

CELLULOSE and WOOD

CHEMISTRY and TECHNOLOGY

Editor: Conrad Schuerch

**Biogenesis and Structure of Cellulose
The Cellulose-Water System
Chemistry of Cellulose and Wood
Surface Chemistry of Wood and Paper
Cellulosic Membranes**

CELLULOSE AND WOOD — CHEMISTRY AND TECHNOLOGY

Biogenesis and Structure of Cellulose
The Cellulose–Water System
Chemistry of Cellulose and Wood
Surface Chemistry of Wood and Paper
Cellulosic Membranes

Proceedings of the
Tenth Cellulose Conference

江苏工业学院图书馆

藏书章

Sponsored by

The Cellulose Research Institute
State University of New York
College of Environmental Science and Forestry

Held at

Syracuse, New York
May 29 – June 2, 1988

Editor

Conrad Schuerch

State University of New York
College of Environmental Science and Forestry
Syracuse, New York 13210 USA

Copyright © 1989 by John Wiley & Sons, Inc.

All rights reserved.

Reproduction or translation of any part of this work beyond that permitted by Section 107 or 108 of the 1976 United States Copyright Act without the permission of the copyright owner is unlawful. Requests for permission or further information should be addressed to the Permissions Department, John Wiley & Sons, Inc.

Library of Congress Cataloging-in-Publication Data:

Cellulose Conference (10th : 1988 : Syracuse, N.Y.)

Cellulose and wood—chemistry and technology : biogenesis and structure of cellulose—cellulose—water system chemistry of cellulose and wood surface chemistry of wood and paper cellulosic membranes : proceedings of the Tenth Cellulose Conference / sponsored by the Cellulose Research Institute, State University of New York, College of Environmental Science and Forestry, held at Syracuse, N.Y., May 29–June 2, 1988 : editor, Conrad Schuerch.

p. cm.

Proceedings of the Tenth Cellulose Conference are dedicated to Dr. Anatole Sarko, professor of chemistry, chairman of the Faculty of Chemistry, associate director of the Cellulose Research Institute, and associate member of the Polymer Research Institute at SUNY College of Environmental Science and Forestry in Syracuse, N.Y.

Bibliography: p.

ISBN 0-471-51256-7

1. Cellulose—Chemistry—Congresses. 2. Sarko, A.—Congresses. I. Schuerch, Conrad. II. Sarko, A. III. College of Environmental Science and Forestry. Cellulose Research Institute. IV. Title. TS933.C4C42 1988

674'.13—dc20

89-31461
CIP

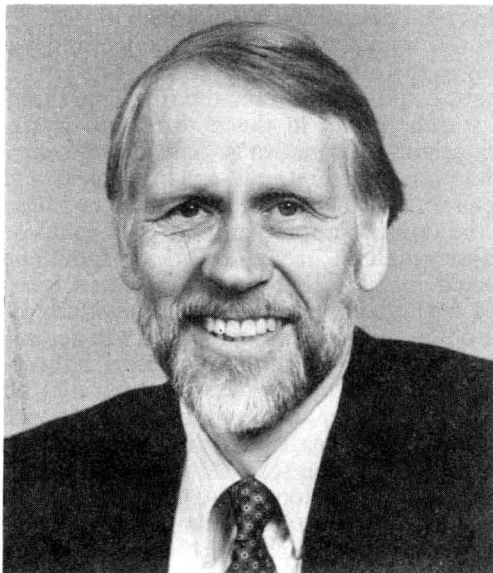
Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

DEDICATION

Anatole Sarko

*To Whom the Proceedings of the Tenth Cellulose Conference Are
Dedicated*



The Proceedings of the Tenth Cellulose Conference are dedicated to Dr. Anatole Sarko, Professor of Chemistry, Chairman of the Faculty of Chemistry, Associate Director of the Cellulose Research Institute, and Associate Member of the Polymer Research Institute at the SUNY College of Environmental Science and Forestry in Syracuse, New York. Dr. Sarko is an internationally recognized authority on the chemistry of the polysaccharides, and especially their solid state properties. His pioneering studies on the crystallographic structure of cellulose and starch are particularly noteworthy.

Anatole Sarko was born on May 27, 1930, in Tallinn, Estonia, receiving his early education in this country and in Germany. He graduated from Uppsala College, East Orange, NJ, with a B.S. in chemistry in 1952, after which he was employed as a chemist by General Foods Corporation in 1963. In 1961 he received an M.S. in physical chemistry from the evening division of New York

University. He resumed his graduate studies in 1963 at the SUNY College of Forestry in Syracuse, where he studied under the direction of Robert H. Marchessault, using X-ray techniques to investigate the crystal structure of amylose triacetate. After having received his Ph.D. degree in physical and polymer chemistry in 1966, he continued to do research with Marchessault as a postdoctoral fellow for one year.

Dr. Sarko was appointed Assistant Professor at the SUNY College of Forestry in 1967, and has since remained at this university, now as a Professor of Chemistry. He became Acting Chairman of the Department of Chemistry in 1984, assuming his present position as Chairman in 1986.

Dr. Sarko's research until 1970 was concerned with the solid state properties of amylose. In these and later investigations, Sarko, using X-ray diffraction analysis, could establish for the first time that amylose, the linear component of starch, exists in three different crystallographic forms, depending on its origin. The native A- and B-amyloses are organized in a double helix, while the regenerated V-amylose forms a single helix. Other investigations dealt with the light-scattering characteristics of starch granules.

Since 1970, the crystallographic properties of cellulose have been one of Dr. Sarko's major research areas. Working independently, Sarko and Blackwell reported in 1974 that native cellulose I has a parallel chain arrangement and not an antiparallel, as had previously been assumed. The detailed location of the various hydrogen bonds was determined. A somewhat different pattern of hydrogen bonding could later be established for regenerated cellulose II, which had an antiparallel chain arrangement. Celluloses III and IV were later subjected to similar X-ray diffraction analyses. In recent years, Dr. Sarko has turned his attention to the mechanism of mercerization of cellulose in the solid state. It was found that there are five different polymorphs of Na-celluloses. An elegant mechanism was suggested to explain how cellulose I with parallel chains can be converted in the solid state into Na-cellulose I, which has antiparallel chains.

Dr. Sarko has also studied the crystallographic properties of several other polysaccharides, for example curdlan, dextran, galactan, lentinan, mannan, mycodextran, pachyman, and paramylon. He has established the crystal structure of maltose and gentiobiose. The results obtained with starch and cellulose have been summarized in several excellent reviews. Together with P. Zugenmaier, Sarko is currently preparing a monograph on the crystallographic properties of cellulose and cellulose derivatives. Over the years, Sarko has made important contributions toward improvements in X-ray crystallographic techniques and computer methods for conformational analysis of polysaccharides. He has also developed better methods for determining the molecular weight of polymers by light scattering and sedimentation velocity.

Anatole Sarko is not only an exceptionally innovative and productive research scientist but also a dedicated and inspiring teacher, who during the last 20 years has been responsible for six courses in polymer and physical chemistry. An excellent administrator, he has served the Faculty of Chemistry over the last four years as its chairman with great distinction, devoting much of his time and efforts to this demanding position. In 1982, Dr. Sarko organized the Ninth Cellulose Conference, and in 1988 he was responsible for a symposium on the structure of cellulose at the Tenth Cellulose Conference.

As a research scientist, Anatole Sarko has been able to inspire his graduate students, postdoctoral fellows, and other co-workers to do their best and has always given them freely of his time. As a teacher, he has upheld very high standards but also recognized the needs of students with an insufficient background. As a department chairman, he has always been willing to listen to different opinions among his faculty, while at the same time exerting a firm leadership.

Anatole Sarko's interests are not limited to research, teaching, and administration. His major hobby is skiing. He is keenly interested in current events and keeps in constant contact with colleagues in this and other countries. An internationally well known scientist in his field, he has spent much time lecturing and doing research in France, Germany, and Japan.

Tore E. Timell

Preface

This volume constitutes the proceedings of the Tenth Cellulose Conference held at Syracuse May 29 to June 2, 1988 under the auspices of The Cellulose Research Institute of the SUNY College of Environmental Science and Forestry.

The Conference was opened with an appreciative statement of recognition and welcome by the College President, Dr. Ross Whaley, and a challenging Plenary Lecture on "Cellulosics as Advanced Materials" by Dr. Robert H. Marchessault, NSERC-Xerox Professor of McGill University. Later in the program, our horizons were broadened by Dr. Bruce Ganem of Cornell University who gave the Serendipity Lecture "Studies on the Inhibition of Carbohydrate Metabolism", an account of the biochemical significance of glycosidases and the exciting potential of his research on their inhibition. The participants enjoyed two pleasant interludes, a recital by the distinguished Chinese pianist, Cui Shi-Guang, and a banquet at which Dr. Vivian Stannett of North Carolina State University gave a modest and whimsical account of his pioneering work on cellulose grafting.

The program of the Conference consisted of symposia on Cellulose Structure and Its Characterization organized by Dr. Anatole Sarko; on the Cellulose-Water System and Surface Chemistry of Cellulose, Wood and Lignin organized by Dr. Philip Luner; on Biogenesis of Cellulose organized by Dr. Tore Timell; and on Cellulosic Membranes by Dr. Israel Cabasso. In the General Papers were

contributions on specialty products and derivatives, cellulose and wood chemistry and technology, degradation and analysis.

Local arrangements for the Conference were carefully organized by Horace Shaw and the staff of the Office of Continuing Education. Design and publicity were provided by Ronald Karns and the staff of the Publications Office. The considerable correspondence and clerical work were provided by Ragan Feidt, Liz Poda, Shirley Thomas, and Pauline Tonnesen. The Conference Committee wishes to express their appreciation to these colleagues and also to acknowledge the generous support of the Conference by the following organizations:

Proctor and Gamble Company
Xerox Research Centre of Canada
Dow Chemical Company
Separex Corporation/Air Products
and Chemicals, Inc.
International Paper Company
Aqualon Company

C. Schuerch
General Chairman
Tenth Cellulose Conference

Conference Committee

I. Cabasso
P. Luner
A. Sarko
C. Schuerch
T. Timell

CONTENTS

Dedication	xi
Preface	xv
Plenary Lecture: Cellulosics as Advanced Materials <i>R.H. Marchessault</i>	1
Serendipity Lecture: Studies on the Inhibition of Carbohydrate Metabolism <i>B. Ganem</i>	21

Symposium on the Cellulose Structure and Its Characterization

An X-Ray Fiber Diffraction Study of Ramie Cellulose I <i>R.P. Millane and T.V. Narasaiah</i>	39
Structural Variation of Native Cellulose Related to Its Source <i>T. Okano, A. Koyanagi, Y. Kondo, and A. Sarko</i>	53
New Structural Models for Cellulose II Derived from Packing Energy Minimization <i>A. Sakthivel, A.F. Turbak, and R.A. Young</i>	67
Memory Phenomenon of the Original Crystal Structure in Allomorphs of Na-Cellulose <i>J. Hayashi, T. Yamada, and Y.-I. Shimizu</i>	77
Computer Models of Cellulose <i>A.D. French</i>	103
Electron Microscopic and X-Ray Diffraction Study of Cellulose III _I and Cellulose I <i>J. Sugiyama and T. Okano</i>	119
Structural Change of <i>Valonia</i> Cellulose Crystals during Alkaline Treatment <i>H. Bradford and J.-F. Revol</i>	129
Refinement of the Crystal Structure of Ramie Cellulose I with Additional Meridional X-Ray Intensities <i>D.P. Miller and A. Li</i>	139
Comparisons of Structures Proposed for Cellulose <i>A.D. French and P.S. Howley</i>	159
Studies on the Structure of Cellulose Using Raman Spectroscopy and Solid State ¹³ C NMR <i>R.H. Atalla and D.L. VanderHart</i>	169

Chirality and Structure of Cellulose and Cellulose Derivatives <i>A.M. Ritcey, J. Giasson, J.-F. Revol, and D.G. Gray</i>	189
A Combined Electron and X-Ray Diffraction Study of Cellulose Tripropionate <i>Y. Shuto, K. Okamura, J.-I. Azuma, F. Tanaka, and H. Chanzy</i>	207
Technology of NMR Imaging in Wood <i>P.C. Wang, S.K. Mun, J.S. Chang, and J.R. Olson</i>	221
NMR Imaging of Eastern Hardwoods <i>S.J. Chang, J.R. Olson, and P.C. Wang</i>	235
Undecenyl Pyranosides as Sidechain Mesogens of Chitosan <i>R.H. Marchessault, C.J. Monasterios, K. Holme, and L.D. Hall</i>	249
The Structural Association between Cellulose and Xyloglucan in the Primary Cell Wall of Beans (<i>Phaseolus vulgaris</i> L.) <i>I.E.P. Taylor and J.C. Wallace</i>	273
Structural Consequences of β (1 \rightarrow 4)Glycan Modification <i>W.T. Winter</i>	283
<i>In Vitro</i> Exploration of Chitin Fine Structure <i>M.L. Bade, K. Hickey, and A. Stinson</i>	293
Comparative Studies of Cellulose Diacetate in Acetone as Prepared by Conventional and New Acetylation/Ripening Processes <i>K. Ueda and S. Saka</i>	309

Symposium on the Cellulose–Water System

Studies on the Water Vapor Sorption Hysteresis of Viscose Rayon and of Chemically Modified Viscose Rayon <i>S.H. Zeronian and M.S. Kim</i>	325
Moisture Sorption Properties of Acetylated Lignocellulosic Fibers <i>R.M. Rowell and J.S. Rowell</i>	343
Nonisothermal Diffusion of Moisture in Wood <i>R.M. Nelson Jr.</i>	357
Volume Contraction of the Cellulose–Water System <i>B. Alince</i>	379
The Dynamic Viscoelasticity of Cellulose in Water <i>S. Yano, H. Hatakeyama, and T. Hatakeyama</i>	389
Water–Cellulose Interactions Studied by ^2H NMR. Effects of Beating <i>T.-Q. Li, U. Henriksson, and L. Ödberg</i>	403
DSC and NMR Studies on the Water–Cellulosic Polyelectrolyte Systems <i>H. Hatakeyama, K. Nakamura, and T. Hatakeyama</i>	419

Structural Change of Water Restrained in Cellulosic Hollow Fibers <i>T. Hatakeyama, S. Yamamoto, S. Hirose, and H. Hatakeyama</i>	431
Study of Percolation Transition in Cellulose Pulps and Latexes in the Microwave Domain <i>F. Henry and P. Noe</i>	447

Symposium on the Biogenesis of Cellulose

Purification of Cellulose Synthase from <i>Acetobacter xylinum</i> <i>F.-C. Lin and R.M. Brown Jr.</i>	473
Electron Diffraction Analysis of Altered Cellulose: Implications for Cellulose Biogenesis <i>C.H. Haigler and H. Chanzy</i>	493
The Nascent Structure of Bacterial Cellulose <i>A. Kai, J. Kogusuri, T. Koseki, and H. Kitamura</i>	507
The Role of Cyclic Diguanylic Acid in the Regulation of Bacterial Cellulose Synthesis <i>M. Benziman, P. Ross, D. Amikam, R. Mayer, H. Weinhouse, P. Weinberger-Ohana, and D. Michaeli</i>	519
Cellulose Biosynthesis in <i>Acetobacter xylinum</i> : A Genetic Approach <i>I.M. Saxena and R.M. Brown Jr.</i>	537
<i>Acetobacter xylinum</i> as a Model System for Cloning of Genes Involved in the Synthesis of Cellulose <i>S. Valla</i>	559
Prospects for the Commercialization of the Biosynthesis of Microbial Cellulose <i>D.G. White and R.M. Brown Jr.</i>	573
Evolution of the Cellulosic Cell Wall in the Charophyceae <i>A. T. Hotchkiss Jr. and R.M. Brown Jr.</i>	591
The Evolution of the Cell Wall in Green Algae: Scales, Glycoproteins, and Cellulose <i>D.S. Domozych</i>	611
Cellulosic Cell Walls of Red Algae <i>M.R. Gretz and C.M. Vollmer</i>	623
Cellulose Biogenesis and a Decade of Progress: A Personal Perspective <i>R.M. Brown Jr.</i>	639
A New Cellulose Synthesizing Complex in <i>Vaucheria hamata</i> and Its Relation to Microfibril Assembly <i>S. Mizuta, E.M. Roberts, and R.M. Brown Jr.</i>	659
Correlation between Structure and the Biogenic Mechanisms of Cellulose: New Insights Based on Recent Electron Microscopic Findings <i>S. Kuga and R.M. Brown Jr.</i>	677

Biosynthesis of Cellulose II in <i>Acetobacter xylinum</i> <i>E.M. Roberts, I.M. Saxena, and R.M. Brown Jr.</i>	689
<i>In Vitro</i> Regulation of Plant β -Glucan Synthase: A Native Activator and Its Synthetic Analogues <i>M. Benziman, T. Callaghan, P. Ross, P. Weinberger-Ohana,</i> <i>and G. Wohlman</i>	705
The Biosynthesis of (1 \rightarrow 4)- β -D-Glucan by <i>Lupinus albus</i> <i>D.O. Brummond</i>	721
Molecular Size of 1,4- β -Linked Products Formed by Membranes from UDP-Glucose <i>R. Gordon and G. MacLachlan</i>	739
The Relationship between the Synthesis of Cellulose and Callose in Higher Plants <i>D.P. Delmer</i>	749
Helicoidal Arrays of Cellulose in Quince Seed Epidermis: Evidence for Cell Wall Self-Assembly in the Plant Cell Periplasm <i>J.H.M. Willison and R.M. Abeysekera</i>	765
Helicoidal Order in the Periplasmic Cellulose Arrays of Quince Seed Epidermis: A Hypothesis for Its Origin <i>R.M. Abeysekera</i>	783
Inhibitor Effects on Putative Cellulose Synthetase Complexes of Vascular Plants <i>W. Herth</i>	795
The Role of the Cytoskeleton during Oriented Microfibril Deposition. II. Microfibril Disposition in Cells with Disrupted Cytoskeletons <i>R. W. Seagull</i>	811
Potential Use of Affinity Labels in Subunit Identification Studies of (1,3)- β -Glucan Synthase <i>B.P. Wasserman, S.M. Read, D.J. Frost, T.L. Mason,</i> <i>R.R. Drake, and B.E. Haley</i>	827

General Papers

Mechanisms of Formation of the Major Volatile Products from the Pyrolysis of Cellulose <i>M. Essig, G.N. Richards, and E. Schenck</i>	841
Accelerated Thermal Degradation of Pulp Sheets: Effect of Beating and Importance of Humidity <i>S.B. Lee, J. Bogaard, and R.L. Feller</i>	863
The Effects of Mode of Calcium Carbonate Deposition on Thermal Decomposition of Cellulose and Flame Retardant Treated Cellulose <i>I.R. Hardin, L.J. Martin, and Y. Qiu</i>	885

Viscose Rayon Coating of Fibers and Yarns <i>B. Collier, J. Collier, and H. Modh</i>	907
Cellulose in Depth Filtration Media <i>C.T. Badenhop</i>	929
Synthesis of Controlled Cellulose–Synthetic Polymer Graft Copolymer Structures <i>R. Narayan</i>	945
Analysis of Polysaccharide Degradation Products <i>G.K. Bonn and H.F. Hormeyer</i>	963
FTIR Internal Reflectance Spectra and Bonding of Wood Surfaces Activated with Non-Conventional Agents <i>A.J. Michell and J.P. Yuritta</i>	975
Second Derivative FTIR Spectra of Woods <i>A.J. Michell</i>	995
A New ^{13}C -NMR Approach for Determination of Substituent Distribution in Cellulose Ethers <i>Y. Tezuka, K. Imai, M. Oshima, and T. Chiba</i>	1011
Multivariate Characterization of Pulp Using Solid State C-13 NMR <i>B. Nördén, U. Edlund, and L. Wallbäcks</i>	1023
Effect of Sulfur Dioxide on Wood Surface Quality <i>D.N.-S. Hon and W.Y. Chao</i>	1037
Oxidative Modification of Cellulose by Ozone <i>M.P. Godsay and M. Lewin</i>	1059
Anthraquinone Pulping and Its Effect on the Supermolecular Structure and Accessibility of Cotton Cellulose <i>M.A. Abou-State, S.A. Helmy, and N.A.A. El-Ghany</i>	1085
Some Physical Properties of Cellulose Derivatives Prepared by Homogeneous Periodate Oxidation <i>T. Morooka, M. Norimoto, and T. Yamada</i>	1103
Preparation and Redox Behavior of Cellulose Derivatives Having Viologen Moiety <i>T. Sato, Y. Nambu, and T. Endo</i>	1119
Molecular Design of Linear Aromatic Polymers Derived from Phenols Related to Lignin <i>S. Hirose, H. Hatakeyama, K. Nakamura, and T. Hatakeyama</i>	1133
Environmental Stress Responses in Molecular Parameters of Cotton Cellulose <i>J.D. Timpa and D.F. Wanjura</i>	1145
Papermaking Properties of White Birch TMP <i>Z. Koran</i>	1157
Variables Affecting the Longitudinal Flow of Gas in Hardwoods <i>E.T. Choong, S. Achmadi, and F.O. Tesoro</i>	1175

Fiber Dimension Analysis of Five Selected Juvenile Hardwoods <i>P. Chow, G.L. Rolfe, and D. Wei</i>	1197
A Chemical Kinetics Approach to Wood Swelling <i>H. West and W.B. Banks</i>	1215
Kinetics of Sulphonation of Cellulose Fibres <i>B. Lönnberg and J. Jäkärä</i>	1235
Ultrafiltration of Kraft Black Liquor — Distribution of Solutes and Influence on Viscosity and Heat Value <i>K. Forss, E.M. Pulkkinen, and P.-E. Sågfors</i>	1253
Light Bleaching of Paper in the Presence of Sulfur-Containing Compounds <i>S.B. Lee</i>	1273

Symposium on Cellulosic Membranes

The Structure of Dense Glassy Polymeric Films <i>R.E. Kesting</i>	1291
Cellulose Acetate Mixed Esters as Polymers for Reverse Osmosis Membranes <i>R.E. Kesting</i>	1301
Evaluation in CA Gas Separation Membrane for Upgrading Hog Waste Biogas in R.O.C. <i>T.W. Tseng, Y.H. Chang, J.S. Lee, S.Y. Wang, and S.N. Tong</i>	1317
The Use of Cellulosic Membranes in Medicine <i>P. Konstantin</i>	1333
Transport Phenomena in Reverse Osmosis Cellulose Acetate Membranes <i>M.D. Afonso and M.N. de Pinho</i>	1347
Cellulose Blends with Synthetic Polymers — High Performance Membranes <i>I. Cabasso</i>	1361

Symposium on the Surface Chemistry of Cellulose, Wood, and Lignin

Physical and Chemical Modifications of the Surface Properties of Cellulosic Fibers <i>J.C. Arthur Jr.</i>	1383
Surface Chemistry of Oxidized Wood <i>D.N.-S. Hon</i>	1401

Surface Chemistry of Printing Papers: Surface Composition of Rosin and Synthetic Sized Bond-Type Papers <i>J. Borch and A. G. Miller</i>	1429
Ink Absorption by Cellulosic Paper in Calligraphy <i>R. Oye and T. Okayama</i>	1443
Conductometric Titration of Cellulosic Fibres <i>A. M. Scallan, S. Katz, and D. S. Argyropoulos</i>	1457
Sorption of Alkyd Resins on Cellulose <i>K. Johansson, G. Ström, and P. Stenius</i>	1473
Kinetics of Liquid Spreading along a Paper Surface <i>G. Ström</i>	1497
The Wetting Properties of Hydrophobically Modified Cellulose Surfaces <i>A. F. Toussaint and P. Luner</i>	1515
Mechanistic Aspects of Alkenyl Succinic Anhydride Sizing of Paper <i>J. C. Roberts and W. R. Wan Daud</i>	1531
Applications of Flow Visualization Techniques in Flocculation Analysis <i>F. Onabe and C. Sohn</i>	1547
Surface Charge of Calcium Carbonate in Water and Its Interaction with Cellulose Fibers <i>B. Siffert and P. Fimbel</i>	1567
Determination of Surface Charge of Cellulose Fibre by Potentiometric Titration and Polyelectrolyte Titration <i>R. I. S. Gill, T. M. Herrington, and J. C. Petzold</i>	1585
Considerations in the Continuous Monitoring of Charge in Cellulosic Fiber Systems <i>A. M. Springer and M. Kumar</i>	1601
Author Index	1635

CELLULOSICS AS ADVANCED MATERIALS

R.H. Marchessault

*McGill University
Chemistry Department,
Montreal, Quebec H3A 2A7
Canada*

SYNOPSIS

Because of its unconventional polymeric properties, cellulose is a unique material for functions ranging from information storage to energy conservation. Biomimetic aspects of cellulose utilization: extended chain materials, chemical recognition-based processes, materials based on the higher order structure of cellulose are discussed in the context of state of the art polymer science. Amphiphilic, hydrogel, and chirality properties of cellulose are used as examples of advanced materials attributes.

INTRODUCTION

Value-added materials with advanced performance in electronic, mechanical and optical applications are being actively researched. Cellulosics are generally not considered for these applications because molecular design demands degrees of freedom which cellulosics don't provide. This bias against the polymer which was the prototype for the development of polymer science seems more the result of ignorance than fact. In the following pages I will try to provide examples where cellulosics are in the running for high-tech applications, provided targeted advanced development is undertaken with perseverance.

At the recent IUPAC CHEMRAWN VI conference [1] in Tokyo the theme "Advanced Materials for Innovations in Energy, Transportation and Communications" focussed on the relation of materials to technical progress (Fig. 1). In particular, the biomimetic aspects with examples relating to intelligent devices, photosynthesis, energy conversion etc. were emphasized. The unique success of cellulosics in membrane devices is an advanced materials success. Cellulose is a polymer with unconventional properties and has potential for functions ranging from information storage to energy conservation. But like all