awards including the Forest Products Society's Wood Award (1990), Society of Wood Science and Technology's George Marra Award (1991 and 1995), Cahn Instruments' Cahn Award (1992), and Wood Louisiana-Pacific Endowed Professorship of Wood Materials and Engineering (1997). He received a B.S. degree in Wood Science and M.S. degree in Forestry from the University of Maine, and a Ph.D. degree in Materials Engineering Science from Virginia Tech.

Yibin Xue
Research Coordinator
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Dr. Yibin Xue is Research Coordinator in the Department of Engineering at Clark Atlanta University in Atlanta, Georgia. Dr. Xue is responsible for leading experiment, numerical, and analytical studies of woodfiber-plastic composites. Previously, she was Senior Research Scientist at Microcosting Technologies, Inc. and a Research Associate at Georgia Institute of Technology. She received a B.S. degree in Applied Mechanics from Dalian University of Technology in Dalian, Liaoning, P.R. China, and M.S. and Ph.D. degrees in Mechanical Engineering from Georgia Tech in Atlanta, Georgia.

Wenyang Zhang
Plastic Materials Engineer
AM Plastics, Ltd.
Toronto, Ontario, Canada

Dr. Wenyang Zhang is a Plastic Materials Engineer at AM Plastics, Ltd. in Toronto, Ontario, Canada. His responsibilities include checking standard for the contaminate from industrial plastic scraps; improving the existing recycle process by reviewing the processing procedure; and plastic materials test. Previously, he was a Ph.D. Candidate at the Institute of Materials Science, University of Kassel, Kassel, Germany. He received a German Patent 201045842, "Verbundwerkstoff" (March 2001) and has been the recipient (four times) of the Provincial Invention Award (1991-1994).

SESSION ABSTRACTS

MONDAY MORNING, MAY 19

OPENING PLENARY SESSION

Natural and Woodfiber Composites in North America and Europe

James Morton, John Quarmley, and Lou Rossi, Senior Partners, Principia Partners, Exton, Pennsylvania, USA

Natural and woodfiber-plastic composites (WPC) have become the most dynamic growth materials of this decade. The products compete with a broad array of traditional and performance materials including lumber, plastics, concrete, and metal. Driven by their distinct competitive advantages, demand for WPCs are projected to reach over \$1.4 billion worldwide by 2007 with continued strong growth through 2010. The growth of WPCs continues in both Europe and North America as demand for established automotive and building products increases and new applications are commercialized. Myriad new building product, infrastructure, industrial, and consumer applications are emerging as significant outlets for WPCs, and offer major opportunities for suppliers of wood/forest products, plastics, and processors. Principia Partners has conducted extensive research on the world market for this exciting and rapidly changing industry. This paper presents the results of a detailed study of applications for wood and natural fiber composites, the market opportunities, and takes the first detailed look at the European WPC industry, which is poised for dramatic growth.

The Increasing Use and Application of Natural Fiber Composite Materials Within the Automotive Industry

Brett C. Suddell, Research Officer, and *W. John Evans*, Professor/Director, Interdisciplinary Research Centre for Computer Aided Materials Engineering, School of Engineering, Univ. of Wales, Swansea, United Kingdom

Composite systems based on natural fibers is not a new concept - they were first introduced some 3,000 years ago in ancient Egypt where straw and clay were used together to build walls. Interest in natural fibers diminished with the advent of other more durable construction materials such as metals and it was not until the 1940's that natural fibers began to make a comeback. Within the last 15-20 years the field of natural fiber research has experienced an explosion of interest, particularly with regard to its replacement for glass fibers within composite materials. The main area of increasing usage of these novel materials is the automotive industry, predominantly for interior applications. The increase in interest in these composites has been triggered by the demands of the consumer along with government legislation also encouraging their adoption. This presentation will cover the results of a recent survey on the current status of these novel materials. The aim of the presentation is to present a broad overview in terms of the different fibers currently being employed throughout the world along with their respective applications. Particular emphasis will be given to their increasing use in composites within Europe and other countries from around the world. The reasons why these novel materials are being used more frequently and the future that lies ahead will be assessed.

Experiences with the Development and Commercialization of Engineered Woodfiber-Plastic Composites

Donald A. Bender, Professor/Director, and *Michael P. Wolcott*, Associate Professor/Research Director, Wood Materials & Engineering Lab, Washington State Univ., Pullman, Washington, USA

As a university laboratory that works with numerous companies and government agencies, our experiences with developing woodfiber-plastic composites (WPCs) are different than those of an individual firm. The objective of this presentation is to highlight some of our general experiences in hopes that they will bring value to the WPC industry with regard to developing and launching engineered, code-conforming building products. Insights on commercial opportunities for engineered products can be gained by considering trends in the regulatory environment for engineered construction. Building codes are transitioning from prescriptive to performance-based requirements, with more rigorous enforcement. Structural demands on building systems, such as seismic and extreme wind, are increasing. Design meth-

ods are being developed to give credit to structural systems that have ductility and can dissipate energy during a seismic event. Durability of building materials and the use of toxic chemicals are growing concerns. The opportunities are tremendous to develop WPC products to respond to market opportunities to impart material performance and structural shapes in novel building components. Relatively low capitalization requirements for WPC manufacturing allow innovation and rapid introduction of new products. Navigating the code approval process can be daunting and can hamper innovation. We will share our experiences with codes and standards, with the goal of showing how to make the process work for you. In addition, we will discuss our approach for overcoming the "chicken and egg" problem with commercializing new technology. Finally, we will summarize our lessons learned and share our vision for commercial opportunities in engineered WPC products.

MONDAY AFTERNOON, MAY 19

CONCURRENT SESSIONS

SESSION 1A: FIBER-MATRIX ADHESION AND INTERPHASE

Epolene™ Maleated Polyethylene Coupling Agents

Travis Keener, Product Development Representative, and *Tom Brown*, Technician Associate, Eastman Chemical Company, Longview, Texas, USA

Since polar natural fibers and non-polar polyolefins have negligible attraction for each other, the result is encapsulation of wood fibers in the polyolefin matrix with little or no interaction. Coupling agents help overcome the polarity disparity to increase composite strength and moisture resistance. The Epolene™ G Series product line includes new maleated polyethylenes developed for wood/polyethylene (PE) composites - the largest portion of the natural fiber composite market. With the maleated PE coupling agents, wood fibers more effectively serve as reinforcement instead of filler. The amount of maleic anhydride in a coupling agent measured by acid number gives an indication of its attraction to the natural fiber. The molecular weight (or melt index) of the coupling agent gives an indication of its attraction to the polyolefin. The statistical evaluation results of wood/PE composite tests are presented, indicating the best combinations for melt index and acid number. The balanced attraction of coupling agents toward wood and polyolefins is evidenced by strength improvement data, such as tensile strength increasing from 3000 to 6000 pounds per square inch for wood/PE composites without and with coupling agent, respectively. Other composite data and a general discussion of the related benefits are presented.

Coupling Polystyrene and Cellulose Fibers with a Blend of Hydrophilic and Hydrophobic Silanes: Effects on Interfacial Properties

William T.Y. Tze, Ph.D. Candidate, Advanced Engineered Wood Composites Center and Lab for Surface Science & Technology, *Douglas J. Gardner*, Professor/Program Leader, Advanced Engineered Wood Composites Center, *Carl P. Tripp*, Associate Professor, Lab for Surface Science & Technology, *Shane C. O'Neill*, Research Associate, Advanced Engineered Wood Composites Center, and *Stephen M. Shaler*, Professor of Wood Science/Assistant Director, Advanced Engineered Wood Composites Center, Univ. of Maine, Orono, Maine, USA

The objective of this research was to examine the effects of hydrophilic- and hydrophobic-functional silanes, individually and in combination, on the surface chemistry of fibers and subsequently the interfacial properties of cellulose-fiber/polystyrene composites. Cellulose fibers were treated with 1) amine silane, a hydrophilic-functional silane which is expected to keep the fiber surfaces highly polar, and 2) phenyl silane, a hydrophobic-functional silane which, with its benzene ring, is expected to have good compatibility with polystyrene. Some cellulose fibers were also silanated with an equal molar of amine and phenyl functionalities. For reference, fibers were modified with silane of alkane groups which are known to be non-reactive and hydrophobic. To quantify the affinity of fibers to water, dynamic contact angle analysis was carried out for surface wettability. To predict

the fiber/polymer interaction, inverse gas chromatography was performed on both fibers and the matrix polymer for their respective non-polar and polar interaction capabilities. To examine the fiber/polymer interphase, Raman micro-spectroscopy was conducted for strain distributions based on the frequency shift of strain-dependent Raman bands of cellulose at various locations of the interphase. Results show that the interfacial properties of cellulose-fiber/polystyrene composites do not depend solely on the hydrophilicity or hydrophobicity of the fibers. However, using a bond promoter bearing a blend of hydrophilic and hydrophobic functionalities may have an impact on the response of the interphase to water attack.

Synthesis of Di-block Copolymers as Wood-Plastic Compatibilizers

Kaichang Li, Assistant Professor, *Cheng Zhang*, Graduate Student, and *John Simonsen*, Associate Professor, Dept. of Wood Science & Engineering, Oregon State Univ., Corvallis, Oregon, USA

Extensive studies on filled polymer composites suggest that an ideal compatibilizer should be a di-block copolymer, having one block that has strong adhesion to the polymer matrix and the other block able to form strong bonds with the filler. Because thermoplastics such as polyethylene are quite chemically inert, strong adhesion of a compatibilizer with the thermoplastic mainly relies on strong entanglements or segmental crystallization. It is thus essential that the plastic binding domain has the same or a very similar structure as that of the plastic matrix. Therefore, in the case of wood-polyethylene composites, an ideal compatibilizer is supposed to be a di-block copolymer, consisting of polyethylene as one block and a strong wood-binding domain as another block. In this study, we investigated how to introduce a functional group such as a hydroxyl group, a carboxylic acid group, and an amino group to the chain end of polyethylene. We also investigated how to connect a polyethylene chain to a wood-binding domain via a terminal functional group of polyethylene. Di-block copolymers thus produced were also evaluated as a wood-polyethylene compatibilizer.

Vinyl Acetate-Acrylic Acid Copolymers as Coupling Agents for Wood Flour-Vinyl Composites

Gerard T. Caneba, Associate Professor, Dept. of Chemical Engineering, Michigan Technological Univ., Houghton, Michigan, USA

The free-radical retrograde-precipitation polymerization (FRRPP) process has been used to efficiently produce copolymers of vinyl acetate and acrylic acid. As a copolymer coupling agent, the acrylic acid segments would bond to the wood surface while the vinyl acetate segments would be compatible with the vinyl matrix. The copolymers that were produced range from almost purely block type (>98% block material) to purely random type (with almost equal spacing of acrylic acid in the polymer chains). For economic reasons, acrylic acid contents at 10 wt % or lower have been produced with effective amphiphilic properties. Molecular weights are in the order of 30-40 kDaltons, and polydispersity indices in the 2-3 range. This paper will provide details of the properties of some of these newly-synthesized vinyl acetate-acrylic acid copolymers. Use of one of these copolymers as coupling agents for wood flour-vinyl composites is being investigated, and results will be shown. Comparisons will be made with composites employing no coupling agents.

Transcrystalline Interphases in Polypropylene Composites: Exploring the Possibilities

Morwenna J. Spear, Research Officer, and *Callum A.S. Hill*, Senior Lecturer, School of Agricultural & Forest Sciences, and *Jeremy Tomkinson*, Director, The BioComposites Centre, Univ. of Wales, Bangor, Gwynedd, United Kingdom

Natural fiber filled thermoplastics are becoming widely accepted in a range of non-structural or low impact uses. The full potential of long natural fibers (such as hemp, flax, jute, and sisal) is however not being harnessed. In order to maximize the benefit of the strength and length of these fibers, a greater understanding of the properties of the interphase region is required. Among the issues to study are the interfacial shear strength and the deformation mechanism of the interphase material around the fiber. Polypropylene is unique among polymer matrices in offering a range of different interphase morphologies. Many semi-crystalline matrices yield a phenomenon known as transcrystallinity when fibers are present. Polypropylene, which has four different crystalline morphologies (α , β , ν , and σ) can give transcrystallinity of either the α - or the β - form. Fiber surface chemistry and topography play significant roles in determining the structure of the interphase material. Transcrystalline layers are common around cellulose fibers.

The presence of lignin on the fiber surface, and compatibilizer in the matrix can alter the structure of the interphase significantly, as can processing conditions. Examples of the effect of generating and exhibiting α - and β - transcrystalline structures will be given in this presentation. A variety of chemical modification methods were applied to TMP and hemp fibers to achieve these results.

SESSION 1B: DURABILITY

Combined UV and Water Exposure as a Preconditioning Method in Laboratory Fungal Durability Testing

Rebecca E. Ibach, Research Chemist, *Craig M. Clemons*, Research General Engineer, and *Nicole M. Stark*, Chemical Engineer, USDA Forest Products Lab, Madison, Wisconsin, USA

During outdoor exposure, woodfiber-plastic composites (WPCs) are subject to biological, moisture, and UV degradation, or a combination thereof. The purpose of laboratory evaluations is to simulate outdoor conditions and accelerate the testing for quicker results. Traditionally, biological, moisture, and UV laboratory tests are done separately, and only combined in outdoor field exposure. This research evaluates WPCs exposed to a combination of UV, moisture, and fungal degradations. Due to the slow moisture sorption of WPCs, the ASTM D 1413 Standard laboratory soil block test was modified to include preconditioning by UV and water. WPCs consisting of 50% western pine wood flour and 50% high-density polyethylene (HDPE) were extruded into 1.2" x 5.5" radius edge deck boards. Four formulations were extruded: 1) control, 2) 1% zinc borate, 3) 1.5% UV package, and 4) 1% zinc borate + 1.5% UV package. Specimens (3 by 13 by 89 mm) were cut from the boards and then exposed to one of two preconditioning methods: 1) weatherometer for 1000 hours plus a 2-week water soak, or 2) 2-week water soak. After the 2-week water soak, the autoclaved "wet" specimens were placed in a horizontal soil block test against the brown-rot fungus *Gloeophyllum trabeum* for 12 weeks. Moisture content, weight loss, and thickness were monitored. Matched field stakes were placed above and in-ground in Madison, Wisconsin, and Saucier, Mississippi for ultimate comparison.

Borates as Fungicides in Woodfiber-Plastic Composites

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The use of woodfiber-plastic composites (WPCs) in North America has grown dramatically over the last 5 years, driven primarily by their use in outdoor decking products. Initially, these materials were assumed to be inherently resistant to fungi and insects and were touted by the manufacturers as being a 'maintenance free' product. It was thought that the thermoplastic resin would completely envelop the wood particle, thereby protecting it against wood destroying organisms. Standard laboratory tests evaluating the performance of commercially produced WPCs against decay fungi have exhibited weight losses of between 10 and 20% in as little as 4 months time - this equates to a 20 to 40% weight loss of the wood component for WPCs with a wood:plastic ratio of 50:50. The ability for these materials to absorb moisture has been identified as a significant factor in determining decay susceptibility in these laboratory tests. The aforementioned evaluations were carried out on 'virgin' material that was purchased at retail outlets and had not been exposed to the elements. In separate tests, subsequent weathering of this material - both accelerated laboratory weathering (QUV) and natural exterior exposure to the elements - yielded significant increases in moisture uptake relative to the unexposed samples. The relevance of this increased moisture uptake to decay susceptibility and possible impact on long-term performance will be discussed. When solid wood and wood composites are used in applications where susceptibility to decay and termites may be an issue, it is common practice to utilize a preservative to provide protection against wood destroying organisms. This paper will also describe results evaluating the use of zinc borate as a preservative treatment for WPCs. Borates have been used globally as wood preservatives for over 60 years and zinc borate has been commercially utilized as a preservative treatment for woodfiber-composites for the last decade. The thermal stability of zinc borate allows it to be incorporated during the manufacture of both woodfiber and woodfiber-plastic composites. Results from this work indicate that preservative treatment of WPCs with zinc borate can provide protection against decay fungi.

Processing Effects on the Photodegradation of Wood-Polyethylene Composites

Nicole M. Stark, Chemical Engineer, USDA Forest Products Lab, Madison, Wisconsin, USA, *Laurent M. Matuana*, Assistant Professor, Dept. of Forestry, Michigan State Univ., East Lansing, Michigan, USA, and *Craig M. Clemons*, Research General Engineer, USDA Forest Products Lab, Madison, Wisconsin, USA

Wood-plastic lumber is promoted as being a low-maintenance high-durability product. As a result, the use of wood-plastic composites by the construction industry for exterior non-structural or semi-structural building products are on the rise. This has led to a concern about the durability of these products. It has been shown that wood-plastic composites exposed to accelerated weathering may experience a color change and/or loss in mechanical properties. The method of manufacturing wood-plastic composites leads to different surface characteristics, which can influence weathering. In this study, 50% wood flour filled high-density polyethylene (HDPE) composites underwent accelerated weathering in a xenon-arc weathering apparatus. The composites studied were either injection molded, extruded, or extruded with the surface planed. After 1000, 2000, and 3000 hours of accelerated weathering the samples were analyzed for color fade and loss of flexural strength and modulus of elasticity. In addition, Fourier transform infrared spectroscopy was employed to monitor surface chemical changes and changes in HDPE crystallinity.

Performance of Plastic Lumber Composites Under Simulated Wildfire Exposures

Stephen L. Quarles, Wood Durability Advisor, *Laurence G. Cool*, Research Associate, and *Frank C. Beall*, Professor/Director, Forest Products Lab, Univ. of California, Richmond, California, USA

In order to assess the contribution of commonly-used construction materials to the vulnerability of structures in the urban wildland interface, UCFPL researchers have developed fire test protocols for roof coverings and assemblies, attached decks, exterior wall claddings, and windows. This paper presents an overview of the test results on all-plastic, wood-plastic, and solid wood decking materials. Test decks were constructed from five 600 mm (24 in.) boards supported by two Douglas-fir joists. Decks were either subjected to an under-deck fire (three minute exposure to an 80 kW flame propane flame) or an above-deck exposure (an ASTM E-108 "A" brand). Deck performance was evaluated by three criteria: 1) dropping of flaming debris, 2) accelerating flaming combustion, and 3) collapse of a deck board. Performance of the decking products depended on the cross-section form (solid, hollow, or channeled), material composition (e.g., plastic component and wood-plastic ratio), and fire exposure (under- or above-deck). For example, channeled products, regardless of material, did poorly in the under-deck exposure tests, while the hollow products performed poorly in the above-deck exposure tests.

Molecular Relaxations Contributing to Phase Transitions Creep in Thermoplastic Wood Composites

Michael P. Wolcott, Associate Professor/Research Director, *David Harper*, Graduate Research Assistant, and *Karl Englund*, Research Associate, Wood Materials & Engineering Lab, Washington State Univ., Pullman, Washington, USA

Thermoplastic wood composite formulations contain several polymeric components that aid in both the processing and performance of the end material. These commercial lubricants and additives show limited solubility in the homopolymer matrix. Their selection is often targeted specifically to induce phase separation, thereby facilitating external lubrication of the melt or interfacial coupling between the two material components. Microbeam Fourier transform infrared spectroscopy has been used to chemically image the spatial distribution of lubricants and coupling agents in a wood-polypropylene composite. Both lubricants and coupling agents tended to congregate in the amorphous regions between the crystallites. Other researchers have found that these regions have a large influence on the overall deformation of the bulk materials. The approach to this research has been to investigate the molecular origins of relaxations using dynamic mechanical analysis (DMA) and to compare this behavior to time-dependent creep and recovery behavior of the materials. This research demonstrates the overall role of processing aids in controlling mechanical performance of the solidified composite as well as the rheological behavior of the composite melt. In addition, material response to long-term loading appears to be strongly correlated to the copolymer selection.

TUESDAY MORNING, MAY 20

CONCURRENT SESSIONS

SESSION 2A: FIBER AND MICROSTRUCTURE

Advanced Technology for the Processing of Natural Fiber Plants for Industrial Application

Friedrich Munder, Project Manager, *Christian Fülll*, Head of Department, and *Heiz Hempel*, Engineer, Inst. of Agricultural Engineering Bornim e.V., Potsdam, Germany

Natural fibers of hemp, flax, and linseed are gaining progressive acceptance as renewable and environmentally acceptable raw materials for industrial applications. Due to their first-rate mechanical properties, hemp, flax, or linseed fibers can substitute for synthetic, carbon, and glass fibers in a wide range of industrial products. A complete new machine line for the processing of natural fiber plants was developed, which includes all process stages from pick-up and cutting of straw bales up to the cleaning of the final products, fibers, and shives. The fiber plants are processed with the same technology that suits both freshly harvested green and retted plants. The developed decorticating machine ensures complete fiber decortication and an efficient fiber yield of up to 29% for flax and up to 26% for hemp. The processed fibers have a fineness in the range from 2.5 to 15 tex. The length of the fibers is adjustable in the range from 50 to 200 mm. These fibers can be shortened by additional cutting to a defined length, e.g. from 2 to 10 mm. The tear strength of the fibers varies in the range from 32 to 44 cN/tex. A capacity of 3 t/h of straw and the low investment costs permit manufacturing of natural fibers at competitive prices while meeting the requirements of many industrial applications.

Characterization of Wood Fibers for Woodfiber-Plastic Composites: Nondestructive Nuclear Magnetic Resonance Relaxometry Analysis of Secondary Metabolites in Maritime Pine Fibers

Bernard De Jéso, Professor, Organic Chemistry, and *Nicole Labbé*, Ph.D., Laboratoire de Chimie des Substances Végétales, *Michel Pétraud*, Research Engineer, Centre d'Etude Structurale et d'Analyse des Molécules Organiques, *Max Ratier*, Research Engineer, Laboratoire de Chimie Organique et Organométallique, and *Gilles Sèbe*, Associate Professor, Laboratoire de Chimie des Substances Végétales, Université Bordeaux 1, Talence, France

Reinforcement in composite materials implies a strong adhesion between the fiber and the polymeric matrix. Coupling agents are used in order to improve the physical properties of fiber-reinforced composites. Depending on their origin, wood fibers may contain different secondary metabolites such as lipids, terpenes, and water. These compounds may interact with the coupling agents, which may have a significant influence on the efficiency of the coupling between the fibers and the matrix. The purpose of this work was to characterize the water and extractives present in wood fibers by using Nuclear Magnetic Resonance Relaxometry. By combining Free Induction Decay (FID), Spin Echo techniques (Carr-Purcell-Meiboom-Gill) and low resolution NMR, it was possible to discriminate free and bound water as well as secondary metabolites. Depending on molecular mobility, different transverse relaxation times (T_2), ranging from 0.5 to 500 ms, were found. In order to measure these T_2 constants, we used the CONTIN algorithm proposed by Provencher. In the case of maritime pine (*Pinus pinaster*), the untreated sapwood exhibited a four components distribution of T_2 , for both water and extractives. On the other hand, results obtained with heartwood appeared to be more variable since three to five components were observed, depending on the sample. The methodology consists of combining chemical as well as high resolution NMR analysis. For instance, organic solvent added on the sample drastically changed the mobility of organic phases and the corresponding T_2 from 10 up to 1000 ms. The molecular structure of the components of each organic phase was determined by NMR spectroscopy. In this way, we were able to clearly characterize the water phase and the mobile organic phase present in wood fibers. In summary, the NMR techniques proposed in this paper give new insight into the molecular composition of the so-called liquid phase in wood, namely free and bound water and other secondary metabolites. This technique can be used to monitor the chemical modification of wood fibers involved in the design of wood-plastic composites.

Influence of Fiber Treatment on the Thermal Long-time Behavior of Wood and Hemp Fiber-Polypropylene Composites

Klaus Specht, Ph.D. Student, and *Andrzej K. Bledzki*, Professor, Institut für Werkstofftechnik, Kunststoff- und Recyclingtechnik, Universität Kassel, Kassel, Germany

Natural fiber composites like wood or bast fiber-reinforced polymers are increasingly being used in applications in the automotive, furniture, or building industry. In addition to processing and physical properties, the long-time behavior of these materials is a very important parameter in respect to the design layout, product guaranty, and finally, the product liability. There are many factors that influence long-time behavior of natural fibers and fiber composites: Harvesting method, pulping techniques, agglomeration or compounding processes, injection molding or extrusion parameters, mechanical properties, and also environmental impact in application on the natural fiber composites products. Fundamental investigations were made as to the impact of fiber treatment of wood flour and hemp fibers on their thermooxidative long-time behavior. In addition, the influence of coupling agents, fiber content, and the polypropylene matrix material on mechanical and thermo analytical properties was studied. Thermal tests were made at 80°C, 120°C, and 160°C for up to 30 days. The fibers were tested for DSC, TGA, and the degree of polymerization. Tensile, bending and impact tests, TGA, and DSC-OIT measurements of the composites are described. Physical and thermo analytical parameters are represented in Arrhenius-charts in order to extrapolate the lifetime of the composites.

Impact Toughness of Cellulose Fiber-Reinforced Polypropylene: Influence of Microstructure in Laminates and Injection Molded Composite

Craig M. Clemons, Research General Engineer, and *Daniel F. Caulfield*, Research Chemist, USDA Forest Products Lab, Madison, Wisconsin, USA, and *A. Jeffrey Giacomini*, Professor, Mechanical Engineering & Rheology Research Center, Univ. of Wisconsin, Madison, Wisconsin, USA

Unlike their glass-reinforced counterparts, microstructure and dynamic fracture behavior of natural fiber-reinforced thermoplastics have hardly been investigated. We characterized the microstructure of cellulose fiber-reinforced polypropylene and determined its effect on impact toughness. Fiber lengths were reduced by one-half when compounded in a high-intensity thermokinetic mixer and then injection molded. At low fiber contents, there was little fiber orientation; at high fiber contents, a layered structure arose exhibiting differing fiber orientations through the thickness of the specimen. Scanning electron microscopy of acid etched specimens revealed spherulitic structure emanating from cellulose fibers (i.e. transcrystallinity) in injection molded composites containing less than 5% fibers. The etching procedure failed to provide any matrix surface relief in high fiber content composites. To better control composite microstructure and understand its influence on impact toughness, model laminates containing aligned fibers were produced and tested. Instrumented Charpy impact tests were performed and analyzed using linear elastic fracture mechanics. Dynamic critical energy release rates and dynamic critical stress intensity factors increased with cellulose content and with orientation of fibers perpendicular to the crack plane. A simple model successfully related the microstructure to the dynamic fracture toughness for both injection molded composites and laminates.

Micromechanical Aspects of Stiffness and Moisture Expansion in Woodfiber-Reinforced Thermosets

E. Kristofer Gamstedt, Assistant Professor, Dept. of Solid Mechanics, Royal Inst. of Technology (KTH), Stockholm, Sweden

Woodfibers for paper applications may be utilized as reinforcement in plastics. This study concerns the use of some conventional wood pulp fibers to form composites by resin transfer molding. The matrix was an epoxy vinyl ester. A micromechanical model has been developed to account for the contribution of the fiber stiffness to that of the composite. The fiber anisotropy, volume fraction, and orientation distribution are taken into account. In this way, the potential of various types of fibers can be investigated, even if their composite microstructures are different. An independent test method to characterize fiber stiffness by compression of unimpregnated fiber mats has been devised, and used as validation of the micromechanical stiffness model. Dimensional stiffness by moisture expansion has also been investigated. A model has been developed to assess the role of the fibers in through-thickness and in-plane moisture expansion of the composite

laminates. The proposed methodology may be used as a tool to generically compare the usefulness of different fiber qualities in composites with respect to stiffness and dimensional stability.

Damage Assessment in Woodfiber-Plastic Composites by Means of Material Level Microstructural Characterization

Stephen M. Shaler, Professor of Wood Science/Assistant Director, *Eric Landis*, Associate Professor of Civil Engineering, and *Lech Muszynski*, Assistant Scientist, Advanced Engineered Wood Composites Center, Univ. of Maine, Orono, Maine, USA, and *Svetlana Vasic*, Research Scientist, National Inst. for Structures & Materials Testing, Belgrade, Serbia and Montenegro, Yugoslavia

Material level damage characterization and assessment is potentially a powerful tool for designing optimal manufacturing process parameters, allowing optimal engineering of properties of wood-based materials for extended durability. Changes in microstructure due to both processing variations and damage are, however, difficult to characterize at high resolution within the material. For wood-plastic composites, the heterogeneous nature of the material is an added parameter to be considered when producing characterizations. The objective of this project was to develop experimental tools to quantify damage and other changes in the microstructure that accompany a variety of different loading regimes for wood-plastic composites. In the project, X-ray microtomography (XMT) and laser scanning confocal microscopy (LSCM) were used to create three-dimensional images of internal microstructure at different scales of observation: 3-4 μm for XMT; 0.5 μm for LSCM. Numerical tools were developed to extract quantitative information of the nature and distribution of the different phases of the composite. Filtering and segmentation algorithms were applied to isolate different phases in the 3D images. A hybrid edge detection/watershed approach was found to isolate phases successfully, at a reasonable computational cost. Lattice fracture model of the composites was used in order to match material response to load, based on the heterogeneous microstructure of the composite. Nonlinear load-deformation response can be modeled in a lattice framework that includes accumulated damage, however damage-visco-elastic coupling requires further research effort for more general predictions. The conceptual framework of the project and preliminary results will be presented.

SESSION 2B: PERFORMANCE AND APPLICATIONS

Woodfiber-Plastic Composites for Furniture Applications

Takeyasu Kikuchi, Director, EIN Engineering Co., Ltd., Tokyo, Japan
To date, the market for WPCs has primarily been exterior applications, mainly outdoor decking. EIN offers new applications in the furniture market. The key issues in the furniture market segment are surface finishing and cost reduction. This presentation will cover how we tackled the key issues, how we have developed the new applications, where we are going in the future, and a business model actually developed in Japan.

Woodfiber- and Natural Fiber-Plastic Composites in China: Opportunities and Obstacles

Wayne (Weining) Song, President, Futuresoft Technologies (Beijing) Co. Ltd., Beijing, P.R. China

In this presentation, the development of woodfiber- and natural fiber-plastic composites (WPCs) in China is described, including the current markets, research, obstacles, and future prospects. With its 1.27 billion population, an averaged annual growth rate over 10% for the last 20 years, and GDP (purchasing power parity) of US\$5.56 trillion, China is emerging as one of the largest markets for WPC in several specific markets, including wood-plastic pallets, construction products, etc., though WPC production started less than 10 years ago in China. China has a total land base of 9,326,000 square kilometers with less than 15% forest coverage. China imports wood from North America, Russia, and South Asia. Chinese wood pallets and other packaging materials have longhorn beetle problems, which has no natural enemies. Since 1998, the U.S., Canada, EU, and Japan have banned non-manufactured solid wood packaging products for entry unless they are fumigated. At that time, China was desperate to develop alternatives. Futuresoft formally went into the China market to develop and market wood-plastic pallets in 1999. Since then, Futuresoft has licensed and established six turn-key plants across China with a production capacity of 30,000 tons/year. With China as a huge construction site, WPC has even bigger potential in China's construction material markets. However, construction materials are highly regulated. It is expected that more production of WPC will take place soon. China is an agricultural country with an annual production of rice and corn of

450,000,000 tons. The agricultural fibers, including ricehull, rice and corn straw, cotton straw, etc., are more than 600,000,000 tons per year. Therefore, the majority of the production of natural fiber-plastic composites is currently made from ricehull and plastics, instead of wood fiber. One of the biggest obstacles for Chinese and foreign companies to develop woodfiber-plastic composite technology and markets is pirating. Pirating plants with inferior quality and much lower price products will make it difficult for quality producers to compete and convince customers of the real benefits of woodfiber-plastic composites. In conclusion, China has already become the world's workshop and has tremendous potential for domestic markets for WPC. To grasp the opportunities and avoid the pitfalls, a lot of effort, local cooperation, and long-term strategies are needed.

A Survey of Industrial Applications of Natural Fibers in South America

Alcides Lopes Leão and *José Caraschi*, Professors, UNESP, College of Agricultural Sciences, São Paulo State Univ., Botucatu, Brazil

New opportunities are arising due to an increase in demand by car makers in applying natural fibers in automotive parts. Several crop fibers have been developed in Brazil, including caroá, piaçava, pupunha, mutum, and others. For the automotive industry, which requires large quantities of fiber with uniform qualities, the alternatives are sisal (170,000 ton/yr.), curauá (150 ton/yr. in 2003), and malva, 200 ton/yr. Brazil is the single largest producer country of sisal, and commercially, the only one producing curauá. For South America, the alternatives are sisal in Colombia, abaca in equator, flax in Argentina, and curauá in Venezuela. Crop fibers can be an economic alternative to coca in the Andes region, thereby providing an instrument of land reform and the reduction of drug plantations. Several companies have a strong program for applying natural fiber-based components in their products: Volkswagen do Brazil, DaimlerChrysler, and General Motors do Brazil. Among their suppliers are companies such as Pematec (curauá), Toro (sisal, coir, and jute), Incomar (sisal and jute), Ober (jute and curauá), Indaru (jute and sisal), Antolin (imported kenaf), Tapetes São Carlos (sisal), Poematec (coir), and Art-Gore ("Woodstock" wood and natural fibers). Figures on production and demand are discussed in the paper.

Standards and Codes - Bringing Products to Market

Robert J. Tichy, Research Engineer, Wood Materials & Engineering Lab, Washington State Univ., Pullman, Washington, USA

The past decade has seen enthusiastic development and use of wood-fiber-plastic composites (WPCs) in construction applications. At least in the decking products market, it appears WPCs are finding a home. This paper will discuss some of the reasons for the trend toward WPCs, and the physical and mechanical properties important to building construction applications. Also discussed will be how these products are being tested and evaluated in North America, with specific discussion on how these materials are being scrutinized and accepted by the model building codes.

Maintaining the Aesthetic Quality of Woodfiber-Plastic Composite Decking with Isothiazolone Biocide

Peter Dylingowski, Manager, Biocides Lab, Plastic Additives, Rohm & Haas Company, Spring House, Pennsylvania, USA

While composites are often thought of as being unthreatened by microbes, experiences to date demonstrate that woodfiber-plastic composites (WPCs) face unique vulnerabilities to the effects of microbial activity. Since the useful life of a WPC can be shortened by either physical deterioration or by loss of aesthetic integrity (such as unsightly permanent stains), it is important to use an antimicrobial that is effective in preventing the microbial activity of many strains of fungi and other microorganisms capable of producing these undesirable effects. Performance comparisons of selected antimicrobials in various representative composite formulations were conducted to determine optimal preservation capabilities. Biocides such as zinc borate may be effective in preventing deterioration by wood destroying fungi such as *Gleophyllum trabeum* (brown rot), but may not provide adequate protection from molds such as *Aspergillus*, *Penicillium*, and *Aureobasidium*. These molds, depending on nutrient availability, may produce permanent stains ranging from black, or green, to red. The phenomenon of "blue stain" or "sap stain" is well known and documented in the wood industry. Likewise, the plastic industry recognizes "pinkings" of plastic materials. This work shows that the incorporation of isothiazolone biocides into the composite, in particular 4,5-Dichloro-2-n-octyl-4-isothiazolin-3-one (DCOIT), will prevent growth of these stain-producing molds. The biocide active ingredient is

incorporated into a plastic pellet and introduced in the extrusion process with virgin or recycled plastics as well as wood flour. The biocide is completely dissolved into the matrix and is an integral part of the composite. The slow diffusibility of the isothiazolone allows very low levels on the surface to protect the composite from invading fungi. In time, this diffusion allows for replenishment of the active ingredient at the surface for long-term protection.

Influence of Natural Fibers on the Phase Transitions in High-Density Polyethylene Composites Using Dynamic Mechanical Analysis

Mehdi Tajvidi, Ph.D. Candidate, College of Natural Resources, Univ. of Tehran, Tehran, Iran, *Robert H. Falk*, Research Engineer, and *John C. Hermanson*, Research General Engineer, USDA Forest Products Lab, Madison, Wisconsin, USA, and *Colin Felton*, Technical Manager, Teel-Global Resource Technologies LLC, Baraboo, Wisconsin, USA

In the present study, Dynamic Mechanical Analysis (DMA) was employed to evaluate the performance of various natural fibers in high-density polyethylene composites. Composites were made at 25 and 50% by weight fiber contents. One and 2% MAPE was also added, respectively. Kenaf fibers, newsprint, rice hulls, and wood flour were used as the fibers. Temperature scans in the range of -110 to +100°C were performed and storage modulus, loss modulus, and mechanical loss factor ($\tan\delta$) were recorded over the selected temperature range. Different transitions were monitored and the effects of natural fibers on location and intensity of such transitions were investigated. Beta transition was hard to detect while alpha transition was shifted to higher temperatures when fibers were present. The results also indicated that beta transition is not a major transition in such composites while $\tan\delta$ curves of the composites tended to deviate from the pure plastic curve at temperatures above the alpha transition temperature.

TUESDAY AFTERNOON, MAY 20

CONCURRENT SESSIONS

SESSION 3A: MATERIALS AND PROCESSES

A Rheology Study of HDPE-Maple Composites

Michael P. Wolcott, Associate Professor/Research Director, and *T.Q. Li*, Post-Doctoral Fellow, Wood Materials & Engineering Lab, Washington State Univ., Pullman, Washington, USA

HDPE-maple composites were studied with capillary rheometry and small-strain dynamic tests in parallel geometry. Mooney analyses on composites with maple of varying volume content and particle size reveal both significant contribution of wall slip to overall shear flow in a capillary and an increase in viscosity with increasing wood content and decreasing particle size. Yield stress was evident at higher maple concentrations. Formulations with typical additives were examined with both Mooney analyses and small-strain dynamic tests. It was found that addition of maleated polyethylene (MAPE) results in higher shear viscosity and may affect external lubrication in different ways depending on its content and the wood loading. The different roles of two typical lubricating systems were identified through Mooney analyses. The additives were also found effective in changing the yield stress behavior. Small-strain dynamic tests indicate strong dominance of storage modulus in overall response. The activation energy based on linear time-temperature shift factors support the true shear viscosity results obtained through Mooney analysis.

Polymer Nano-Composites Based on Cellulose

Lars A. Berglund, Professor, Dept. of Fiber & Polymer Technology, Royal Inst. of Technology (KTH), Stockholm, Sweden

Polymer nano-composites is a field of research that is rapidly increasing in interest. Initial work by Toyota researchers on polyamide 6/clay nano-composites raised strong interest due to the dramatic property improvements observed. Effects seem to be strongest in polymers in the rubbery state or close to the glass transition temperature. One reason is that a finely distributed phase of high stiffness will influence the molecular mobility of a rubbery polymer. Another effect is that for basic mechanics reasons, a rubbery polymer will show a larger relative improvement in modulus than a glassy polymer. Early attempts by Kubat's group at Chalmers in Sweden demonstrated that hydrolyzed cellulose may be homogenized to form needle-shaped microfibrils able to strongly reinforce a rubbery latex. This has been followed by extensive efforts by Dufresne, Cavaille, and others in Grenoble, France,

working on large tunicin cellulose whiskers extracted from sea animals. Strong reinforcement effects have been demonstrated in the rubbery state. French activities also include cellulose from wheat straw and potatoes. Winter at New York State University in Syracuse and colleagues have studied nano-composites based on microbial cellulose, and from bagasse subjected to hydrolysis and homogenization. Their work includes surface modification of the cellulose. The attraction of cellulose nano-composites lies in the reinforcing potential of the cellulose microfibrils. The axial Young's modulus of the microfibrils is expected to be higher than 120 GPa. If it were possible to produce cellulose microfibrils on a commercial scale and disperse them in composite materials, we could create a new class of composite materials with unique properties. Practical challenges include cheap extraction of the microfibrils as well as controlled dispersion of the microfibrils in the polymer matrix. These issues will be discussed as well as successful results on polyurethane rubbers reinforced by microcrystalline cellulose. The strain to failure, modulus, and strength of the PUR rubber were increased significantly by the cellulose addition.

Applications of Nano-Composites and Woodfiber Plastics for Microcellular Injection Molding

Lih-Sheng (Tom) Turng, Assistant Professor/Co-Director, Polymer Engineering Center, and *Mingjun Yuan* and *Hrishikesh Kharbas*, Graduate Research Assistants, Dept. of Mechanical Engineering, Univ. of Wisconsin, Madison, Wisconsin, USA, and *Daniel F. Caulfield*, Research Chemist, USDA Forest Products Lab, Madison, Wisconsin, USA

This paper reviews the processing advantages and challenges of microcellular injection molding and presents recent research results on applications of nano-composites and woodfiber-filled plastics and new process developments for the microcellular injection molding process. In particular, two types of polyamide (PA-6) neat resins and their filled counterparts, such as a PA-6/montmorillonite nano-composite, a cellulose-fiber-reinforced PA-6 composite, and a hybrid PA-6/cellulose/Wollastonite composite, were injection molded into ASTM test-bar samples with both conventional and microcellular injection molding. These molded samples were then subjected to scanning electron microscope (SEM) analysis, tensile testing, and impact testing to study how the process conditions and micro-/nano-fillers affect the microstructure and mechanical properties of the microcellular injection molded components. For all the materials studied, the microstructure and the mechanical properties of the molded samples were found to be strongly dependent on the process conditions and presence of the filler systems. Finally, initial results of a novel co-injection molding process that combines the aesthetic and processing advantages of injection molding with the property attributes and benefits of microcellular plastics (MCPs) are presented.

Microcellular Woodfiber-Polypropylene Composites in an Injection Molding Process: Effect of Fiber Type and Chemical Foaming Agents on Physico-Mechanical Properties

Omar Faruk, Scientific Staff, and *Andrzej K. Bledzki*, Professor, Institut für Werkstofftechnik, Kunststoff-und Recyclingtechnik, Universität Kassel, Kassel, Germany

Polymer-woodfiber composites utilize wood fibers as a reinforcing filler in the polymer matrix and are known to have advantages over neat polymers in terms of materials cost and some mechanical properties such as stiffness and strength. Recent studies have demonstrated the feasibility of developing microcellular structures in polymer-wood fiber composites. An experimental investigation was conducted to study microcellular behavior in the injection molding foam processing of polypropylene-wood fiber composites using chemical foaming agents. The effects of fiber type (hardwood and softwood fibers) and different chemical foaming agents (endothermic, exothermic, and endo/exothermic) on the density, physico-mechanical properties, surface roughness, and cell morphology of foamed PP-woodfiber composites were studied. A compatibilizer maleic anhydride polypropylene copolymer (MAH-PP) was used with the intent of improving the mechanical properties of foamed composites. The structures of the foamed composites were examined using scanning electron microscopy and optical microscopy to determine the cell size, shape, and distribution of cells to account for this behavior. The density of microfoamed hardwood fiber-PP composites was reduced by about 30% and decreased up to 0.7413g/cm³ with the use of an exothermic chemical foaming agent. Optical microscopy showed that the cells are round and that cell sizes are affected by chemical foaming agents. Tensile and flexural tests were performed on the foamed composites to investigate the dependence of these properties on the density and void

content of foamed specimens and compared with non-foamed composites; MAH-PP exhibited improved physico-mechanical properties of up to 80%. Chemical foaming agents also had an effect on surface roughness, which decreased surface roughness of the foamed composites compared to the non-foamed composites. Water absorption and thickness swelling of the composites was also investigated. The experimental results indicate that due to the unique properties, microcellular plastics containing wood fibers can be used in a large number of innovative industrial and automotive applications.

Resin Transfer Molding of Polyester-Natural Fiber Composites for Performance Applications

David Rouison, Graduate Student, Dept. of Chemical Engineering, Univ. of New Brunswick, Fredericton, New Brunswick, Canada, *Mohini Sain*, Associate Professor, Faculty of Forestry, Univ. of Toronto, Toronto, Ontario, Canada, and *Michel Couturier*, Professor, Dept. of Chemical Engineering, Univ. of New Brunswick, Fredericton, New Brunswick, Canada

Cellulose-based fibers have higher specific strength than most regular synthetic fibers. They are also low in cost, light weight, and biodegradable; therefore, they seem to be good candidates to replace synthetic fibers in some structural applications. Even though European carmakers already use natural fiber composites, very little basic research has been done on these materials. One major concern with cellulose-based fibers is the presence of moisture before processing and the possibility of moisture absorption once the composite is produced. In this work, hemp/kenaf fiber-unsaturated polyester composites were manufactured using a resin transfer molding (RTM) process. The fiber mats were dried in a mold under vacuum to achieve low moisture contents. Samples with various fiber contents, up to 43%, were prepared. The wetting of the fibers was very good. However, the resin injection time was observed to increase dramatically at high fiber contents due to the low permeability of the mat. The mold was kept at a constant temperature to obtain fast and homogeneous curing of the part. The cure of the resin in the mold was simulated and was shown to be in quite good agreement with experimental results obtained by thermal measurements at different positions in the cavity. The performance of these samples was evaluated by measuring tensile and flexural strengths. The evolution of temperature at three different locations in the mold was recorded. The dielectric properties of the resin were recorded as well, but the dielectric method did not produce reliable results. The cure of the resin in the mold was simulated and was shown to be in good agreement with experimental results obtained by thermal measurements at different positions in the cavity. This report also compares the data shown on the graph to the curing model obtained from DSC measurements. This unique approach helps develop software to optimize the RTM process conditions in the manufacture of thermosetting natural fiber parts. Surface treatment of hemp fibers was investigated to improve the moisture resistance of the composites and the fiber-matrix adhesion. Once again, the performance of these improved materials was evaluated by measuring tensile and flexural strengths, as well as their moisture uptake under various conditions. The parts produced were tested to determine thermal conductivity, heat capacity, and density of the composites as well as some key mechanical properties such as tensile strength and flexural strength. Target applications for the manufactured parts are in automotive and construction applications.

SESSION 3B: AUTOMOTIVE

Measurement and Reduction of Odors of Natural Fiber-Filled Materials Employed in the Automotive Industry

Andrzej K. Bledzki, Professor, *Volker E. Sperber*, Senior Lecturer, and *S. Wolff*, Ph.D. Student, Institut für Werkstofftechnik, Kunststoff-und Recyclingtechnik, Universität Kassel, Kassel, Germany

The significant increase in the use of natural fiber-filled composites in automotive parts manufacturing in Europe required special attention to their odor characteristics. This paper describes conventional and new methods of odor detection in automobile parts. Odors can come from the matrix, the natural fiber, or from the combination of both. In order to detect possible sources of odors and to reduce the amount of emission or the intensity of odors, olfactometric measurements and chemical identification using gas-chromatography and mass-spectroscopy were combined. Although it is hoped that an "electronic nose" can soon replace other methods, the standard characterization method for odor measurements is still based on the human nose. Natural fibers such as flax, hemp, jute, kenaf, cotton, wood, and others were combined with polymer matrices such as polypropylene, polyurethane, epoxy resin, or acrylic resin in order to produce lighter components,

used mainly for car interiors. Odor control and, if required, odor reduction without adversely influencing mechanical properties, surface appearance, flammability, or other important properties of the composites is a must for their successful application. Control of processing parameters and the use of anti-emission additives contribute to achieving the goal of the European automotive industry of delivering an emission- and odor-free car to the customer.

Hybrid Cellulose Composites: Evaluation of a Cellulose/Wollastonite in Nylon 6 and Nylon 6,6 Composites

Rodney E. Jacobson, President, A-J Engineering Co., LLC, Madison, Wisconsin, USA, and *Daniel F. Caulfield*, Research Chemist, USDA Forest Products Lab, Madison, Wisconsin, USA

Techniques have been developed to first combine ultra-pure cellulose fibers with wollastonite fibers into a usable pellet form. The pellets were comprised of 50% cellulose fibers and 50% wollastonite fibers that could be easily feed and metered into a twin-screw extruder for compounding and mixing. At a 40% loading level of pellets during the compounding sequence, the resultant hybrid cellulose composite (HCC) consists of 20% cellulose, 20% wollastonite, and 60% nylon 6. This presentation will review the technique for combining the cellulose and wollastonite into extruder-feed pellets, and also review the technique for compounding these pellets into nylon-6 and nylon 6,6. Critical processing characteristics to reach 40% loading levels of cellulose/wollastonite into nylon 6 and 33% cellulose/wollastonite nylon 6,6, injection molding techniques, and mechanical property evaluations of hybrid cellulose composites will also be discussed.

Design and Engineering of Bio-Composites from Natural Fibers and Bacterial Bio-Plastic for Automotive Applications

Amar K. Mohanty, Visiting Associate Professor, *Lawrence T. Drzal*, University Distinguished Professor/Director, and *Manju Misra*, Visiting Assistant Professor, Composite Materials & Structures Center, Michigan State Univ., East Lansing, Michigan, USA

Natural fiber composites (bio-composites) are now emerging as realistic alternatives to glass fiber-reinforced composites, and automakers see the strong potential in making auto-parts from bio-composites. Composites derived from natural fibers and traditional polymers like polyethylene, polypropylene, polyester, and epoxy are not sufficiently environmentally friendly because the matrix resin is non-biodegradable. Biopolymers are now moving into the mainstream and polymers that are biodegradable or based on renewable "feedstock" may soon be competing with commodity plastics. Bacterial polyesters have been produced in industrial quantities by fermentation for a number of years and have been used commercially for cosmetic bottles, paper coatings, and medical applications. The costs of such bioplastics have been higher than petroleum-based plastics thus limiting their applications. Recent proprietary genetic technology allows the production of bacterial polyesters at more competitive prices. Eco-friendly green composite materials are fabricated from inexpensive chopped natural fiber and a bacterial polyester, e.g. poly (3-hydroxybutyrate) (PHB), through extrusion followed by injection molding processing. The incorporation of 30 wt. % of hemp fiber into the composite structure improves the modulus and impact strength of virgin "PHB" bio-plastic by around 350 and 70%, respectively. The heat distortion temperature (HDT) of virgin PHB bio-plastic improves by about 50°C upon reinforcement with 30% hemp fiber. The natural fiber PHB-based bio-composites showed improved noise absorption over glass fiber-based composites as analyzed through dynamic mechanical analysis. Auto companies are looking to bio-composites for their sound abatement capability in addition to their reduced weight for fuel efficiency. The effect of surface modifications and processing conditions on performance of the resulting green/bio-composites are evaluated and compared with glass fiber-polypropylene counterparts. Through a blend of surface-treated bast and leaf/fruit fibers, "engineered natural fibers" (ENFs) were designed which upon reinforcement with PHB showed promising properties. Natural fibers as reinforcement in a PHB matrix have a bright future in designing and engineering of sustainable green composite materials - novel bio-composite materials for 21st century automotive applications.

Challenges in the Foam Process of Natural Fiber-Reinforced Microfoams

Wenyang Zhang, Plastic Materials Engineer, AM Plastics, Ltd., Toronto, Ontario, Canada

The foaming of microcellular composites with different natural fibers is very difficult due to the following problems: 1) The process temperature must be under the damage temperature of about 220°C for the natural fiber, 2) If a chemical blowing agent and a thermoplastic resin are employed in a foam process using injection molding, a full dissolution of the chemical blowing agent and a lower viscosity and higher flow ability of the resin demands a higher process temperature, and 3) Controlling foam grade of polyurethane resin in a foam process is difficult using compression molding. In this work, all of the above challenges were solved, and the following new developments successfully obtained. The shear dilute theory was firstly developed in an injection molding foam process to produce short natural-fiber-reinforced polypropylene microfoams. The foamed specimens were a sandwich structure with an unfoamed skin and a foamed core. The average cell size of the foamed specimens was about 50 µm. The effect of the foam pressure and temperature on the foam grade by using compression molding technology for polyurethane composites with woven and non-woven flax and jute fabrics was first systematically investigated. The average cell size of the foamed specimens was about 67 µm. These composites exhibit a combination of relatively good engineering properties and lower density that makes them suitable for automotive and building applications.

Critical Processing Strategies for Making Fine-Celled Woodfiber-Plastic Composites for Automotive Applications

G.M. Rizvi, *G. Guo*, *K.H. Wang*, and *Chul B. Park*, Professor and Canada Research Chair in Advanced Polymer Processing Technologies, and Director, Microcellular Plastics Manufacturing Lab, Dept. of Mechanical & Industrial Engineering, Univ. of Toronto, Toronto, Ontario, Canada

Tighter restrictions on vehicle emissions and increased fuel economy standards call for reducing the total vehicle mass. Although glass-fiber/carbon-fiber reinforced composites have been dominantly used as a lightweight material for automotive applications, new interest in woodfiber-plastic composites is driven by the lowered cost, environmental regulations, and advances in processing. However, the shortcomings of woodfiber-plastic composites, such as low ductility, low-impact strength, and heavy weight, have limited their use in automotive applications. These shortcomings can be compensated for by effectively foaming and incorporating a fine-celled structure in these composites. The volatiles released during processing are known to deteriorate the structure of cells in the composites. The maximum processing temperature during extrusion of fine-celled woodfiber-plastic composite influences the cell morphology. This study was undertaken to identify the critical temperature above which the cellular structure of woodfiber-plastic composite foams is significantly deteriorated. The strategy of lowering the maximum processing temperature to suppress moisture emission from woodfibers was applied in this study and the corresponding critical temperature was identified in terms of the cell structure and density of the woodfiber-plastic composite foams. A method of estimating the emissions from woodfiber during extrusion processing by using the TGA data is also proposed.

POSTER PRESENTATION ABSTRACTS

POSTER 1

Woodfiber-Plastic Composite Product Adoption Within Distribution Channels

Nathan Deringer, Graduate Research Assistant, and *Timothy M. Smith*, Assistant Professor, Marketing, Dept. of Wood & Paper Science, Univ. of Minnesota, St. Paul, Minnesota, USA, and *Paul M. Smith*, Professor, School of Forest Resources, Pennsylvania State Univ., University Park, Pennsylvania, USA

The past decade has seen a dramatic increase in the use of new and substitute products in the building trades. While the adoption rates of many of these products have been examined from the builder perspective, the role of channel intermediaries in influencing innovation adoption has yet to be explored. This study examines the attitudes of distributors and retailers toward woodfiber-plastic composite (WPC) product adoption in the building materials industry. A mail survey of the top 200 building material wholesalers and retailers, respectively, was conducted in November of 2002 to examine organizational familiarity with WPC products, determine what types of WPC products are being carried by these intermediaries, and to gauge the substitution potential of WPCs in different types of building applications. An analysis of empirical data will be presented.

POSTER 2

Characterization and Comparison of the Thermal and Mechanical Properties of Different Natural Fiber-Filled Polypropylene Composites

Ana Espert, Ph.D. Student, and *Sigbritt Karlsson*, Professor, Dept. of Fiber & Polymer Technology, Royal Inst. of Technology (KTH), Stockholm, Sweden

Four different types of natural fibers were used as fillers in two different polymeric matrixes - pure PP, and recycled PP from domestic waste. The thermal and mechanical behaviors of these types of composites were studied. The fibers used for the preparation of the composites were: 1) residual cellulose fibers from the Kraft pulping process of Eucalyptus wood, 2) sisal fibers, 3) coir fibers, and 4) Luffa sponge fibers. Different composites were prepared with the two different types of polymeric matrix and fiber content was varied in the composites from 10 up to 30% wt. DSC experiments were performed in order to investigate the influence of fiber content on the thermal behavior of the composites and on crystallization behavior. For all composites studied, the temperature of crystallization and the melting point decreased with the increasing fiber content. The temperature of oxidation also decreased for all composites compared to the polymer matrix itself. Strain-stress tests showed that mechanical behavior is affected by the incorporation of the fibers; the values of stress and strain at upper yield decreased drastically in the composites compared to the polymer matrix, while Young's modulus increased. The advantages of using a recycled polypropylene as a matrix was proved since the composites prepared with this material present good thermal and mechanical properties.

POSTER 3

Extruded Woodfiber-Plastic Composite Decking and Retaining Wall for CG Shore Facilities

Douglas J. Gardner, Professor/Program Leader, *Roberto Lopez-Anido*, Assistant Professor of Civil Engineering, *Habib J. Dagher*, Director, and *Stephen M. Shaler*, Professor of Wood Science/Assistant Director, Advanced Engineered Wood Composites Center, Univ. of Maine, Orono, Maine, USA

Wood composite members for applications at Coast Guard (USCG) shore facilities are being tested and developed. The focus is on decking and retaining wall use in waterfront structures. Three different tasks are being investigated under this study. 1) *Demonstration of Wood Composite Decking at the USCG Pier in New Haven, Connecticut*. Woodfiber-plastic composite decking (1.25" x 5.5" solid profile) was manufactured on the Davis Standard Woodtruder using 60% wood fiber and 40% polyolefin plastic. The appropriate ASTM standards for physical, mechanical, and durability testing were followed to determine decking material properties. One thousand (1000) square feet of decking was manufactured and installed at the pier in

New Haven. A field evaluation of the decking performance is being conducted. 2) *Demonstration of Slip Resistant Decking at a USCG Facility*. Slip-resistant wood-plastic composite decking (1.25" x 5.5" solid profile) is also planned to be manufactured on the Davis Standard Woodtruder using 60% wood fiber and 40% plastic. The plastics to be used are polyvinyl chloride (PVC) and polypropylene. At least two different formulations for each of the boards will be manufactured to evaluate slip resistance. Other decking sections may be proposed for evaluation. The slip resistance of each type of decking will be measured per ASTM D1679. The decking material will be installed at a USCG facility such that each covers approximately a 4' x 10' walkway area. 3) *Develop Retaining Wall System for use at USCG Facility Waterfront*. A Woodfiber-Plastic Retaining Wall (WPRW) system that could replace a typical wood retaining wall used in USCG waterfront construction is being developed. The desirable features of the WPRW are: a) Durable - will outlast preservative-treated wood. More resistant to biodegradation and marine borers than treated lumber; b) Not Harmful to Environment - no negative impact on surrounding soil, water, or marine life; c) Made from Recycled Materials - WPRW components are expected to use more than 60% sawdust waste and some recycled thermoplastics; d) Lightweight - simpler to erect than traditional timber or steel components that are heavier; and e) Recyclable - WPRW can be ground-up and re-extruded into a new wall or other composite product. This task includes formulation of WPRW preliminary design concepts, selecting a final design, determining a manufacturing process for components, and producing prototype components for testing.

POSTER 4

Study of the Crystallization Behavior of Extruded Polyolefin Woodfiber-Plastic Composite Lumber by Post Die Process Conditions

Jungil Son, Post-Doctoral Research Associate, *William T.Y. Tze*, Graduate Research Assistant, *Douglas J. Gardner*, Professor/Program Leader, and *Shane C. O'Neill*, Research Associate, Advanced Engineered Wood Composites Center, Univ. of Maine, Orono, Maine, USA

The formation and size of crystalline domains in polyolefin materials is impacted by the temperature history during processing. The faster a polyolefin composite cools during processing, the smaller the crystalline domains, while the slower the composites cools, the larger the crystalline domains. Extruded polyolefin wood-plastic composite lumber will be manufactured on the Davis-Standard Woodtruder™. The wood-polymer ratio will be 60:40. After coming out of the die, the boards will be placed either in ovens or under refrigeration to control the rate of cooling. Temperatures of controlled cooling will include 100°C, 75°C, 50°C, 25°C, 0°C, and -25°C. The crystallization of extruded polyolefin woodfiber-plastic composite lumber according to post die process conditions will be quantified using DMTA, DSC, and Raman Spectroscopy. Dynamic mechanical thermal analysis (DMTA) will be conducted on a model Mk IV DMTA instrument from Rheometrics Scientific. Tests will be performed over a wide frequency range (5, 10, 25, and 50Hz) and the temperature programs will be from -20 to 150°C under a controlled sinusoidal strain, at a heating rate of 5°C/min. under a flow of liquid nitrogen. An oscillating dynamic strain of 0.01 or 0.05% will be used. The viscoelastic properties such as the storage modulus (E'), the mechanical loss factor (E''), and damping ratio (E''/E') will be recorded as a function of temperature and frequency. Activation energies will be also calculated. To obtain the degree of crystallization, we can apply the other method in use of DMTA. During the DMA experiments, the temperature will be raised rapidly from ambient to 200°C. Following a 10-minute conditioning period, the specimen will be cooled to 150°C at 5°C/min., from 150 to 110°C at 2°C/min., and from 110°C to ambient at 5°C/min. Differential Scanning Calorimetry (DSC, Perkin-Elmer Model Pyris-1) will also be used to confirm crystallization temperatures and degree of crystallization from the heat of fusion. The temperature corresponding to the maximum heat flow will be chosen as the crystallization temperature (T_c). Raman spectroscopy will be performed on extruded products that have been subjected to different rates of post-die cooling. The spectroscopy experiments will employ a Renishaw Ramascope that is equipped with a diode laser source (785 nanometers) and a microscope. The resulting Raman spectra will be analyzed for the intensities of the 830 cm⁻¹ (I₈₃₀), 840 cm⁻¹ (I₈₄₀), and 808 cm⁻¹ (I₈₀₈)

bands which correspond, respectively, to the melt-like amorphous phase, the isomeric defect phase, and the crystalline phase of the polypropylene (PP) polymeric chains. The PP degree of crystallinity (χ^c) in the samples also will be determined.

POSTER 5

A Rice Husk Powder-Reinforced Thermoplastic Polymer Composite

Jungil Son, Post-Doctoral Research Associate, Advanced Engineered Wood Composites Center, Univ. of Maine, Orono, Maine, USA, and *Han-Seung Yang*, Ph.D. Candidate, and *Hyun-Joong Kim*, Assistant Professor, School of Biological Resources & Materials Engineering, Seoul National Univ., Suwon, South Korea

Studies are being actively carried out on the development of composites utilizing recycled materials. The focus is on the development of composites using environmentally friendly lignocellulosic materials as reinforcing fillers and thermoplastic polymers as matrixes. These composites can contribute to resolving environmental problems and also the production of products having various properties is possible, which could not be expected using only lignocellulosic materials. Furthermore, the convenience of these composites lies in the fact that composite ingredients can easily be obtained from wastes and these composites can be manufactured relatively easily. Previous studies have demonstrated the possibility of using woodfibers or wood flour as a reinforcing filler over reinforcing fillers added in existing plastics such as CaCO_3 , talc, and clay. The use of lignocellulosic materials as a reinforcing filler for synthetic polymers offers a significant benefit from the aspect of environmental protection. The benefits of lignocellulosic reinforcing fillers include the production of lightweight final products, decrease in the wear of the machine used for processing these substances, and low cost. The lignocellulosic materials that could be used as reinforcing fillers could come from various sources including waste wood, pulp, and agricultural wastes such as rice husk and rice straw. The present study was done to determine the possibility of using rice husk powder as a reinforcing filler in a lignocellulosic fiber-thermoplastic polymer composite and the mixing ratio of reinforcing filler according to the type of thermoplastic polymer. Furthermore, we determined physical, mechanical and viscoelastic properties of the basic composite according to the amount of compatibilizing agent added.

POSTER 6

Testing of Woodfiber-Plastic Composites

Marek Gnatowski, Technical Director/President, and *Christine Mah*, Materials Chemist, Polymer Engineering Co., Ltd., Burnaby, British Columbia, Canada

Woodfiber-plastic composites (WPCs) are a group of new materials made from a combination of wood particles and plastics, most frequently thermoplastic resins. Recent expansion of WPC into the construction industry, including exterior decking and railing material, brings requirements for a more uniform and accurate evaluation of product properties across the industry. Recently, laboratories and regulatory bodies have tried to recommend or apply testing standards for WPC developed for wood or plastics with mixed success. There is a significant difference in material structure when wood, plastics, and WPCs are compared. This causes different responses to test conditions, including durability. The size of specimens required for testing often creates difficulties with respect to the shape of extruded profiles versus commercial lumber or wood composites used to set up standards. As test examples, water absorption, accelerated weathering, and fungi resistance of WPC will be discussed. Differences in WPC samples made by compression molding and extrusion (two frequently used methods) with respect to wood particle orientation, density, and surface properties will be described. Kinetics of water absorption by WPCs versus plastic and wood will be demonstrated, including in water immersion and humidity chamber environments. The accelerated weathering process involves UV and leaching. Stress associated with wood dimensional stability in dry/wet cycles may be an aging factor. In many products, accelerated weathering causes color change associated with microcracking visible under a microscope. Color stability of WPC seems to not be sufficient to assess damage caused by weathering, and further microscopic evaluation is required. Weathering conditions of material may result in a different response to fungi resistance. Water absorption by WPCs, including commercial products, and weathering may influence the resistance to fungi. The effect of moisture in the material and degree of decay was assessed in laboratory

conditions. Work conducted by Polymer Engineering Company Ltd. indicates that most WPCs have the potential for high water absorption. This, in combination with weathering, creates the possibility for subsequent decay and mold growth. The obtained results also indicate that there is a need for future work on testing methods and durability of WPCs covering specific properties and service conditions of these unique products.

POSTER 7

Mechanical Properties of Plastic Composites Containing Soy Hulls or Big Blue Stem Fibers

Subba Rao Gurram, Graduate Research Assistant, and *James L. Julson* and *K. Muthukumarappan*, Associate Professors, Dept. of Agricultural & Biosystems Engineering, South Dakota State Univ., Brookings, South Dakota, USA, and *Douglas D. Stokke*, Assistant Professor, Dept. of Forestry, Iowa State Univ., Ames, Iowa, USA

There is a growing interest in the use of natural fibers as reinforcing components for thermoplastic and thermosets. This is primarily due to improvements in process technology, their low costs, and the quest for renewable sources. Concern over environmental issues has also raised considerable interest in biodegradable plastics. As a result, natural fiber composites are now fast emerging as a realistic alternative to glass-fiber-reinforced polyester composites. The objective of this study was to investigate the effects of soy hulls, big blue stem (BBS), and wood on the properties of fiber plastic composites. Composites consisting of polypropylene (PP), or high-density polyethylene (HDPE), and bio-renewable fibers like soy hulls, BBS, and wood were prepared by extrusion processing. The extruded composite products were palletized and the test samples were prepared by injection molding. Mechanical properties, such as tensile, flexural, impact strength, melt flow index, and shrinkage of the composite were evaluated. The effect of fiber type and content on the mechanical properties of natural fiber/PP composites and natural fiber/HDPE composites were studied.

POSTER 8

Effect of Steam Exploded Wood on the Properties of High-Wood Content Thermoplastic-Polymer Composites

Ryo Ikuto, Graduate Student, *Rie Furukawa* and *Yoko Nagata*, Undergraduate Students, *Takashi Kitayama*, Lecturer, *Masahiro Takatani*, Associate Professor, and *Tadashi Okamoto*, Professor, Faculty of Agriculture, Kin-ki Daigaku Univ., Nara-shi, Nara, Japan

The effect of steam-exploded wood added to wood flour/thermoplastic polymer composites, of high wood content was examined by using steam-exploded wood from wood residue, wood flour, polypropylene, and compatibilizer. The composite boards were manufactured using a conical twin-screw extruder (Titan 45, Cincinnati Extrusion Co.). Two kinds of steam-exploded woods, powdered steam-exploded wood flour (SEF), or non-powder steam-exploded wood (NPSE), were used. Composites of wood flour/biodegradable polymers were also examined. The composite boards with added SEF showed improved fracture strength and water resistance proportional to the amounts of added SEF. The maximum modulus of rupture (MOR) and modulus of elasticity (MOE) were 50 MPa and 6 Gpa, respectively. In contrast, added NPSE slightly decreased the MOR of composite boards as the amount of steam-exploded wood was increased, with the maximum MOR of 40 MPa and MOE of 6 GPa. Although the water resistance of boards with added SEF was good, that of added NPSE was poor, being almost unchanged with or without added NPSE. Composite boards were successfully made using biodegradable polymer as the thermoplastic polymer, but the fracture strengths and water resistance of boards were not as good as those of polypropylene.

POSTER 9

The Properties of Wood Flour/Thermoplastic Polymer Composites with a High-Wood Content: The Effect of Repeated Molding

Masahiro Takatani, Associate Professor, *Ayumi Ikemiya*, *Yoko Nagata*, and *Rie Furukawa*, Undergraduate Students, *Ryo Ikuto*, Graduate Student, *Takashi Kitayama*, Lecturer, and *Tadashi Okamoto*, Professor, Faculty of Agriculture, Kin-ki Daigaku Univ., Nara-shi, Nara, Japan

The properties of wood flour/thermoplastic polymer composites with high wood contents (exceeding 70 to 80%) were examined using wood flour, steam-exploded wood flour (SE) from wood residue, and four kinds of thermoplastic polymers (polystyrene, polymethylmethacry-

late, polyvinyl chloride, and polypropylene). The effect of repeated molding was also examined to appraise the recyclability of wood/polymer composite boards. Composites were manufactured by compression molding and twin-screw extrusion molding. The fracture strengths of boards made by once-repeated compression molding as compared with those of virgin boards decreased to 30 to 85% / 40 to 90% with/without a compatibilizer, respectively. The reproduced boards showed good fracture strength and water resistance in the case of the mixture ratio of wood/SE/polystyrene (PST), 0/7/3 with or without a lubricant. The composite boards made by compression molding showed excellent fracture strength and water resistance with increases in SE to an extent dependent on the polymer species and the compositions of wood/SE/polymer. However, the effect of SE addition on the strength of extruded composite was not clear, albeit the extruded composites showed better fracture strengths and water resistance than the composites made by compression molding. Water resistance of the composite boards from extrusion molding was improved by the addition of SE.

POSTER 10

Freeze-Thaw Durability of HDPE/Wood-Flour Composites

Jeanette Maurice, Graduate Research Assistant, and *Laurent M. Matuana*, Assistant Professor, Dept. of Forestry, Michigan State Univ., East Lansing, Michigan, USA

The durability of woodfiber-plastic composites exposed to biological organisms and ultraviolet light has been extensively investigated over the past years. Although woodfiber-plastic composites are being used in applications such as docks and decks in colder regions where freeze-thaw action is prevalent, little information is available in the open literature on the freeze-thaw durability of woodfiber-plastic composites, which was the goal of this study. High-density polyethylene was filled with wood flour (either hardwood or softwood) in 50:50 ratio by weight with 12% of the plastic component being lubricant. Samples were processed in a conical twin-screw extruder and exposed to accelerated cyclic freeze-thaw actions according to ASTM standard D6662. The durability of exposed samples was assessed in terms of the flexural properties and dimensional stability. The experimental results indicated that the stiffness (measured by the modulus of elasticity (MOE) of the composites) was significantly affected (approximately 40% reduction) by freeze-thaw cycling, regardless of wood filler species. The composites filled with pine wood flour retained 95% of their strength (modulus of rupture) after exposure to 15 freeze-thaw cycles whereas only 82% of the strength of composites filled with maple flour was retained after 15 freeze-thaw cycles. Overall, the deleterious effects of freeze-thaw cycling seemed more pronounced in the composites with maple flour (hardwood) than in those with pine flour (softwood). The dimensional stability of the samples was not significantly affected by freeze-thaw cycling actions. Both the width and thickness expanded less than 3% after 15 freeze-thaw cycles, regardless of wood filler species.

POSTER 11

Effect of Environmental Physical Factors on Discoloration of Wood Flour Thermoplastic Composites by Biological Agents

Ben Dawson-Andoh, Associate Professor, Division of Forestry, West Virginia Univ., Morgantown, West Virginia, USA, and *Laurent M. Matuana*, Assistant Professor, Dept. of Forestry, Michigan State Univ., East Lansing, Michigan, USA

Woodfiber-plastic wood composites are increasingly being used in exterior environments that promote physical degradation and biodegradation. The question that was addressed by this study was the effect of physical factors on the discoloration of high-density polyethylene-hardwood fiber composites by fungi. Woodfiber-thermoplastic composites consisting of wood flour, high-density polyethylene, and lubricant in the weight ratio of 50:45:5 were made by twin-screw extrusion. Two wood species, southern pine and maple, were used. Test panels measuring 3/8 x 1 x 9" were exposed to cycles of freeze-thaw, and UV radiation with intermittent water spray before final exposure to fungi. The results of this study will be discussed in terms of changes in color and hue (L^* , a^* , b^*) and fungal growth. Environmental scanning electron microscopic data will also be presented.

POSTER 12

Hemp Fiber-Reinforced Cellulosic Plastic-Based Bio-Composites: Physico-Mechanical and Morphological Properties Evaluation

Lawrence T. Drzal, University Distinguished Professor/Director, *Amar K. Mohanty*, Visiting Associate Professor, *Arief Wibowo*, Graduate Research Assistant, and *Manju Misra*, Visiting Assistant Professor, Composite Materials & Structures Center, Michigan State Univ., East Lansing, Michigan, USA, and *Brain D. Seiler*, Lab Head, Cellulose Esters Research, Eastman Chemical Company, Kingsport, Tennessee, USA

Bio-composites consist of a bio-based polymer as the matrix material and natural fiber as a reinforcing element. Cellulose esters (plastic made from wood/plant cellulose) are considered potentially useful materials for producing biodegradable composite structures of the future. By embedding inexpensive natural cellulosic fibers into biopolymeric matrices, novel value-added bio-composites can be made. This paper deals with experimental results on performance of bio-composites derived from chopped natural fiber (hemp) and cellulosic plastics. Two different processing approaches were taken: 1) powder impregnation and 2) traditional extrusion followed by injection molding processing. The resulting bio-composites were evaluated for their physico-mechanical and thermo-mechanical properties and compared with glass fiber composites. Cellulose acetate (CA) plasticized with 30% citrate plasticizer proved to be a better matrix over traditional polypropylene (PP) for hemp fiber reinforcements. Processed through extrusion and injection molding, a CA-based bio-composite with 30 wt.% of hemp fiber exhibited flexural strength of ~78 MPa and modulus of elasticity of ~5.6 GPa. Between cellulose acetate and cellulose acetate butyrate (CAB), the latter proved to be a better matrix over the former for bio-composite applications. Experimental findings show that CA needs to be plasticized, unlike CAB, for bio-composite fabrication with powder impregnation processing. The heat deflection temperature of cellulosic plastic is substantially enhanced by reinforcement with hemp fiber. The fiber-matrix adhesions were evaluated through Environmental Scanning Microscopy (ESEM) analysis. The water absorption and biodegradation behaviors of bio-composites are in the process of being evaluated.

POSTER 13

Green Composites from Natural Fiber and Soy Protein-Based Bio-Plastics

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Most of today's plastics and synthetic polymers are produced from petrochemicals. As conventional plastics are persistent in the environment, improperly disposed plastic materials are a significant source of environmental pollution. For these reasons, replacement of non-degradable polymers by degradable plastics is of major interest to the plastic industry. Soy protein-based bio-plastics have gained significant interest for various applications and have been considered as a potential alternative to petroleum polymers. Poor processability, strength, and stiffness limit their applications as structural materials. The processability issue can be solved by blending soy protein with a plasticizer and the strength problem can be solved by the addition of natural fibers to the soy-based plastics. This presentation discusses the fabrication of soy protein-based bio-plastics and the effect of the plasticizer on the mechanical and thermal properties of the bio-plastics. The presentation also focuses on natural fiber - soy protein-based bio-composites and characterization of their mechanical, thermal, and morphological properties. Studies show higher thermal stability, tensile, and flexural properties of the plastic when Sorbitol was used as a plasticizer as opposed to Glycerol being used as a plasticizer. There was a substantial increase in tensile, flexural, and impact properties with the addition of up to 30 wt.% hemp natural fiber to the soy protein-based bio-plastic.

POSTER 14

Moisture Influence on the Physico-Chemical and Mechanical Behavior of Flax Pulps and of Their Polypropylene Matrix Composites

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The influence of water uptake on the long-term behavior of natural fiber/polymeric matrix composites is not well known. In this study, the influence of absorbed water on the behavior of both single fibers and their polypropylene (PP) matrix composites was studied. The fibers used were flax pulps from a paper supplier. The effects of water uptake on the single pulps behavior was analyzed by micromechanical testing, using a Minimat equipment, and also by infrared spectrophotometry, optical microscopy, and thermogravimetry. The influence of several moisture conditions on the mechanical properties of the PP matrix composites will also be presented, correlating them with the mechanical behavior of fibers and also with the modifications on the fiber/matrix interphase as a consequence of water sorption.

Crystallinity of PP surrounding the fibers was analyzed by both differential scanning calorimetry and optical microscopy.

POSTER 15

Influence of Biological Extraction Time on Banana Fiber Behavior

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In recent times, several studies on traditional natural fibers such as flax, sisal, or jute as reinforcement in composite materials have been conducted. The natural fibers present important advantages as low-density, appropriate stiffness, and mechanical properties, as well as appropriate thermal behavior. Moreover, they are recyclable and biodegradable. In addition to these traditional fibers, a number of other vegetable plants may produce adequate fibers for polymeric reinforcement. One possibility is banana fibers obtained from cultivation wastes. Banana production generates a high amount of waste, materials which cause environmental problems. The main wastes are shoots, stems, and leaves. From all of these wastes it is possible to extract fibers. The fiber extraction process can be performed by mechanical and biological procedures. Each treatment results in different characteristics. The mechanical method is fast, and produces long fibers, but its effectiveness is lower than that for biological extraction. Using biological methods it is possible to get a higher production of fibers, however the extraction time has an important influence on the quality of fibers obtained. In this study, the variation on the chemical structure of the banana fibers was evaluated by FTIR spectroscopy. Important changes in fiber structure due to the extraction process were observed. The effect of these variations in chemical composition on mechanical behavior was also evaluated.

POSTER 16

Characterization of Rice Husks Using Microscopic and Micro-Analytical Techniques for Rice Husk/Thermoplastic Composites

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Rice husks are a by-product of the rice milling process, and a potential resource as a raw biomass material for manufacturing value-added composite products. One of the potential applications is to use rice husk as filler for manufacturing lignocellulosic fiber-thermoplastic composites. This study was conducted to examine the anatomy of and silica distribution in rice husks in preparation for use as a reinforcing filler for thermoplastic polymers. Microscopic techniques, such as LM, SEM, FE-SEM, and TEM, were used to observe the microstructure of the rice husks. Microscopic examination showed that main compo-

nents of the husks consisted of outer epidermis, layers of fibers, vascular bundles, parenchyma cells, and inner epidermis, in sequence from the outer to the inner surface. The outer epidermal walls were extremely thick, highly convoluted, and lignified. The underlying fibers were also thick-walled and lignified. Parenchyma cells were thin-walled and unligified. Inner epidermal cells were also unligified. The outer surfaces of rice husks were conspicuously ridged, but the lower surfaces had a flat appearance. FE-SEM-EDXA provided valuable information on the distribution of silica in the husks. Most of the silica was present in the outer epidermal cells, being particularly concentrated in the dome-shaped protrusions. These observations on the organization of husk tissues and the distribution of silica aids in understanding the performance of rice husk/thermoplastic composites.

POSTER 17

Nuclear Magnetic Resonance Relaxometry Applied to Wood Fibers

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Chemical coupling is a very efficient means for the modification of surface properties of fibers used in woodfiber-plastic composites. Precise knowledge of the reactivity of the solid wood components (cellulose, hemicelluloses, lignin) is needed in order to optimize the chemical reactions. In this work, we propose a ^1H Nuclear Magnetic Resonance Relaxometry technique applied to the solid phase of wood. Three time domains were observed. The smallest time was attributed to the less mobile structures in wood. The two other time constants were assigned to more mobile hydrogen atoms, such as proton from hydroxyl groups, after 37.2% of these atoms were exchanged by contact with deuterium oxide. This techniques should give new insight on the reactivity and accessibility of OH groups involved in wood-water interactions and reactions with chemicals.

POSTER 18

Microscopic Study on the Composites of Wood and Polypropylene

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Optical and scanning electron microscopies coupled with a thin-sectioning method and a chemical treatment to remove cell wall material were adopted to investigate morphologically the dispersion of wood fillers and the interface between the wood and polypropylene (PP) matrices in injection-molding composites. Wood fillers were well dispersed in PP matrix with a tendency toward longitudinal and concentric orientation. The interface between wood and PP was well illustrated by the chemical digestion method. It was demonstrated with this method that PP can penetrate into macro-cavities such as fiber lumina inside wood particles through cracks of inter- and intra-wall fractures and comprises a three-dimensional network within the particles and also connecting to PP matrix outside. Wood fillers were always completely isolated and covered by PP probably owing to their high wettability at their interface, although this did not directly result in stiff chemical bonding. This suggests that the chemical bonding of wood fillers and PP matrix is more important for the improvement of the adhesion properties than the surface compatibility.

POSTER 19

High Performance Micro- and Nano-Biofibrils Manufacturing Process for Reinforced Natural Composites

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After decades of high-tech developments of artificial fibers like carbon, aramid, and glass it is remarkable that natural fibers have gained a renewed interest, especially as a glass fiber substitute, partly due to ecological concerns. Fibers like hemp, flax, sisal, jute, and vegetable fibers hold potential for such innovations. These natural fibers are

bundles of individual strands of fibers held together by means of interface of pectin and lignin. If these binding materials are removed by thermal treatment and individual fibers released by mechanical shear force, without harming them, it would be possible to produce materials of very high strength at a low cost in an environmentally-friendly manner. Heat treatment experiments of bast fibers above the glass transition temperature of lignin in a nitrogen environment seemed to provide enough fiber release without effecting the associated tissues of the fibers. It was found that there was indeed a release of fibers upon heating and that the total number of fibers increased for the equal weight of fibers, with some fibers of lesser diameter than the original fibers. The tensile strength and modulus of fibers treated in nitrogen were found to have increased, due to the production of fibers of lesser diameter. Scanning electron microscopy showed the migration of lignin from the core to surface. Our focus has also been to develop bio-composites from root crops like rutabaga, Swede root, sugar beet root, etc., which are found in abundance, with non-elongated fibers called cellulose microfibrils for making thermoplastic nano-composites. These microfibrils are cellulose chains that aggregate to form a fibril - long thread-like bundles of molecules stabilized laterally by hydrogen bonds between hydroxyl group of adjacent molecules. The molecular arrangement of these fibrillar bundles is called nano-sized microfibrils. The microfibrils are around 10 nm diameter, also referred as nano-fibers, and are comprised of 30 to 100 cellulose molecules in extended chains. We will present evidence for isolating nano-sized microfibrils from bast as well as from root crops.

POSTER 20

Exxelor Coupling Agents for Polyolefin/Woodfiber Composites

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Woodfiber-reinforced polyolefin composites based on recycled raw materials have been used for many years in decking applications. More recently, composite manufacturers have started developing new applications requiring improved performance. This paper will highlight the benefits of using coupling agents (maleic anhydride grafted polyolefins) to improve performance such as HDT, impact resistance, tensile strength, and reduced water absorption. A practical methodology has been defined with a view to developing compounding guidelines for the production of composites meeting well-defined requirements.

POSTER 21

Additives for Improving the Processing and Performance of Wood-Polyolefin Composites

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Although they are generally used at low levels, additives play an important role in determining the processing and performance of woodfiber-plastic composites. This paper will look at various additive technologies used in wood and natural fiber-filled polyolefins. Processing aids, which improve surface appearance and extrusion performance, will also be discussed. In addition, products such as coupling agents and foaming agents which affect mechanical properties, long-term durability, and other end-use properties will be described. Recommendations for starting formulations will be given.

POSTER 22

Manufacturing Woodfiber-Plastic Composite Panels Using Wood Chips of *Eucalyptus Grandis* WHill Ex-Maiden and Recycling Low-Density Polyethylene

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This work utilized wood chip residues of *Eucalyptus grandis* WHill exMaiden, and recycled plastic pellets (PEBD), in ratios of 40%/60%, 50%/50%, and 60%/40% wood/plastic in the composite. To eliminate density as a source of variation an analysis of covariance was conducted, with density as covariate. No difference was observed among the

mechanical properties. Regarding physical properties, only thickness swelling after 2 hours, 24 hours, and residual swelling presented variation among treatments. Those treatments with a higher proportion of plastic resulted in a better performance. Overall, most results of mechanical properties reached the minimum values specified by the ANSI A208.1 standard, except for MOR and MOE in the treatment where a smaller amount of plastic was used.

POSTER 23

Additives for Improving the Performance of Wood/Polymer Composites

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Generally speaking, wood-thermoplastic composite materials, especially in the case of 50 to 80% wood powder content, exhibit some problems (for example poor physical properties and appearance) due to the poor compatibility between resins and wood powders. Therefore, some manufacturers have installed special machines and/or have introduced additives to improve these problems. In this study, it was determined that small amounts of the additive, Acrylic Modified PTFE, provides a smooth surface and improves toughness of wood-thermoplastic composites. In this report, we discuss the performance of Acrylic Modified PTFE as an additive for wood-thermoplastic composite products.

POSTER 24

Chlorinated Paraffin Wax Promotes Adhesion and Helps Maintain Strength in Woodfiber-Thermoplastic Composites

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Woodfiber-thermoplastic composites (WPC) that contain approximately 50% (or more) wood absorb moisture and swell, causing a reduction in mechanical properties and an increase in susceptibility to fungal decay. Modification of the wood/plastic interface can improve dimensional stability in WPC and help prevent strength loss. A short chain chlorinated paraffin wax, Chlorez 700 SSNP (Dover Chemical Corporation, Dover, Ohio), is an established flame retardant for plastics and a strong adhesion promoter that finds use in paint formulations, among other applications. Preliminary investigations have shown that it may be a strong enough adhesion promoter to improve the dimensional stability of WPCs in response to moisture absorption. WPC that contained 5% Chlorez, 34.9% polypropylene, and 60% wood (40-mesh ponderosa pine) swelled as much as 20% less than non-Chlorez containing composites despite absorbing equal amounts of water (measured as a percentage of the original sample weight) after 120 days of exposure in a high humidity environment and in liquid water. Ongoing work is investigating strength retention as a benefit of thickness swell reduction. Exposures include ultraviolet light and moisture content cycling in a weatherometer in addition to exposure in a high humidity environment. Strength loss resulting from fungal decay is also being investigated.

POSTER 25

Mechanical Properties of Woodfiber Composites Under the Influences of Temperature and Humidity

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Woodfiber-thermoplastic composites (WPCs) have received considerable attention from the forest products industry for civil engineering applications due to the fact that WPC can be fabricated using traditional composite processing techniques. The major limitation of using woodfibers for reinforcement is the poor interfacial adhesion between the polar-hydrophilic woodfibers and the nonpolar-hydrophobic plastics. The aim of this research was to systematically study the mechanical properties of aspen-fiber polypropylene (PP) composites (APCs) and optimize the composition of APCs to increase their mechanical

reliability and life span. This was accomplished by examining APCs prepared with woodfiber of 0, 30, 40, 50, and 60 weight percentages (wt%), and introducing 2 wt.% Maleic Anhydride Grafted Polypropylene (MAPP) in the composite by replacing the corresponding PP. Tensile and flexure tests were conducted according to ASTM specifications at room and elevated temperatures. Results showed that the tensile modulus and strength of APC are functions of the woodfiber weight contents. For example, with the MAPP additives, the tensile strength is a parabolic function of the woodfiber weight percentage and the maximum strength appears at 50 wt.% woodfiber. Results also showed that the flexure modulus of the composite almost linearly increases as the woodfiber content increases and the flexure strength increases almost parabolically with respect to the woodfiber weight fraction and reaches a maximum value at the weight fraction of 40% with PP only, and at 50% weight fraction with MAPP. The tensile and flexure tests were also conducted at elevated temperature (40°C) and near frozen temperature (4°C). The tensile strength at the elevated (40°C) temperature showed a slight reduction (approximately 10%) compared to those tested at room temperature, whereas the tensile strengths at the near frozen (4°C) temperature were overall higher (approximately 10 to 50%) than those from room temperature tests. Accelerated aging of APC under high temperature and high humidity was conducted by merging the APC on boiling water. Tensile and flexure tests were subsequently conducted, the results for which will also be reported. In general, aspen fiber polypropylene composites are found to exhibit mechanical advantages over the non-reinforced polymer. MAPP as an additive to the polypropylene matrix enhances the microscopic interfacial bonding between woodfiber and matrix, and improves the tensile and flexural strength of the composite.

POSTER 26

Microcellular Injection Molding of Nylon-Cellulose Composites

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Super-critical-fluid (SCF) injected into the composite melt in the barrel of an injection molder affords a means of preparing injection molded parts of reduced weight with microcellular morphology. Composites of cellulose-fiber-reinforced/PA-6 and a hybrid composite (cellulose/Wollastonite/PA-6) were injection molded into ASTM test-bar samples both with and without super-critical N₂ addition, for the purpose of comparison. The impact and tensile strengths of injection molded PA-6 with and without cellulose fiber and wollastonite mineral fillers were measured. Comparisons between conventional injection molding and microcellular injection molding processes were also studied. Although the microcellular injection molding of neat nylon appears to improve its impact performance, both the tensile strength and impact tests of the composite materials with microcellular gas injection exhibit reduced properties. The reductions in properties were greater than the weight reductions. Scanning Electron Microscopy (SEM) photographs are used to give better understanding of the microcellular structures and to assist in explaining the experiment results. The microcellular structure in the neat polymer may provide a crack-stopping mechanism that improves toughness. However, the fiber inclusions in the composites provide more flaws and defects to the structure than can be counter-acted by the presence of microvoids. Supercritical fluid injection molding affords a process for reducing the temperature and shear conditions to which cellulose fibers are subjected. There is evidence that these less damaging conditions may be optimized for further property improvements.



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