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Polymer Science in Austria III, Universities in Linz, Innsbruck and other Research Institute in Austria including Industry

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Polymer Science in Austria III: Universities of Linz, Innsbruck and other Research Institutions in Austria, Including Industry

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in cooperation with

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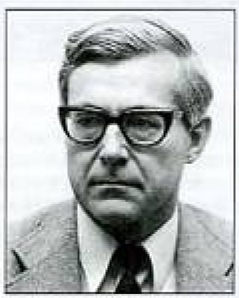

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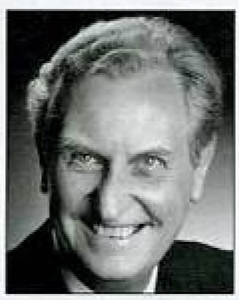

Otto Vogl

University of Linz, Administration Building

University of Linz, The Johannes Kepler University (Herman Janeschitz-Kriegl)

The University of Linz is officially called the Johannes Kepler University, named after the famous astronomer Johannes Kepler who spent a considerable part of his active life in Linz.

Although the University of Linz was officially founded in its present form in 1966; it has roots reaching as far back as the 16th century to the year 1574 when it was originally founded as a Protestant School of Agriculture. It was in this school that Johannes Kepler taught from 1612 to 1626, after spending the period from 1594 to 1600 in Graz and from 1600 to 1611 in Prague. His most famous work entitled "Harmonices Mundi" was published in 1619 while he was teaching in Linz. The Protestant School suffered during the religious and political upheavals of the 17th century in Europe and was then united with the so-called Latin school.

Today the University of Linz offers 18 areas of study organized into 3 faculties and has about 15,000 students. A total of 70 professors, 20 associate professors, 350 assistants and 560 lecturers are teaching in the university. The University of Linz consists of three schools: a School of Social Sciences and Business, a Law School and a School of Technical and Natural Sciences. The latter school has the following departments: Applied Mathematics, Informatics, Technical Physics and Technical Chemistry. Recently, the department of Mechatronics was created.

Polymer research in the Institute of Chemistry is carried out in the Divisions of Physical Chemistry and Fundamentals in Engineering.

Institute for Chemistry, Division of Physical Chemistry and Process Technology (Hermann Janeschitz-Kriegl).

The Institute of Chemistry is the home of polymer chemistry; it consists of five Divisions: 1.) General and inorganic chemistry where solid state chemistry is studied. 2.) Analytical chemistry

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Hermann Janeschitz-Kriegl

which is concerned with the development of analysis methods for bioanalytic and environmental problems; 3.) Organic chemistry which involves the investigation of pyrrol pigments; 4.) Physical chemistry, which includes the study of methods of rheology, viscoelasticity and polymer melts; 5.) Process engineering, which emphasizes transport phenomena in highly viscous media (elastico-viscous media for plastics technology, heat transfer and crystallization).

University Linz

Three areas of importance have been identified and are being pursued in this Institute: a.) Characterization of polymers by measuring the complex moduli of polymer melts; this effort is headed by Alois Schausberger; b.) Industrial polymer rheology, headed by Rudolf Sobczak and c.) Crystallization of polymer melts under conditions of heat transfer and flow, headed by Hermann Janeschitz-Kriegl.

The correlation between mole mass distribution and the dynamic moduli (the loss and the storage moduli as functions of circular frequency) is one of the focuses of this work. For linear polymers a procedure was developed for the calculation of a discreet relaxation time spectrum from a given molar mass distribution function. Such a spectrum allows the prediction of all linear viscoelastic material functions. A concept was developed which involves a time-concentration superposition principle, which enables scientists to enlarge substantially the experimental window for the measurements of material functions. This was done by adding relatively small quantities of chemically related low molecular weight compounds.

Linz

The polymer characterization group has a number of objectives. One subject is the correlation between the molar mass distribution, as determined by gel permeation chromatography (GPC), and the loss and the storage molduli of the melt as a function of circular frequency. This kind of information would allow us to relate rheological properties for predicting processing behavior for accurate measurements obtained from GPC.

In the polymer characterization group major progress is being made in the development of an apparatus for the measurement of very high viscosity in polymer melts (absolute measurements). This "Magnetoviscometer" is designed to study dynamic measurements of the elastic part and is applicable for the investigation of solidification mechanisms of polymer melts, investigation of the influence of molecular parameters (molecular weight) on the molecular weight distribution, on the degree of branching, on the addition of solvents and on the linear viscoelasticity of polymer melts. It will also be useful for the measurement of linear viscoelasticity through a relaxation spectra for the calculation of nonlinear material functions from linear relaxation spectra.

Research on industrial rheology of polymers is concentrated around a newly developed rheometer. This instrument is a falling sphere rheometer which is driven by a variable (inhomogeneous) magnetic field. In this apparatus the speed of iron spheres can be varied outside the range accessible to the gravitational field which is much too weak to observe polymer melts. A theory was developed which uses data from differential scanning calorimetry and relates them in terms of a temperature dependent nucleation time spectrum. This discovery is of great importance for obtaining and utilizing processing data. The solidification process of semi-crystalline polymers under conditions where heat transfer is well

Linz, Main Square

controlled and understood is the most important practical utility. Nucleation and crystallization induced by shear are also pursued in this research.

Of great practical significance is the use of simple measuring cells which can determine the progress of gelation and of chemical crosslinking reactions. A new device was also developed which can measure viscosity under pressure and at elevated temperatures. Several conventional viscometers, a screw extruder and equipment for the measurement of flow birefringence are also available.

Research on polymer solidification by crystallization has been a significant part of the work of this group. A theory developed by G. Eder can explain results from differential scanning calorimetry measurements. This combination of easy data acquisition with a sound theory is very important to obtain meaningful processing data. Shear induced nucleation and crystallization are being studied by. S. Liedauer who worked out the kinetics of this process for polypropylene.

Teaching in the Department of Physical Chemistry and Process Engineering is concerned with many important technical processes which include thermodynamic phase-relations, surface phenomena, distillation, crystallization, reaction kinetics, polymerization, electrochemistry, crystal structural analysis, quantum mechanics, spectroscopy, colloid chemistry and macromolecules, rheology, material science and processing of plastics.

Research in Process Engineering is involved in rheology, thermal transfer and crystallization of polymer melts. A very close cooperation exists with the Department of Physical Chemistry with particular emphasis on the use of model experiments, on their theoretical foundations and on their practical explanations.

University of Innsbruck, the Leopold Franzens University

The University of Innsbruck, whose official name is now 'Leopold Franzens University' was founded in 1669 by Emperor Leopold I and later confirmed by Emperor Franz I.

Today the University of Innsbruck has 28,000 students and six faculties: Catholic Theology, Law, Social and Economic Science, Philosophy, Natural Science and Architecture. Four of their former students in their later careers received the Nobel Prize.

During the 300 years of teaching and research, natural science subjects were part of the faculty of philosophy. Since 1975 the Faculty of Natural Science has been an independent Faculty. It consists of six fields: Physics/Astronomy, Mathematics, Chemistry, Pharmacy, Biology, Earth Sciences and Psychology, with 22 Institutes. Since 1851 Chemistry has had a separate Chair. Since then the department has expanded to include 5 institutes: Inorganic/Analytical, Organic/Pharmaceutical, Physical Chemistry, Biochemistry and Radiochemistry. In 1972 the Institute of Radiochemistry installed a Chair for Radiochemistry and Applied Physical Chemistry. The Institute also has activities, which are not included in other institutes, e.g. Industrial Chemistry. Usually lecturers who are working in industrial companies in Austria and neighboring countries are engaged.

Research and teaching activities involving polymers are carried out at the Institute of Radiochemistry.

Institute of Radiochemistry (Ortwin Bobleter)

Ortwin Bobleter

Several projects involving polymer research are being studied in the Institute of Radiochemistry. They involve the chemistry of plant biomass transformation and development and use of analytical techniques related to these problems.

A process was developed for the degradation of different kinds of plant materials (hardwood, wheat, staw, bagasse, etc.) which utilizes water at elevated temperatures. With superheated percolating water between 180 and 220°C practically all the hemicellulose and a considerable part of the lignin of plant materials can be dissolved. At temperatures of 270 to 300°C, the cellulosic residue is also hydrolytically degraded to low molecular sugars and other products. Because of the hydrolytic action of water at these high temperatures (and pressures), the process has been called "hydrothermolysis".

Two main technical uses of this development are envisaged: 1.) Formation of sugars and the subsequent fermentation to obtain motor fuel, mainly in the form of ethanol; 2.) Production of pulp from waste materials (e.g. straw and bagasse); 3.) Energy obtained from easily grown plant products (e.g. Poplar trees, *Miscanthus sinensis giganteus*). The influence of some reaction parameters (temperature, time etc.) on the degree of polymerization (DP) of the cellulose residues were examined. Experiments have been carried out using conventional methods and also newly developed methods to determine the molecular weight of the residues. Chromatographic DP measurements were obtained by dissolving the cellulose on

Maria-Theresien Strasse, Innsbruck

"cadoxene" and applying stable commercially available gel permeation columns (W. Schwald, O. Bobleter).

Work on hydrothermally pretreated plant matter for pulp production was also carried out. It was accompanied by DP measurements, using dimethylacetamide/LiCl solvents (A. Zemann, O. Bobleter). The cellulose obtained by this process was examined with regard to its molecular size distribution and to its fiber properties. This work is being carried out in cooperation with P. Krkoska of Bratislava, Slovakia.

Hydrothermolysis is also an efficient method for the enzymatic saccharification of cellulose. Investigations are under-way to determine the pore structure of pretreated cellulose in order to obtain a better understanding of the accessibility of the cellulose enzymes which is connected with the rate of saccharification.

Improvements in the analyses of the oligomer saccharides (G. Bonn) are the starting points for additional research. HPLC was used to obtain rapid results using ion exchange columns for the separation of oligomeric glucans. High polymer hemicelluloses and other sugar derivatives were analyzed electropherometrically using specially treated thin layer plates. Specially prepared polystyrene/divinylbenzene beads have shown excellent performance in the HPLC separation of proteins.

It is believed that sometimes in the next century the chemical industry will have to seriously consider changing from crude oil as a raw material to other resources, which will most probably be plant biomass. The degradation of the macromolecular constituents of biomass, cellulose, hemicellulose and lignin, leads to sugar, acids and phenolic materials. High yields of fermentation products, such as ethanol, butanol, acetone, citric acid, antibiotics etc., could be obtained using even now well known processes.

At this time the price of desirable products obtained by these degradation processes are still prohibitive. A number of now well known high polymers could be visualized to be produced from plant biomass conversion product. In has already been demonstrated that pulps from wheat straw could be made by this high temperature-pressure hydrolysis process free of added chemicals which cause problems with the environment. The group in Innsbruck has demonstrated that test sheets can be prepared from intermediates from the hydrothermolysis process which have greater tensile strength than those from recycled paper. There is no question that plant biomass is the raw material for the plastics industry in the future. The chemistry is now, in principle, on hand, the question is only at what time can these processes be carried out in an economically competitive way.

Golden Roof, Innsbruck

Institute of Textile Chemistry and Textile Physics

(Ortwin Bobleter)

In 1982 the Institute of Textile Chemistry and Textile Physics was created. The founding members were not only the federal Ministries and the University of Innsbruck, but also the state of Vorarlberg and the local textile industry association for research and development. The Institute is located in Dornbirn, the center of the Austrian Textile Industry. Dornbirn is also the site of the annual International Chemistry Fiber Conference.

Much of the research of the Institute is devoted to environ mental problems. For example a flotation process for cleaning alkaline textile solutions was developed. The pore structure of cotton fabrics were analyzed by chromatographic methods and the influence of typical textile pretreatment processes were evaluated. A new electrochemical reduction process is being developed in an attempt to substitute the chemical compounds that are presently used for the reduction of vat, indigo and sulfur dyes, which still represent a large part of the cotton dying process. An electrochemical process could eliminate chemical reaction products from the waste water and the whole dying process may be carried out free of waste water.

Austrian Plastics Institute (Dietmar Loidl, Brigitte Blasch)

Dietmar Loidl

Brigitte Blasch

The Austrian Plastics Institute (OeKI) is located in Vienna's Arsenal area, where several other public and private research institutes are also located. This proximity affords an easy cooperation with other institutes which are in or near the Arsenal complex.

The Austrian Plastics Institute (Oesterreichisches Kunststoffinstitut, OeKI) is the oldest division of the Austrian Research Institute for Chemistry and Technics (Oesterreichisches Forschungsinstitut fuer Chemie und Technik, "OeFI") in Vienna which is now Austria's leading testing laboratory. OeKI was established in 1953 as a private research and testing institute for plastics; its first director was Reichherzer. There were two subsequent directors: Hans Tschamler and Otto Hinterhofer. Since 1991 Dietmar Loidl is head of the institute.

Although the OeKI is not a government institution, it is authorized by some official Austrian government institutions and agencies to carry out testings procedures concerning plastics and rubbers. Certificates of OeKI tests are official government documents. Such test certificates include the analysis of thermoplastics, thermosets, elastomers, bonding agents and coatings (excluding varnishes). Official tests also include the examination of semifinished and finished products, such as polymer composites. The control of the processes for the production of these articles are also being examined. Plastic products are judged with respect to their behavior in contact with food. Judgements are also made for the admission of plastic drums and jerricans for the transport of dangerous goods. They are important parts of the authorization of these products for public use.

The Plastics Institute's unique situation is the fact that it is also associated with five other divisions of the OeFI working in different fields of plastic applications. One of the divisions is responsible for the investigation of varnishes and coatings (OeLI), another deals with materials used in the building industry (OeBI), another is responsible for materials in sports application (OeIST) and another for the investigation of materials for medical applications (OeIBW). The OeFI has a special division responsible for public relations with regard to plastics as materials of general use for the benefit of the public. A total of about sixty employees are employed by OeKI.

The technical responsibilities of the Plastics Institute involve all kinds of mechanical, physical and chemical examinations of plastic or rubber materials and their components. The products are analyzed with respect to properties of interest for its use in the environment. Information and advice are also given in questions concerning engineering applications and construction. More recently, recycling of plastics has become an important issue.

The OeKI is not only a testing laboratory, but it is also involved in a limited number of research programs. Most of the programs are carried out in close relationship with industry and involves problems of materials applications.

Some projects also have as their objective the development of new testing methods. Examples of successful research programs that have been concluded within the last two years are the comparison of long term behavior of reinforced plastics, recording of the composition of the plastic fraction in garbage, a study about volatile pollutants from plastic building products, the analysis of polymer modified bitumen by site exclusion chromatography or the optimization of a testing method for determining the thermal conductivity of tube-like insulation foams made of plastics.

Some members of the Plastic Institute's staff also serve as Adjunct Professors at Austrian universities. Seminars about special current developments and scientific advances are being organized by the OeKI.

The most significant annual event of the OeFI is the presentation of the medal of the OeFI, also called the Herman F. Mark Medal. Since 1989 the Symposium associated with this event has achieved worldwide reputation and International flavor, as scientists from the U.S.A. (O. Vogl), Japan (T. Saegusa) and Sweden (B. Ranby) have been awarded this medal which has attracted world-wide participation in the Symposium.

Otto Vogl *Hermann Jenschitz-Kriegl*

Austrian Industries A.G., Vienna (Gerhard Stern)

The Austrian Industries A.G. is an agglomarate of what formerly was the Nationalized Industries of Austria. It is a Holding Company

and consists of a number of relatively independent companies. The total amount of sales of Austrian Industries is about 15 billion dollars; the most important components of Austrian Industries A.G. are steel, oil, electrical industries and mining. About one half of the activities (7 billion dollars) of Austrian Industries AG is in production and sale of products of crude oil, called the OeMV (Oesterreichische Mineraloel Verwaltung). Most of the activities in the OeMV are in exploration, production (about 1.2 million tons per year in Austria, or 12% of the national needs) and refining (about 8.5 million tons per year) of oil. Natural gas is also produced in Austria (1.3 billion cubic meters per year, or 25% of Austria's national needs)

The OeMV also has all the major chemical, agrochemical and plastic production. The chemistry part of OeMV is called Chemie Linz Ges.m.b.H.; it has annual sales of over 300 million dollars; the plastics producing part is called PCD and has annual sales of about 800 million dollars.

(a) Chemie Linz Ges.m.b.H., Linz (Gerhard Stern)

Chemie Linz Ges.m.b.H. (Chemie Linz) is located on the Danube river in Linz, Upper Austria. It is a producer of large scale chemicals but also of intermediates. Most of the large scale chemicals and polymer intermediates including monomers are sold and used elsewhere. The company has a working force of about 1,000 people, with subsidiary companies of about 1,800, about 75 are Ph.D's or University graduates.

Of the large scale products, Chemie Linz produces melamine and maleic anhydride. Other products, so-called intermediates, are produced in much smaller quantities. The largest product of Chemie Linz is melamine; with the recent acquisition of the melamine facilities in Castellanza, Italy which was bought from Montedison, the melamine capacity of Chemie Linz is over 80,000 ton, which makes it the largest producer of this very important commodity in Europe. The melamine production of Chemie Linz is also larger than that of any single producer in Japan and amounts to the production capacity of almost 70% of the Japanese production of melamine.

Chemie Linz also produces maleic anhydride, an intermediate for the production of unsaturated polyester and other important polymer intermediates. Maleic anhydride is also an intermediate for the synthesis of maleimides and bismaleimides. Until recently, Chemie Linz also was the owner of a subsidiary company, Multicon Electronic Ges.m.b.H., which was recently sold to an Italian Company.

Intermediates are of increasing interest to Chemie Linz. Two groups of intermediates are polymer intermediates or potential polymer intermediates. The first group consists of N-substituted acrylamides, prepared from acrylonitrile and tertiary alcohols or 2-methyl substituted olefins. Chemie Linz has also the largest ozonolysis capacity in the world. Using the technology of ozonolysis, glyoxalates are prepared from maleates and fumarates. This technology has also the unique capability of opening double bonds of unsaturated cycloolefins to produce alpha, omega-functionalized compounds.

Chemie Linz, Research Building

(b) Petro Chemie Danubia, Linz (Florian Altendorfer and Manfred Reatzsch)

Petro Chemie Danubia (PCD) is the successor company of Danubia which was originally a joint company of OeMV and Montecatini of Italy. Danubia was founded in 1960, it was the first licensee of Montecatini and operated the first polypropylene facility outside of Italy.

Since 1968, when the company was still called Danubia, it became fully owned by OeMV; it was recently reorganized and named PCD. PCD produces polypropylene in Schwechat, near Vienna with a capacity of about 200,000 tons. PCD also produces polyethylene, both low density and high density polyethylene in Burghausen, Germany with a capacity of about 300,000 tons.

Weinberg Castle

PCD is now concentrating on the polymer engineering aspects of polyolefin production. This effort includes the maximization of polyolefin properties by optimizing the conditions of extrusion, injection molding, blow molding and orientation. PCD is also involved in research and in the production of filled compositions of polyolefins, polyolefin blends and alloys with the ultimate aim of producing lower priced engineering plastics of the highest quality and with optimum properties based on polyolefins.

PCD is one of the most important polyolefin producers in Europe. Its activities to support the production are therefore concentrated upon this group of products. An important line of work is the enlargement of the assortment of the types for polypropylene (PP) and high density polyethylene(HDPE), based on the needs of the market. For the transfer of the research and development activities into production, modern production equipment and pilot plant facilities are available which allow a quick reaction to market requirements. Research on PP-compounds led to reinforced types with enhanced stiffness and strength. Examples for this line of development are new impact resistant and transparent co-PP-types which permit the opening up to new fields of application. In addition, high quality materials based on copolymers of propylene and ethylene are under development. Investigations into polymerization mechanisms, structure investigations and the evaluation of the efficiency of various catalysts are being carried out.

Important activities are directed toward the development of thermoplastics for the building industry which are now being introduced into the market. At present, blends and alloys of PP are in the center of PCD's interest. Longer-range plans include investigations of new polymer structures based on polyolefins. Attempts are being made to enhance the compatibility in polyolefin blends as well as to improve the stiffness and the thermal stability of PP and its blends. Shorter range objectives include the technological development of new polymer blends with special focus on reactive polymer blends. An efficient production technology for polymer felt has been developed and is being used by the daughter organization of PCD, POLYFELT.

A necessary extension of the methods of testing and characterizing of new materials and the application of such polymers is being pursued in close cooperation with universities and research institutions in Austria. Successful cooperation exists with the Universities of Linz, Graz, and Leoben. Plans are underway to extend and strengthen this cooperation.

PCD policy is also to stress the command of the theoretical foundations of the science in polyolefin research in order to correlate the experimental results with the theory through model calculations.

Lenzing A.G, Lenzing (Juergen Lenz)

The "Zellwolle Lenzing A.G." founded in 1939 as a major producer of viscose fibers is located in Lenzing, Austria. At the time of its founding,viscose fibers were in high demand but had a number of deficiencies with respect to processability, tenacity in the dry and wet state, dimensional stability and evenness of dyeing. Development work was directed at the improvement of the pulp, of the viscose preparation, of spinning technique, and after-treatments and finishings.

After the Second World War the demand for viscose fibers increased tremendously and the textile industry required a much higher quality of products. Rapid development of polymer science played an essential role in the improvement of the viscose fibers. A high wet modulus fiber type was developed, which was characterized by an optimal balance between the different desired mechanical properties.

In 1969, Lenzing A.G. founded a department for research and development and appointed H. Kraessig as its director. The department began research activities on polyester fibers, on films, on fibers and on laminates based o polyolefins. Films and fibers were also made from polytetrafluorethylene, polyacrylonitrile and other acrylic polymers.

One of the more recent developments at the Lenzing A.G. are high temperature resistant polyimides which, as polyimides, are also nonflammable. This development led to the first commercially available polyimide fiber in the world. he so-called "P 84"-fibers, a polyimide, shows temperature stability in excess of 300°C, a glass transition temperature of about 315°C, a high chemical resistant, especially against acids, and a thermal decomposition temperature of 450°C (no melting and the possibity of producing spun-dyed fibers). The properties of the "P 84"-fibers make them also interesting for textile and other technical end-uses like: i.) High temperature filtration; ii.) Braided packings; iii.) Protective clothing; and as iv.) Interior construction materials for the aircraft and aerospace applications. To prepare the P 84-solutions, the polyimide polymer is dissolved in an organic solvent and this solution can be applied directly for heat resistant coatings.

A solvent spinning process for a new generation of cellulosics fibers utilizes the so called amine oxide process, which is presently being investigated. A highly viscous amine oxide solution of cellulose is being spun into water and the cellulose is coagulated as a fiber. These fibers surpass, on the basis of wet and dry strength, the performance of the traditional cellulosic fibers cotton, viscose and 'Modal'.

Other research topics at Lenzing A.G. include also the biotechnological treatment of pulp and viscose fibers. For the last 3 years, Lenzing A.G. has also been engaged in the exploration of biotechnological processes which are involved in the pulp and viscose fiber production. Xylanases for pulp treatment have been developed and used for the removal of hemicellulose.