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International Symposium on Macromolecular Architecture

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Jane C. Vogl, Tatsuki Kitayama and Otto Vogl, International Symposium on Macromolecular Architecture, *Polymer News*, 21(2), 66-74 (1996); *Progress in Polymer Science*, 22(1), 185-201 (1997)

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Jane C. Vogl



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Otto Vogl

The International Symposium on **Macromolecular Architecture**, with the subtitle "Nature as a Model for the Molecular Design of the Polymeric Materials of Tomorrow" was held at the Royal Institute of Technology from April 20-21, 1995 under the cochairmanship of *Ann-Christine Albertsson*, Professor and Head of the



Department of Polymer Technology of the Royal Institute of Technology, Stockholm, Sweden and *Otto Vogl*, Herman F. Mark Professor of Polymer Science, Polytechnic University, Brooklyn, NY,

U.S.A. It consisted of 18 invited lectures and a Panel Discussion. The Symposium was held to honor *Bengt Rånby* on his 75th birthday.

The Symposium attracted 185 participants from 20 countries and was opened by *Stig Hagström*, the Chancellor of Swedish Universities and Colleges, Member of the Royal Swedish Academy of Sciences and President of EVA, the Swedish Engineering Academy. Subsequently, *Hiroshi Yoshida*, Professor of Hokkaido University, Sapporo, Japan, presented Professor Rånby with the Silver Medal and Certificate of the "Award of Distinguished Service for the Advancement of Polymer Science, SPSI" on behalf of the President of the Society of Polymer Science, Japan, *Yukio Imanishi*.

Greetings were conveyed by *Torvard Laurent*, the Past President of the Royal Swedish Academy of Sciences, *Tornbjörn Norlin*, the President of the Swedish Chemical



Bengt Rånby





Ann-Christine Albertsson



Stig Hagström



Torvard Laurant



Janne Carlsson

Society, Otto Vogl on behalf of the Polymer Division of the American Chemical Society and the Pacific Polymer Federation and Nikos Hadjichristidis on behalf of the European Polymer Federation.

The final greetings of the morning were presented by Professor Janne Carlsson, the President of the Royal Institute of Technology.

On the previous evening a reception was held at the Sheraton Hotel in Stockholm. At this occasion, James Gellert, University of Toronto, Canada, discussed "Photochemistry 1961-1995" and J. Johan Lindberg, of the University of Helsinki, Finland, gave a talk on "Hydrogen Bonds and Macromolecules", subjects that were close to Bengt Rånby's interests.

During the Symposium the following papers were presented: Albert Eschenmoser, ETH Zurich, Zurich, Switzerland, discussed "Design of Nucleic Acids". An etiology of life will have to be primarily a chemical etiology, and will be mainly concerned with the origin of the molecular structure which we encounter today in nature's nucleic acids. He demonstrated an experimental approach to understand the origin of biomolecular structures by the systematic study of the chemistry of structural alternatives, molecular structures of which, according to chemical reasoning, could have, but have not, become (or survived as) biomolecules.

Natural nucleic acids have cyclopentose units as principal constituents in their repeating units. Eschenmoser chose cyclohexose derivatives as potential alternatives to the natural nucleic acids based on a chemical hypothesis about the self-assembly process that originally produced the biomolecule, using two criteria; first, whether the alternative can self-assemble, like the biomolecule itself, and, second, whether its chemical properties in principle would allow it to fulfill the biological function of the biomolecule. The chemically synthesized nucleic acids with hexose units did undergo base pairing as did the natural ones but did not form a double helix structure. The difference was discussed in terms of dissociation behavior, molecular dynamics calculations and other functions. Such alternative structures were compared for their chemical properties with those of the actual biomolecule in order to learn why the latter, and not the alternative, has been chosen by nature. Such information will deepen our understanding of the structural basis of the biomolecule's function and, if we are fortunate, we may find candidates for intermediates (if there are any) on the evolutionary path towards the biomolecule we know.



KUNGL TEKNISKA HÖGSKOLAN

today.

The following two presentations on cellulose were arranged to remind the audience that Professor Ranby started his research on a cellulose theme.

R. Malcolm Brown Jr., University of Texas, Austin, Texas, discussed "The Biosynthesis of Cellulose". Cellulose is one of the major commercial products and constitutes the most abundant of the natural polymer systems. Thus, the molecular design and architecture of cellulose with particular reference to the controls of its biosynthesis is of considerable interest. The bioassembly process of cellulose is highly ordered and structured, reflecting the intricate series of events which must occur to generate a metastable crystalline submicroscopic, ribbon-like structure which itself is oriented with respect to the cell surface.

The plant cell wall is an extremely complex composite of many different polymers. Cellulose is the "reinforcing rod" component of the wall. True architectural design demands a polymer which can withstand great flexing and torsional strain. Using comparative hydrophobic cluster analysis of a bacterial cellulose synthase and glycosyl transferases, the multidomain architecture of glycosyl transferases has been analyzed. Cellulose synthase appears to have evolved a mechanism to simultaneously bind at least three UDP-glc's and to polymerize by double addition, two UDP-glc in such a manner that the 2-fold screw axis of the β -1,4-glucan chain is maintained.

Shiro Kobayashi, Tohoku University, Sendai, Tohoku, Japan, presented his talk on "Chemical Synthesis of Natural Type Cellulose via Enzymatic Polymerization". Chemical synthesis of cellulose has long been a challenging problem in polymer chemistry. Many attempts have been made, which include a selective dehydration polycondensation of a 2,3,6-tri-protected glucose and a ring-opening polymerization of bicyclic acetal compounds. These methods, however, did not undergo the stereo- and regio-selective reaction and failed to produce cellulose. Professor Kobayashi reported the first successful chemical synthesis of cellulose by a polycondensation of β -cellobiosyl fluoride monomer catalyzed by cellulase, an extracellular hydrolysis enzyme of cellulose, in an acetate/buffer mixed solvent ("Enzymatic Polymerization"). The polymerization proceeded under perfect control of stereo- and regio-selectivities. The product, synthetic cellulose, was the crystalline allomorph cellulose II, a thermodynamically more stable form, in which neighboring cellulose chains are packed in an anti-parallel manner. He also demonstrated that the enzymatic polymerization with purified cellulase produced cellulose I, a metastable allomorph in which all the cellulose chains are aligned in the same direction. He particularly emphasized the importance of spatial arrangement of cellulase in micelles.

David A. Tirrell, University of Massachusetts, Amherst, MA, U.S.A., presented his view on "Design and Synthesis of Proteins". He explored the synthesis and characterization of artificial proteins for use in materials applications. The design of such materials draws on ideas taken in part from polymer chemistry and physics and in part from structural biology, and exploits the sequence control and chain-length uniformity provided by genetic engineering. He discussed four issues which have been explored by the Amherst group.

I Crystal growth is a process dependent both on the details of local structure and on the homogeneity of the molecular population. He utilized genetic engineering to prepare the series of periodic copolypeptides. The *de novo* design of the periodicity provided the formation of folded-chain lamella crystals of controlled thickness and surface functionality.

II Even though the 20 amino acids encoded naturally by messenger RNA templates provide a broad range of chemical functionality, many functional groups which may be of interest to materials science are not represented. To address this limitation, he has initiated an *in vivo* incorporation of non-natural amino acids into artificial proteins, by using a bacterial host strain that is auxotrophic for one of the 20 amino acids. When the strain was supplemented with an analogue of the limiting amino acid, it incorporates the analogue in high level to give an artificial protein consisting of non-natural amino acid units.

III He focused on the uniformity of chain length of poly (α ,L-glutamic acid) (PLGA); their benzylated derivative, polycy-benzyl glutamate (PBLG), has been known as a rod-like helical polymer that forms liquid crystalline solutions and ordered monolayer films.

IV The design and synthesis of a family of hybrid phosphotriesterases were also described with the emphasis on the prospects for creating new reactive polymers with high catalytic efficiency and specificity.

Joan M.J. Fréchet, Cornell University, Ithaca, NY, U.S.A., discussed the now intensely investigated "Spherical Polymers and Dendrimers". The design and preparation of polymers that have a globular 3-dimensional architecture has attracted attention recently because these materials may open new avenues in polymer science and technology. He discussed the strategy for the preparation and use of dendritic molecules as building blocks in the preparation of various targets such as molecular dipoles, barrel-shaped molecules, or linear-globular polymer hybrids. In particular, he emphasized the versatility of the convergent growth approach for the preparation of complex dendritic structures that have defined shapes or functions. In this approach, dissimilar fragments, each with their own functionality, can be assembled in a final entry that may exhibit unique or unusual properties.

Unimolecular micelles can be obtained, for example, from dendritic molecules with ionic chain ends and a hydrophobic core. Similarly, unimolecular "inverse-micelles" can be prepared by methylation and carbonylation of appropriate internal sites of dendrimers. Other examples where structure has a direct influence on properties include strongly dipolar unsymmetrical globular molecules or linear-dendritic block copolymers that exhibit highly unusual solution behaviors. The properties of dendrimers are quite different from those of other polymer architecture: they do not obey universal calibration and have highly unusual solution and melt viscosity properties resulting from their shape and lack of entanglement. Neutron scattering

and other studies have confirmed the globular shape of dendrimers and show their flexibility at low generation. Fréchet foresees the potential application of these new polymers in molecular devices, medical imaging materials, drug delivery systems, theology control agents and pollution control systems.

Franciska Sundholm, University of Helsinki, Helsinki, Finland, gave her talk on "Modeling of Polymer Properties: Polystyrene and Polysulfones". Molecular modeling provides opportunities to study the structure of amorphous polymer materials at the level of individual atoms. By constructing representative microstructures of amorphous polymer and describing the interactions between the atoms by a force field, she studied macroscopically observed behavior of material under stress. The systems investigated include polystyrene and its *para* substituted derivatives. Based on force field methods combined with Flory's theory of rotational isomeric states she calculated conformation dependent properties such as characteristic ratio, radius of gyration and persistence length of a single chain as a function of the chain tacticity, and obtained a reasonable agreement with experimental results which encouraged further calculations. The force field acts as an intermediary in the transformation from the microscopic level to the macroscopic bulk properties, such as solubility parameters, elastic constants and gas permeabilities.

Anders Hult, Department of Polymer Technology of the Royal Institute of Technology, Stockholm, Sweden, talked about "An Organized Liquid Crystalline Network for Second-Harmonic Generation". Oriented liquid crystalline thermosets are an interesting class of polymeric materials with potential use in a wide variety of applications, since they may constitute oriented polymer networks with mechanical and thermal stability. Orientation in the crosslinked systems can be achieved by allowing an external field to align either the already made polymer or, prior to polymerization, the monomer. In the second case, the low viscosity of the monomers facilitates the orientation process which can be induced by contacting the monomer with a pre-treated surface or by exposing it to an electric or a magnetic field. Subsequent *in-situ* polymerization of the ordered monomer system results in an ordered polymer. Hult applied this technique to the preparation of ferroelectric liquid crystalline networks that potentially exhibit NLO properties.

Ulf Gedde, Department of Polymer Technology of the Royal Institute of Technology, Stockholm, Sweden, discussed "Dynamics and Structure of Side-Chain Crystalline Poly(vinyl ether)s". He and his colleagues determined dielectric permittivity and loss over the frequency range 10^{-2} Hz - 10 kHz between 100°K and 350°K for a series of mesomorphic side-chain poly(vinyl ether)s with 4-11 methylene carbon atoms in the spacers and phenyl benzoate and stilbeneyloxy used as mesogens. They found the following unified scheme for the dielectrically active processes: a glass-rubber transition (α) in the vicinity of 300°K, and three subglass processes, from high to low temperatures; referred to as β (rotation of carbonyl group) γ (local motions in the spacer groups), and δ (motion of flexible tail group). He also discussed the dependence of these relaxation processes on the spacer length and the main chain tacticity.

Sigbritt Karlsson, Department of Polymer Technology of the Royal Institute of Technology, Stockholm, Sweden, spoke about



Bengt Rånby

Albert Eschenmoser



At the Reception

"Natural Metabolites as Opposed to Degradation Products of Synthetic Polymers". In nature, biomolecules are transformed in anabolic and catabolic cycles. The reactions responsible for these cycles are collectively referred to as metabolism. She pointed out four specific functions of metabolism: a) to obtain energy from degradation of energy-rich nutrients, b) to convert nutrient molecules into the building-block precursors of cell macromolecules, c) to assemble these building blocks into proteins, nucleic acids, polysaccharides and other cell components and d) to form and degrade biomolecules required in specialized functions of cells. In principle the central metabolic pathways are few in number and they are also identical in most forms of life. The catabolic pathways converge to a few end products, e.g. ammonia, water and carbon dioxide. The central metabolic pathways involve the cycling of perhaps several hundred grams of a substance per day, but there are other pathways as well, secondary metabolism, where the flow of biopolymers is much smaller. She showed the analysis of degradation products from synthetic polymers and discussed these characteristics as a measure in comparison with natural metabolites.

Friday morning the following lectures were presented: **Hartwig Höcker**, Wool Research Institute, Aachen, Germany, spoke about his studies on the "Hierarchy of α -Keratin Fibers with a Glance to the Skin Including Oetzi". Oetzi is the man who died more than 5000 years ago and was found in the ice with his hair left on his head. Eventually the hair proved the enormous stability of its constituent α -keratin. Professor Höcker illustrated the origin of the remarkable properties of α -keratin fibers such as human hair and sheep's wool. These fibers have a hydrophobic surface and may take up more than 30 wt-% water with small extension in length and significant extension in width.

Höcker showed the hierarchical architectural design comprising a complex cuticle and a cortex which resembles a fiber reinforced matrix material with "fibers" (microfibrils) and matrix being of similar chemistry (amino acid residues) and both chemical and physical interactions between matrix and microfibrils. The latter are typical intermediate filaments, comprising 32 protein chains as coiled coils with highly sophisticated primary, secondary and tertiary structures of the individual chains. Intermediate filaments are also stabilizing components of skin. The idea cannot be to copy α -keratin synthetically, rather from the hierarchical structure many ideas may be taken to optimize synthetic systems.

Nikos Hadjichristidis, University of Athens, Athens, Greece, presented his work on "Model Non-linear Block Copolymers: Synthesis, Characterization and Morphology". Non-linear block copolymers herein mean star polymers having different polymer arms, A₃B (3 miktoarm star copolymers), (miktoarm comes from the Greek word mikto meaning mixed), and A₂B (4 miktoarm star copolymers), star polymers with block arms, (AB)₃(BA)₃, (inverted 4-miktoarm star block copolymers) and A₂BA₂ (bridged miktoarm star copolymers). Throughout his talk, A is polyisoprene (PI) and B polystyrene.

The synthetic approach to these macromolecular architectures that Hadjichristidis took involves the reaction of methyltrichlorosilane or tetrachlorosilane with monofunctional or difunctional macroanions of B, under conditions unfavorable to chain coupling or linking followed by addition of the monofunctional macroanion of A. He demonstrated the characterization of these polymers in solution by size exclusion chromatography, low-angle laser-light scattering, laser differential refractometry, membrane and vapor pressure osmometry, NMR and UV spectroscopy. The non-linear block copolymers underwent microphase separation as studied by transmission electron microscopy and small angle x-ray scattering. From the comparison with the corresponding linear block copolymers, he found that the macromolecular architecture not only affects strongly the morphological domain borders but it can introduce new morphologies as well. He also discussed the synthesis and association in dilute solution of star polybutadienes with zwitterionic functional end groups.

Xiao-Yin Hong, Qinghua University, Beijing, China, discussed "Modification of Natural Polymers such as Silk, Chitin and Cellulose". The chemical modification of natural polymers is one way for polymer chemists to collaborate with nature. Professor Hong reported remarkable success in this field achieved in China. The following aspects 1.) Graft copolymerization of vinyl monomer onto the natural polymers, such as silk, cellulose and chitosan, which is the most important approach to the modification of these natural polymers. 2.) The modification of the natural polymers to overcome some of their defects: Silk and Chinese lacquer in China have been used in practice for thousands of years as the great contribution of the Chinese ancestors to the civilization of mankind. However, some defects of these natural polymers limit their further applications, for example, the crease and yellowing of silk and the slow cure and brittleness of the Chinese lacquer. 3.) The application of some natural polymers to high-tech materials, through their chemical modification, such as a thermoplastic elastomer from gutta-percha, an enzyme-immobilization on silk fibroin membranes, liquid crystalline polymers from cellulose derivatives and several others.

Virgil Percec, Case Western University, Cleveland, OH, U.S.A. presented "Self-Assembly of Viruses as Models for the Design of New Macromolecular and Supramolecular Architecture". Viruses which most frequently self-assemble into rod-like and icosahedral shapes are the best understood self-assembled natural systems. Regardless of its shape (i.e., rod-like or icosahedral), a virus consists of a RNA or DNA chain coated with proteins of a well-defined shape (*exo*-receptor and *exo*-recognition) which are ultimately responsible for the rod-like or icosahedral shape of the virus and for the well-defined conformation adopted by the nucleic acid chain.

Percec took Tobacco Mosaic Virus (TMV), a classic example of a rod-like virus as a model for a self-assembled supramolecular architecture. In the case of TMV the tapered



Speakers of the Conference

shape of the coating protein generates the rod-like architecture. The interaction between the nucleic acid and protein (endo-recognition) is responsible for the stability, length and diameter of the rod. At the same time, the insertion of the nucleic acid into the center of the rod-like architecture induces its helical conformation. TMV can also self-assemble in the absence of RNA, but its length is not controllable under these conditions. By analogy with the self-assembly, he investigated the self-assembly of various tapered (exo-acceptor) groups into rod-like shapes, and succeeded in generating a cylindrical architecture with a well-defined diameter in the presence and in the absence of synthetic polymer chains. They involve the dependence between the shape and size of synthetic tapered groups and their ability to self-assemble into rod-like and other shapes via various endo-recognition processes.

Maria Spina, E.I. du Pont de Nemours & Co., Wilmington, DE, U.S.A., talked about "Polylactides and Other Natural and Synthetic Polyesters". Polylactic acid (PLA) has been used for biomedical applications, and most of the research in the field was generally aimed at regulating the rate of degradation in drug release systems. Much less attention was given to improving PLA such processability or broadening the physical-mechanical properties, which are much more important for general-use applications.

She discussed several new approaches to molecular design leading to PLA-based materials with a broad range of properties and improved processability. The approaches include: copolymerization (block and stereoblock copolymers), microstructure and architecture control, and stereocomplexation. The versatility in material design for PLA systems is largely based on the chirality of the lactide monomer, the retention of configuration at the chiral center during polymerization, and the living nature of the ring opening polymerization of lactide in the presence of groups with active hydrogens, such as hydroxyl and amino groups. Taking full advantage of these unique features, she demonstrated the synthesis of new PLA materials.

Tatsuki Kitayama, Osaka University, Toyonaka, Osaka, Japan, presented his new concept: "Natural and Synthetic Uniform Polymers". Uniform polymers have been defined in an IUPAC document as "polymers composed of molecules uniform with respect to relative molecular mass and constitution". When nature creates a molecule with sophisticated functions, she designs and produces a uniform polymer, such as protein for catalysis and nucleic acid for replication, which are uniform with respect to molecular weight, sequence arrangement of constitutional units, stereochemistry and spatial conformation or shape, while non-uniform polymers such as cellulose, natural rubber, polyesters of biological origin are also found in nature.

On the other hand, synthetic polymers that man has made so far are usually inhomogeneous with respect to these structural features. Recent advances in polymer chemistry have provided opportunity of controlling molecular weight of polymers via living polymerizations in a variety of mechanisms. Another trend in precise synthesis of polymers is the control of stereochemistry, the importance of which was pointed out earlier by H. Staudinger and realized by G. Natta later by the invention of isotactic polyolefins. Recently Kitayama and his colleagues have reported stereospecific and living polymerizations of methacrylate that gives highly isotactic, syndiotactic, and

heterotactic polymers with narrow molecular weight distributions. Even with the well-controlled living polymerization, however, the number of monomeric units in each polymer molecule formed has a statistical distribution.

This was evidenced by the advanced chromatographic technique, supercritical fluid chromatographic (SFC), which is capable of separating isotactic PMMA with a degree of polymerization (DP) of 66.5 and molecular weight distribution index (M_w/M_n) of 1.07 consisted originally of 105 components of homologous series of isotactic PMMA. By applying this chromatography to the separation of the mixture into each component, it is now possible to obtain synthetic uniform PMMAs with DP up to 100. Uniform polymers are pure model substances of polymers and very desirable for the studies of structure-property relationship of synthetic polymers. Kitayama also showed that end-functionalized uniform polymers could be used as a building block for constructing more complex uniform polymer architectures.

Kenneth P. Chigginio, University of Melbourne, Melbourne, Australia, gave a most informative talk about "Photostabilizing Polymeric Materials". In nature protection from the damaging effects of solar radiation has been achieved by a variety of methods. In the photosynthetic apparatus, as he pointed out, carotenoid molecules have been implicated as excited-state quenchers and scavengers of harmful photoactive intermediates formed following light absorption. Many plants and organisms possess other pigments which act as natural sunscreens and, in some cases, such protection actively responds to solar light levels. While the diversity of natural photoprotective mechanisms has yet to be fully elucidated, additives such as UV absorbers, quenchers and antioxidants have also been widely used to photostabilize synthetic polymer substrates.

Professor Chigginio utilized ultrafast laser spectroscopy to provide an insight into the energy dissipation mechanisms in stabilizers and has demonstrated that the efficiency of transport and trapping of absorbed light energy is crucially dependent on macromolecular structure. The rate of excitation energy migration and transfer in polymers is far greater than predicted by conventional theories suggest that, under certain conditions, the polymer backbone can play a role in effectively coupling energy throughout the system. The results support the view that a true "polymer effect" is operating in macromolecular photochemistry. Based on these recent studies and improved understanding of biological photoprotection, he suggested the design of new synthetic polymers with improved light stability.

Ann-Christine Albertsson, Royal Institute of Polymer Technology, Stockholm, Sweden, the Co-chairperson of the Symposium, discussed "Nature as Model for Degradable Polymers". Nature usually combines polymers with short degradation times with polymers having long degradation times in an energy and material optimizer process involving hierarchical systems. Sometimes a natural system of polymers has evolved to degrade in a month, sometimes in many years. The building blocks of the plant and animal kingdom are biopolymers which are either oxidizable or hydrolyzable. In natural composites combinations of the two are common. Professor Albertsson took a tree as an example, which consists of three polymers: hemicellulose, cellulose and lignin. Hemicellulose is water-soluble and has a short time of degradation, cellulose degrades at



At the Banquet
Carl-Olof Jacobsson

Bengt Rånby

Otto Vogl



City Hall, Stockholm

a medium rate, but lignin has a very long rate of degradation. All three polymers are needed in order for the tree to grow, survive, and ultimately to be disposed of in an orderly manner. The consideration on nature gave her an idea of controlled degradable polymers or degradable polymers with predetermined service-life. She demonstrated the research on this line developed at KTH that include polyanhydrides, polyesters, polycarbonates and others.

A panel discussion was organized by Robert W. Lenz, University of Massachusetts, Amherst, MA, U.S.A. with the panelists: M. Fontanille, University of Bordeaux, Bordeaux, France on "Living Cationic Polymerization", J. Guillet, University of Toronto, Toronto, Canada on "Polymer Photochemistry", Z. Jodlinski, Polymer Institute, Zabrze, Poland on "New Lactide Polymerization" and R. Marchessault, University of Montreal, Montreal, Canada on "Polymer Structures". R. W. Lenz concluded with a discussion of "Polymers and Copolymers of β -Hydroxybutyric Acid".

The Symposium was concluded with a summarizing talk by Otto Vogl, Polytechnic University, Brooklyn, NY, U.S.A., the co-chairman of the Symposium, on "Polymers for the 21st Century". Polymer Science and Technology will be of continuing and increasing importance for the well-being of mankind. Many needs for human life will be influenced by Polymer Science and Technology: clothing, nutrition, housing, health care, construction, transportation, energy and communication. From commodity plastics to highly sophisticated specialty polymers with specific properties (tailor-made plastic materials) the demand will continue.

Based on a survey of the world's plastic market, he explained that commodity plastics have reached a level of maturity in industrial countries but still grow at a rate of about 5% per year. Worldwide sustained growth of commodity plastics will come from the population growth and the demand in lower developed countries. Growth of a business is not always judged by volume growth but also by profitability of a product. The volume growth of commodity plastics can also be sustained by increased production efficiency. Growth efficiency of specialty polymers depends on high profitability at low volume products, which means substantial dependency of quality research and the search for novel applications. This has to be done by highly trained scientists and technologists. Successful global companies have already shifted their thrust from commodity plastics into more profitable ventures.

Vogl also pointed out the following important issues in polymer industries. Economic synthesis of monomers and polymers by optimal processes to obtain ultimate properties of the best polymers at the lowest price? Synthetic processes that do not effect the environment, in other words, catalytic processes are most desirable. Great pressure also exists for the plastics production to decrease the world wide dependence on oil for the plastics production, although only 4% of the oil that is annually produced is used for the production of plastics materials—but 92% are burned for energy production. This lopsided situation is not an emergency problem, still, the use of renewable resources



Axel Wennerholm Bengt Rånby Ann Christine Albertsson Otto Vogl



In the City Hall

as our raw materials for (commodity) plastics production must be continuously addressed.

The Symposium Banquet, held at the Operaternen, the most exclusive Restaurant in Stockholm, was attended by 135 persons including the Rånby Family with children and grandchildren. With Mats Johansson as toastmaster, the banquet was a tribute to Bengt Rånby for his professional and personal achievements.

The first toast was proposed by **Carl-Olof Jacobsson**, the General Secretary of the Royal Swedish Academy of Sciences to Bengt as a respected and active member of the Academy. Then followed a toast to Bengt by **Professor Torbjörn Norin**, Chairman of the Department of Chemistry of the Royal Institute for his assiduous activity to modernize the chemistry curriculum at both the high school and the college level and a toast by **Dr. Lars Gådda**, Director of Research, Neste OY, Finland for promoting cooperation in International Polymer Technology and for initiating the Nordic Polymer Days. A toast by **Dr. Karl-Erik Sahlberg**, chairman of the Federation of the Swedish Chemical Industries and former President of Perstorp AB, Sweden, to Bengt for his fruitful and stimulating contact and

cooperation with the chemical and polymer industries, a toast by **Dr. Alf de Ruen**, Director of Research, Swedish Cellulose AB, to Bengt for his basic work on the cellulose structure and fiber morphology and his continued interest in cellulose research and new product development, of great benefit to the Swedish forest and wood industry and, finally, a toast in metric form by **Professor Kent Abbås**, Director of Research of Borealis, Copenhagen, Denmark to Bengt for his creative and important polymer research.

After dessert, **Bengt Rånby** expressed his warm personal thanks to the banquet speakers for their kind and appreciative words. He thanked particularly **Professor Ann-Christine Albertsson** and **Professor Otto Vogl** for arranging this Symposium which he considered of the highest level both scientifically and socially and the splendid banquet that was given in his honor. He also talked about "Reminiscences of Polymer Science and Industry in my Life". Bengt concluded that he is still looking forward to new fascinating developments in the polymer field, for both natural and synthetic polymers.

On Friday noon, the participants were invited by the mayor of

Stockholm to a reception in the City Hall. The Hall of Nobles was decorated for a formal dinner. After the dinner, the participants were invited to a reception in the City Hall. The reception was held in the Hall of Nobles, which is a very beautiful room. The reception was held in the Hall of Nobles, which is a very beautiful room. The reception was held in the Hall of Nobles, which is a very beautiful room.

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