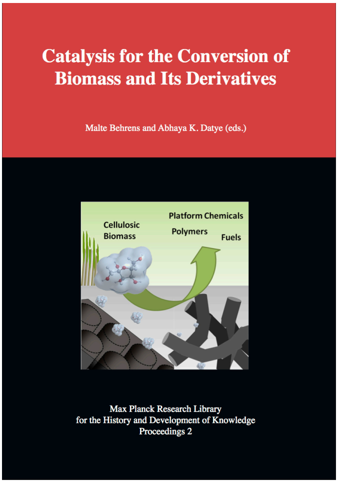
Max Planck Research Library for the History and Development of Knowledge

Proceedings 2

Malte Behrens and Abhaya K. Datye:

Introduction



In: Malte Behrens and Abhaya K. Datye (eds.): *Catalysis for the Conversion of Biomass and Its Derivatives*
Online version at http://edition-open-access.de/proceedings/2/

ISBN 9783844242829

Printed and distributed by:
Neopubli GmbH, Berlin
http://www.epubli.de/shop/buch/25258

The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available in the Internet at http://dnb.d-nb.de

Introduction

Opening Remarks

Fossil fuels such as coal, oil and natural gas currently provide over 75% of the world's energy supply needed to satisfy the great appetite for affordable and freely available energy of individuals and industries worldwide. Unfortunately, the growing global demand for fossil fuel resources comes at a time of rapidly diminishing reserves of non-renewable resources, causing widening concerns about a possible future scarcity of energy and the threat of rising oil prices. Furthermore, questions regarding the developing energy scenario cannot be separated from the discussion of evident changes in global climatic conditions by the increased combustion of fossil energy carriers and the large subsequent contribution to global CO_2 emissions.

In addition to the transportation sector and the energy-producing industries, another important user of fossil resources is the chemical industry, which relies extensively on petroleum for the production of valuable chemical intermediates in a wide variety of applications from polymeric materials to solvents and compounds for pharmaceuticals. There is a demand for renewable carbon-based feedstocks for chemical applications that are independent of fossil sources

The search for renewable alternatives for energy and chemicals is clearly a major societal need in every developed or developing country. Biomass, being a globally distributed resource, can serve as a valuable source for both energy and organic carbon. Due to its renewable nature, it is the only sustainable source of specific functional compounds for the chemical industry. A further advantage of the production of fuels from biomass is the potential to lower greenhouse gas emissions because the CO_2 released during energy conversion is recycled by the subsequent growth of biomass. The selective conversion of renewable biomass resources into tailor-made products is thus an important and attractive new area of research involving the fields of chemistry, biology and engineering.

Molecular manufacturing, i.e., the building of materials from the bottom up while retaining an atom-by-atom precision, has captured the fascination of researchers and the general public alike. However, achieving the same precision on a large scale remains a key challenge. Catalytic technology can carry out such molecular transformations in a precise manner to yield products—fuels, chemicals and other materials to serve the needs of society—in large-scale systems. It relies on a chain of knowledge spanning such areas as the atomistic level of an elementary surface reaction, the materials science of catalytic particles and bench scale test reactors, and the chemical engineering world of reactors in industrial plants. Indeed, the success of the petrochemical industry can be attributed in part to an understanding of conversion processes and chemical mechanisms at a fundamental level such as metal-catalyzed hydrogenolysis, hydrogenation and oxidation reactions. Whereas a petrochemical refinery has reached its present state of efficiency by continuous improvement over the past 50 years, the "biorefinery" and the understanding and knowledge-based manipulation of the involved chemical reactions is still in its infancy. By utilizing new chemical, biological and mechanical technologies, such an envisaged biorefinery provides a means of transitioning to a more energy-efficient and environmentally sustainable chemical and energy economy. In an integrated biorefinery, the production of high-value chemicals will be coupled with the production of high-volume and low-value transportation fuels, leading to a profitable mix and supporting sustainable operations to meet rising energy demands. The biorefinery of the future will be analogous to the petrochemical refinery of the present: a highly integrated system of processes that are optimized for energy efficiency and resource utilization. New catalysts and catalytic processes must be developed to provide the flexibility needed for the biorefinery to adjust and optimize its performance to accommodate changes in feedstocks and market demands.

The development of the necessary technology has been identified as the greatest challenge to bridge the gap between the concept and the realization of a bio-based chemical industry. In the summer of 2010 a workshop to address the challenges in this growing area of research was organized in order to bring together leading academic and industrial experts in the fields of catalytic conversion, biomass growth, life cycle analysis and industrial applications. The workshop on "Molecular Engineering for the Conversion of Biomass-Derived Reactants to Fuels, Chemicals and Materials" was organized by the Fritz Haber Institute of the Max Planck Society and the Partnership for International Research and Education (PIRE) at Kloster Seeon in Bavaria, Germany (photo by Edward L. Kunkes).[1]

[1] More information can be found on https://pire.unm.edu/. The partner institutions, collaborators and principal investigators of this PIRE program are: University of New Mexico (Abhaya K. Datye, PI), University of Virginia (Robert J. Davis, co-PI and Matthew Neurock, co-PI), University of Wisconsin-Madison (James A. Dumesic, co-PI), Iowa State University (Brent Shanks, co-PI), Fritz-Haber-Institute der Max-Planck-Gesellschaft (Malte Behrens, Matthias Scheffler, collaborators, and Robert Schlögl, host Germany), Max Planck Institute of Colloids and Interfaces (Markus Antonietti, collaborator), Haldor Topsøe A/S (Stig Helveg, collaborator), Technical University of Denmark (Jens K. Nørskov, collaborator and Ib Chorkendorff, host Denmark), Twente University (Leon Lefferts, collaborator), Åbo Akademi University (Dmitry Murzin, host Finland), Eindhoven University of Technology (Hans Niemantsverdreit, host Netherlands), Utrecht University (Harry Bitter, Krijn de Jong and Bert Weckhuysen, collaborators).

The objective of this international partnership is to enhance the collaboration between institutions in the United States and the European Union to elucidate the key factors controlling catalytic conversions of biomass-derived reactants, thereby providing a fundamental foundation for the design, development and operation of a biorefinery. The focus of this workshop was primarily pedagogical, assisting students and researchers in the field to clearly formulate some of the challenges and discuss possible paths to achieving a bio-based economy. The lectures presented at the workshop are compiled in this volume for a broader dissemination to the scientific community and interested laypersons.

This volume comprises 13 chapters and starts with the perspectives from industry and start-up companies, which are delivered by Friedrich Seitz and Leo Manzer, respectively. Before taking a deeper look into biomass chemistry, some relevant non-chemical aspects are treated, that define the boundary conditions of a large-scale use of biomass. Robert Anex reports on a life cycle perspective and Mark Stitt discusses aspects of plant growth for biomass production. The following chapter by Michael Ladisch, Eduardo Ximenes, Youngmi Kim and Nathan S. Mosier covers the fundamentals of biomass chemistry. Charles E. Wyman and Carol J. Wyman further focus on its aqueous phase processing. Analytical approaches for biomass conversion reactions are introduced by Dmitry Murzin and Bjarne Holmbom, and Amie Sluiter, Justin Sluiter and Edward J. Wolfrum in the following two chapters. The field of catalytic conversion of biomass is then introduced by Robert J. Davis, and Elif I. Gürbüz and James A. Dumesic, who report on reaction engineering concepts and catalytic strategies, respectively. The development of suitable heterogeneous catalysts and the related challenges are covered in Brent H. Shank's chapter, while Thorsten vom Stein, Walter Leitner and Jürgen Klankermayer focus on the application of homogeneous catalysts for the conversion of biomass. Finally, the important deconstruction reactions of lingo-cellulose are treated in the chapter by Roberto Rinaldi and Jennifer Reece. In the second part of this introduction, short biographical sketches of the authors, the editors and their affiliations are listed to complement the scientific content of this book.

All lectures present introductory material designed to root the subject back into the respective disciplinary foundations as well as state-of-the-art results illuminating current knowledge. While a remote observer may be fascinated by the detail of understanding gained in some aspects of the treatment of the complex and non-uniform material called "biomass," the experts feel that the current understanding of catalysis, mainly devoted to increase the functionality of feedstock molecules for desired chemical reactivity, is still unsuitable to efficiently deal with the transformation of biomass. Here, the over-functionalized bio-molecule needs de-functionalization, being in strong competition with polymerization once it is activated by catalytic or stoichiometric reactions. A new paradigm of catalysis is needed that focuses on the selective activation of large reaction networks under conditions more favorable to precise kinetic control than those provided by present-day tools.

Also, the dimension of the challenge to develop test-tube chemistry into processes suitable to operate under economical constraints given by today's energy market became obvious. The discussions vividly reflected concerns about the large-scale viability of biomass as a resource for transportation fuels and highlighted the responsibility of science to also consider non-scientific aspects when developing new technologies that might interfere with fundamental requirements of human life such as biodiversity, food production or clean water resources.

The decision to make the teaching material of this course available in the present form was made because we believe that this emerging field of energy science requires input from many disciplines that are traditionally not in close contact with each other. The present text may thus be regarded as an annotated introduction into basic concepts and considerations relevant for biomass conversion research. The text is intended to familiarize researchers with questions and concepts of relevant neighboring fields without providing complete textbook reference or literature coverage. The book may be used as an introduction to those areas of knowledge and challenges required to master biomass transformation on a scale relevant for future energy applications.

We acknowledge the support of the PIRE program from the U.S. National Science Foundation Office of International Science and Education (OISE). Additional funding was provided by the Max Planck Society through a grant to the Fritz Haber Institute in Berlin. Besides the contributions from the authors of these lectures, we note that the students and post-docs participating in this workshop actively contributed to its content through their questions and discussion. In a novel format to stimulate exchange among participants, scientists from different teams and areas of research were selected and randomly assigned to groups of three. The tasks of these groups were to reflect on the lectures and formulate questions to each of the speakers. The discussions after dinner were primarily devoted to questions from students and post-docs. By the end of the workshop, every participant had asked a question or contributed to the discussion. The content of these after-dinner discussions is also incorporated in the lectures reproduced in this volume. The open-access format offered by the Max Planck Library for the History and Development of Knowledge allows us to make the contents freely accessible through the World Wide Web. We also express our gratitude to Beatrice Herrmann, Kai Surendorf and Antje Ota for their invaluable technical assistance. Without their expertise and continuous efforts the print-on-demand version and the online production of this book would not have been possible. We thank Beatrice Gabriel for the thorough and fast copy-editing of the manuscripts and Dorothea Damm for her help with organizational issues. Jürgen Renn is acknowledged for his continuous support of the project. The cover picture was designed by Sylvia Reiche.

Abhaya Datye, Malte Behrens and Robert Schlögl

List of Authors, Communicator and Editors

Robert Anex is Professor of Biological Systems Engineering at the University of Wisconsin, Madison. He received his Ph.D. in environmental engineering from the University of California, Davis in 1995, after which he held faculty positions at Iowa State University and the University of Oklahoma. Prior to joining academia Dr. Anex was senior engineer at Systems Control Technology, Inc., in California (1983–1991). He is a member of the editorial board of the *International Journal of Life Cycle Assessment* and is associate editor for the *Journal of Industrial Ecology*. His research focuses primarily on systems analysis and optimization of biological systems.
R. Anex (anex@wisc.edu), Biological Systems Engineering, University of Wisconsin, Madison, WI, USA

Malte Behrens received his Ph.D. in Chemistry at Kiel University in 2006. He then joined the Department of Inorganic Chemistry at the Fritz-Haber-Institut der Max-Planck-Gesellschaft to do his Habilitation with Robert Schlögl. His research interest is the development of nanochemically-optimized catalytic materials for energy storage applications.
M. Behrens (behrens@fhi-berlin.mpg.de), Department of Inorganic Chemistry, Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin, Germany

Abhaya K. Datye is Distinguished Regents Professor of Chemical & Nuclear Engineering at the University of New Mexico, Director of the graduate interdisciplinary program in Nanoscience and Microsystems Engineering and also the Director of the Center for Microengineered Materials, a strategic research center at UNM. He received his B.Tech. degree (1975) from the Indian Institute of Technology, Mumbai, India, his M.S. (1980) from the University of Cincinnati, Cincinnati, OH, USA and his Ph.D. (1984) from the University of Michigan, Ann Arbor, MI, USA, all in chemical engineering. His research interests are in heterogeneous catalysis, materials characterization and nanomaterials synthesis. His research group has pioneered the development of electron microscopy tools for the study of catalysts.
A. Datye (datye@unm.edu), Department of Chemical and Nuclear Engineering, University of New Mexico, Albuquerque, NM, USA.

Robert J. Davis obtained his Ph.D. in Chemical Engineering from Stanford University in 1989. He subsequently worked as a postdoctoral research fellow in the Chemistry Department at the University of Namur in Belgium. He joined the faculty in Chemical Engineering at the University of Virginia in 1990 and

is currently the Earnest Jackson Oglesby Professor. Davis served as the Chair of Chemical Engineering at UVa from 2002 to 2011. His research interests are in the field of heterogeneous catalysis, with a focus on fundamental structure-activity relationships.
R. J. Davis (rjd4f@virginia.edu), Department of Chemical Engineering, University of Virginia, Charlottesville, VA, USA

James A. Dumesic earned his B.S. degree from the University of Wisconsin-Madison and his M.S. and Ph.D. degrees from Stanford University, under the supervision of Professor Michel Boudart. Dumesic joined the Department of Chemical Engineering in 1976, and he currently holds the Steenbock Chair in the College of Engineering and is Michel Boudart Professor of Chemical and Biological Engineering. Dumesic has used spectroscopic, microcalorimetric, and reaction kinetics techniques to study the surface and dynamic properties of heterogeneous catalysts. Dumesic pioneered the field of microkinetic analysis in which diverse information from experimental and theoretical studies is combined to elucidate the essential surface chemistry that controls catalyst performance. He has recently studied how aqueous-phase reforming of biomass-derived carbohydrates can be tailored to selectively produce H_2 or be directed to produce liquid alkanes. Most recently, he has been studying the use of levulinic acid and γ-valerolactone as biomass-derived platform chemicals for the production of fuels and chemicals.
J. A. Dumesic (dumesic@engr.wisc.edu), Department of Chemical and Biological Engineering, University of Wisconsin-Madison, Madison, WI, USA

Elif I. Gürbüz received her B.S. degree in chemical engineering from Middle East Technical University (2007) in Turkey and is currently completing her Ph.D. in chemical engineering at the University of Wisconsin-Madison (2012) under the direction of Professor James A. Dumesic. During graduate school, she studied the conversion of lignocellulose-derived carbohydrates to platform chemicals through successive oxygen removal reactions and upgrading of these platform molecules to obtain fuel and chemical grade products utilizing heterogeneous catalysis. Upon completion of her Ph.D., she will become a postdoctoral fellow under the guidance of Professor Enrique Iglesia at the University of California, Berkeley.
Elif I. Gürbüz, Department of Chemical and Biological Engineering, University of Wisconsin-Madison, Madison, WI, USA

Bjarne Holmbom received his Ph.D. in Chemical Engineering at Åbo Akademi University in 1978. He was visiting scientist at Paprican in Montreal 1979–1980.

He was appointed to full professor in Forest Products Chemistry at Åbo Akademi in 1985. In 1985–1986 he was visiting professor at North Carolina State University in Raleigh, N.C. He was Academy Professor at the Academy of Finland 1998–2003. In 2005 he received the Finnish Science Award and in 2008 the Marcus Wallenberg Prize. He retired in 2009. His research has been focused on wood and paper chemistry, environmental chemistry and related analytical techniques.
B. Holmbom, Wood and Paper Chemistry, Åbo Akademi University, Turku, Finland

Youngmi Kim received her Ph.D. in 2005 in Agricultural and Biological Engineering from Purdue University. Her B.S. (1999) and M.S. (2001) are from Inha University, Inchon, South Korea, both in Biological Engineering. Upon completing her Ph.D., Youngmi Kim joined Dr. Ladisch's team in the Laboratory of Renewable Resources Engineering (LORRE) as a bioprocess research engineer and has been working in the cellulosic ethanol field since 2005. Dr. Kim specializes in pretreatment and hydrolysis technologies for converting cellulosic biomass to fuels and chemicals, bioseparation technologies, process design and simulation of cellulosic biorefinery processes.
Y. Kim, Department of Agricultural & Biological Engineering, West Lafayette, IN, USA

Jürgen Klankermayer obtained his Ph.D. under the supervision of Henri Brunner at the University of Regensburg in 2002. He conducted research as postdoctoral fellow with François Mathey and Duncan Carmichael at École Polytechnique in Paris and with John M. Brown at the University of Oxford. In 2009, he was appointed as Junior Professor in the Cluster of Excellence "Tailor-Made Fuels from Biomass" at RWTH Aachen University. His research interests focus on the molecular understanding of mechanisms in catalysis using NMR spectroscopy, with application of the knowledge mainly towards catalyst design for asymmetric catalysis, novel hydrogenation processes, and selective biomass conversion.
J. Klankermayer, Institut für Technische und Makromolekulare Chemie, RWTH Aachen University, Aachen, Germany

Michael R. Ladisch is Director of the Laboratory of Renewable Resources Engineering (LORRE), and Distinguished Professor of Agricultural and Biological Engineering, with a joint appointment in the Weldon School of Biomedical Engineering. His B.S. (1973) is from Drexel University, and his M.S. (1974) and Ph.D. (1977) from Purdue University, all in Chemical Engineering. He is con-

tinuing his activities with Mascoma Corporation where he has been Chief Technology Officer since 2007. Dr. Ladisch has 35 years of research experience in biofuels, renewable resources, and biotechnology.
M. R. Ladisch (ladisch@purdue.edu), Department of Agricultural & Biological Engineering, Purdue University, West Lafayette, IN, USA

Walter Leitner holds the Chair of Technische Chemie und Petrolchemie at RWTH Aachen University. He is also External Scientific Member of the Max-Planck-Institut für Kohlenforschung and Scientific Director of CAT, the joint Catalytic Center of RWTH Aachen and the Bayer Company. He currently serves as the Chairman of the German Catalysis Society (GeCatS) and as the Scientific Editor of the Journal *Green Chemistry* published by the Royal Society of Chemistry. His research interests are the molecular and reaction engineering principles of catalysis as related to Sustainable and Green Chemistry. The research on selective biomass conversion in his group is strongly embedded in the interdisciplinary Cluster of Excellence "Tailor-Made Fuels from Biomass" at RWTH Aachen.
W. Leitner (leitner@itmc.rwth-aachen.de), Institut für Technische Chemie und Makromolekulare Chemie (ITMC), RWTH Aachen University, Aachen, Germany

Leo E. Manzer received his Ph.D. from the University of Western Ontario in 1973 and immediately joined the DuPont Company in Wilmington, Delaware, USA. He had a successful 32 year career where he was the Founder and Director of the Corporate Catalysis Center and rose to the rank of DuPont Fellow. Following retirement in 2005 he founded Catalytic Insights, LLC and holds the position of CEO. He is actively involved with venture capital firms in assessing startup companies and serves on the Scientific Advisory Board of numerous companies involved in the field of renewable fuels and chemicals.
Leo E. Manzer (Leo@CatalyticInsights.com), Catalytic Insights, LLC, Wilmington, DE, USA

Nathan S. Mosier is an Associate Professor in Agricultural and Biological Engineering at Purdue University. His research addresses fundamental topics in bioprocessing with current projects in enzyme mimicking catalysts for transforming renewable resources to fuels and chemicals, cellulose pretreatment for biofuel and biochemical production, enzyme-based processing technology, fermentation process modeling, metabolomics and transcriptomics of fermentation, and bioprocess simulation. His B.S. (1997) in BioSystems Engineering is from the University of Nebraska, Lincoln, his M.S. (2000) and Ph.D. (2003) in Agricultural

and Biological Engineering is from Purdue University. Dr. Mosier was also a NSF-IGERT Ph.D. fellow in the Innovation Realization Laboratory at the Krannert School of Management.
N.S. Mosier, Department of Agricultural & Biological Engineering, Purdue University, West Lafayette, IN, USA

Dmitry Murzin was born in 1963, graduated from Moscow University of Chemical Technology and received his Ph.D. in 1989 in Chemistry at the Karpov Institute of Physical Chemistry in Moscow with Mikhail Temkin. He defended his Doctor of Science thesis (Habilitation) in 1999 at the same institution. After being associated with BASF from 1995 to 2000, he took the Chair of Chemical Technology at the Åbo Akademi University, Finland. Dmitry Murzin's research focus is in heterogeneous catalysis and catalytic reaction engineering in particular related to biomass valorization.
D. Murzin (dmurzin@abo.fi), Industrial Chemistry and Reaction Engineering, Åbo Akademi University, Turku, Finland

Jennifer Reece was born in 1984 in Conroe, Texas, United States and received her B.A. from Grinnell College in 2006. Her doctorate in chemistry was received from Purdue University in 2010 under the supervision of Dr. Hilkka I. Kenttämaa. During her time there, she worked with C3Bio, an Energy Frontier Research Center funded by the U.S. Department of Energy, towards the direct conversion of plant lignocellulosic biomass to biofuels. Later in 2010 she took a postdoctoral research position at the Max-Planck-Institut für Kohlenforschung in Mülheim an der Ruhr, Germany, investigating mass spectrometric techniques for the analysis of lignin products obtained by novel catalytic strategies developed by Roberto Rinaldi. Currently, she is a postdoctoral fellow with the Colorado Diversity Initiative at Colorado University at Boulder with Dr. Veronica Bierbaum.
J. Reece, Department of Chemistry and Biochemistry, Colorado University at Boulder, Boulder, CO, USA

Roberto Rinaldi studied Chemistry at the State University of Campinas (UNICAMP), Brazil,where he received his doctorate under the supervision of Prof. Ulf Schuchardt in 2006. The award "Outstanding Ph.D. work 2007," sponsored by Evonik-Degussa and the Brazilian Catalysis Society, was given for his work on transition metal free alumina-catalyzed epoxidation. In 2007, he took a postdoctoral position at the Brazilian Synchrotron Laboratory in Campinas, where he worked on the characterization of HTS and LTS-catalysts by XPS. By the end of 2007, he moved to the Max-Planck-Institut für Kohlenforschung, Mülheim an

der Ruhr, Germany to work in the group of Prof. Ferdi Schüth, where he has been developing new strategies to circumvent the recalcitrance of cellulose using ionic liquids. Currently, he is leading a research group on catalysis for lignin, cellulose and coal at the Max-Planck-Institut für Kohlenforschung with funds provided by the Alexander von Humboldt Foundation through the Sofja Kovalevskaja Award 2010.
R. Rinaldi (rinaldi@kofo.mpg.de), Max-Planck-Institut für Kohlenforschung, Mülheim an der Ruhr, Germany

Robert Schlögl was born in 1954 and received his Ph.D. in Chemistry at Ludwig Maximilians University in Munich in 1982. He did his Habilitation with Gerhardt Ertl at the Fritz-Haber-Institut der Max-Planck-Gesellschaft (FHI) in Berlin and went to Frankfurt University for a Full Professorship. Since 1994 he is back in Berlin as the Director of the Department of Inorganic Chemistry at the FHI and since 2011 he is also the Founding Director of the Max Planck Institute for Chemical Energy Conversion in Mülheim. Robert Schlögl's research focuses primarily on the investigation of heterogeneous catalysts, with the aim to combine scientific and technical applicability.
R. Schlögl, Department of Inorganic Chemistry, Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin, Germany

Friedrich Seitz was born in 1955 and received his Ph.D. in Chemistry at the Technical University Munich in 1984. Following a postdoc period at the Massachusetts Institute of Technology, he started work at BASF's Polymer Research in 1986. After several positions within the company in Ludwigshafen and Hong Kong, he became President of the Competence Center for Process Research and Chemical Engineering in 2010. Research in this division focuses on process development, catalysis, synthesis, and the development of new technologies.
F. Seitz (monika.lueck@basf.com), BASF SE, Ludwigshafen, Germany

Brent H. Shanks is the Mike and Jean Steffenson Professor of Chemical and Biological Engineering at Iowa State University and Director of the National Science Foundation Engineering Research Center for Biorenewable Chemicals (CBiRC). He received his B.S. degree from Iowa State University in 1983 and his M.S. and Ph.D. degrees from the California Institute of Technology in 1985 and 1988, respectively. From 1988 to 1999 he worked as a Research Engineer and Department Manager in the Catalyst Department at the Shell Chemical Company technology center in Houston, Texas. He joined the faculty at Iowa State University in 1999 where his work has primarily involved the research and development of novel

heterogeneous catalyst systems for efficiently converting biological-based feedstocks to chemicals and fuels.
B.H. Shanks (bshanks@iastate.edu), NSF Engineering Research Center for Biorenewable Chemicals (CBiRC), Iowa State University, Ames, IA, USA

Amie Sluiter began research in the biofuels field in 1996 at the National Renewable Energy Laboratory. She is an author on 11 Laboratory Analytical Procedures (LAPs). She has taught full biomass compositional analysis procedures to both internal and external colleagues. Amie is responsible for the creation and maintenance of many of NREL's rapid near-infrared (NIR) spectroscopic analysis methods. These methods provide predictions for the composition of feedstock and process intermediates at a significant time and cost reduction compared with traditional wet chemical analyses.
A. Sluiter, National Renewable Energy Laboratory NREL, Golden, CO, USA

Justin Sluiter is a biomass composition specialist with 16 years of experience working in the Biofuels Program at the National Renewable Energy Laboratory. Justin is an author on the majority of NREL's Laboratory Analytical Procedures (LAPs), which are worldwide recognized standards for summative compositional analysis of biomass and biomass derived products. He has performed numerous compositional analysis training classes for external partners, from academia to industry. Justin enjoys working on LAP method optimization for new feedstocks and diverse instrumentation.
J. Sluiter, National Renewable Energy Laboratory NREL, Golden, CO, USA

Mark Stitt studied Natural Sciences at Cambridge University/England and received his Ph.D. degree in 1978. He pursued his academic career in Germany and did his Habilitation in biochemistry of plants at the University of Göttingen in 1984. From 1986 he held the Fiebiger Professorship for Plant Biochemistry of the University of Bayreuth and changed to a full Professorship for Botany at Heidelberg University in 1991. Since 2000 he is Director and Scientific Member at the Max Planck Institute of Molecular Plant Physiology and Honorary Professor at the Universities of Potsdam (since 2002) and of Umeo/Sweden (since 2008). His research interests are physiological processes involved in orchestrating photosynthetic carbon metabolism, growth, and storage. His group studies systems biology with forward and reverse genetic tools to look at metabolite production and allocation.
M. Stitt (mstitt@mpimp-golm.mpg.de), Max-Planck-Institut für Molekulare Pflanzenphysiologie, Department 2: System Regulation, Potsdam, Germany

Thorsten vom Stein received his M.S. degree with distinction from RWTH Aachen University in 2010 and is currently a Ph.D. student in the group of Professor Walter Leitner. In his diploma thesis he developed a one-step fractionation system for lignocellulose, which was awarded with the Hochschulpreis der Stiftung Nachwachsende Rohstoffe in 2011. The focus of his Ph.D. thesis, which is supported by the Max-Buchner Fellowship of DECHEMA, is on the development of new homogeneous catalysts for the selective depolymerization of lignin.
T. vom Stein, Institut für Technische und Makromolekulare Chemie, RWTH Aachen University, Aachen, Germany.

Edward J. Wolfrum serves as the Manager of the Biomass Analysis Section at the National Renewable Analysis Laboratory. This section consists of more than a dozen scientists and technicians who provide analytical chemistry support to both internal and external clients. His research interests include applied spectroscopy and chemometrics, focusing specifically on developing rapid methods for biomass composition determination based on near-infrared spectroscopy.
E.J. Wolfrum (Ed.Wolfrum@nrel.gov), National Renewable Energy Laboratory NREL, Golden, CO, USA

Charles E. Wyman had devoted most of his career to advancing technologies for aqueous conversion of cellulosic biomass to ethanol and other products through leadership positions in academia, national laboratories, and industry. He is currently Ford Motor Company Chair in Environmental Engineering at the University of California at Riverside and also cofounder, Chief Development Officer, and chair of the Scientific Advisory Board for Mascoma Corporation, a startup biofuels company. Wyman has a B.S. degree in chemical engineering from the University of Massachusetts, M.A. and Ph.D. degrees in chemical engineering from Princeton University, and an M.B.A from the University of Denver.
C.E. Wyman c/o Carol J. Wyman (charles.wyman@ucr.edu), Bourns College of Engineering, Chemical/Environmental Engineering, University of California, Riverside, CA, USA

Eduardo Ximenes is a Research Scientist in the Laboratory of Renewable Resources Engineering at Purdue University where he leads efforts in Microbiology and protein biochemistry. He also has a special graduate faculty appointment at Purdue University. His B.S. (1991) and M.S. (1994) are from the University of Brasilia, Brazil, and his Ph.D. (1999) is from the University of Georgia, all in Biology. In addition, Dr. Ximenes has 15 years of experience in the study of fungal fermentations for the production and development of enzymes, characteristics of enzyme formulations from various microbial sources, and genetic engineering of fungal and bacterial hosts.

E. Ximenes, Agricultural & Biological Engineering, Purdue University, West Lafayette, IN, USA