

1996

Polymer Science in Croatia

Otto Vogl

University of Massachusetts - Amherst, vogl@polysci.umass.edu

Franjo Flajsman

Zvonomir Janovic

Helena Jasna Mencer

Follow this and additional works at: https://scholarworks.umass.edu/emeritus_sw



Part of the [Chemical Engineering Commons](#), and the [Chemistry Commons](#)

Vogl, Otto; Flajsman, Franjo; Janovic, Zvonomir; and Mencer, Helena Jasna, "Polymer Science in Croatia" (1996). *Polymer News*. 40.
Retrieved from https://scholarworks.umass.edu/emeritus_sw/40

This Article is brought to you for free and open access by ScholarWorks@UMass Amherst. It has been accepted for inclusion in Emeritus Faculty Author Gallery by an authorized administrator of ScholarWorks@UMass Amherst. For more information, please contact scholarworks@library.umass.edu.

Centers of Polymer Research

Polymer Science in Croatia

Franjo Flajšman^(a), Zvonimir Janović^(b), Helena Jasna Mencer^(b) and Otto Vogl^(c)

(a) INA Oil Company, Zagreb, Croatia, (b) University of Zagreb, Zagreb, Croatia and (c) Polytechnic University, Brooklyn, NY 11201, U.S.A.



Franjo Flajšman



Zvonimir Janović



Helena Jasna Mencer

Introduction

Croatia is a country located in Central Europe: in the northwest it borders on Slovenia, in the northeast on Hungary, in the south on Bosnia-Herzegovina and in the east on Yugoslavia (Serbia and Montenegro). Croatia stretches from the slopes of the Alps deep into the Pannonian Valley and to the banks of the Danube and Drava rivers. Croatia also has a long coastline on the Adriatic Sea of nearly 1,800 km. Much of Croatia consists of islands and isles. When the islands (1,185 have been counted of which 66 are inhabited) are included the coastline is three times as long. This configuration makes Croatia a Mediterranean and central European country.

The shape of the country is unique and resembles a "croissant" or horseshoe as a result of the migration of the croatic (slavic) tribes in the dark ages. Croatia has a population of nearly 5 million people, a land area of about 57,000 sq. km and a territorial sea of about 30,000 sq. km. It is divided into 21 counties.

The capital of Croatia is Zagreb with nearly 950,000 inhabitants. There are a number of other important cities in Croatia: Split, Rijeka, Osijek, Pula, Zadar and the famous city of Dubrovnik.

For centuries, Croatia was an autonomous part of other



Otto Vogl



countries, Hungary, the Austrian-Hungarian monarchy and Yugoslavia. Most of Dalmatia, the coastal provinces, excluding Dubrovnik, was until the Napoleonic period in the early 19th century part of Venice. In September 1991, Croatia proclaimed



Zagreb with Dome



Zagreb—Ban Josip Jelačić Square

total independence and is now a member of the United Nations. Croatia has always been in the crossroads of southern and central Europe.

What is now Croatia was at one time an important part of the Roman Empire. The town of Zagreb was a Roman settlement. In fact, in the area of Zagreb, there were a number of settlements. In the sixth century, Slavic tribes settled this part of the world and in the 10th century (925 coronation of Tomislav), during the reign of King Tomislav, the kingdom was first mentioned. In 1094, Zagreb became known as a bishopship, which constitutes the first



Sabor—Croatian Parliament



St Marc's Church

written history of Zagreb. For some time Zagreb and Croatia were a bulwark against the Tatars and then against the Turkish invasions into the southern part of Europe.

UNIVERSITIES IN CROATIA

Scientific research activities in the Republic of Croatia are carried out in government-financed institutions. Croatia has four institutions of higher learning. The University of Zagreb, the University of Split, the University of Rijeka and the University (actually an agricultural University) in Osijek.

THE UNIVERSITY OF ZAGREB

The University of Zagreb is the oldest and largest university in the Republic of Croatia and one of the oldest universities in Europe. The beginnings of higher education in Zagreb are closely connected to the Jesuit Gymnasium established in 1632 for the teaching of moral theology. Thirty years later in 1662, the academy for a higher level of learning of philosophy was started. The actual history of the University of Zagreb began in 1669 when the then Jesuit Academy in the Royal Borough of Zagreb was granted university status and privileges in a document by the Holy Roman Emperor and Croatian-Hungarian King Leopold I of Hapsburg. The school was given the right to award doctoral degrees.

In 1861 the Croatian Sabor (Diet), at the initiative of Bishop Josip Juraj Strossmayer, passed legislation on the University of Zagreb. Emperor Franz Joseph signed a legal document on the University of Zagreb in 1869 which founded the modern University of Zagreb.

Today the University of Zagreb consists of 28 colleges, 3 arts academies with 48,000 students and 2500 graduate students. Branches of the University of Zagreb on the Adriatic coast are in Dubrovnik and on the Istrian peninsula.

The Faculty of Chemical Engineering and Technology

The Faculty of Chemical Engineering and Technology was founded in 1919, as the first



University of Zagreb

Department of Chemistry was created with the objective to provide education in Chemistry and Chemical Engineering. A number of distinguished scientists had been active in teaching and research in this department, for example **Vladimir Prelog** (Nobel Prize 1975) as professor of Organic Chemistry from 1934 to 1941. **Ivan Marek**, the first professor of Organic Chemistry from 1920–1933, who invented the famous "Marek's Furnace" for elemental organic analysis. **Franjo Hanaman**, the inventor of tungsten filament, was a Professor of Inorganic Chemical Technology and Metallurgy from 1922 to 1944. **Ivan Plotnikov**, active in the field of photochemistry, was a Professor of Physics and Physical Chemistry between 1920 and 1943 and **Rikard Podhorsky** was a Professor specializing in unit operation and unit processes.

Polymer research at the Faculty of Chemical Engineering and Technology started immediately after its establishment. Initially by investigations of natural polymers particularly cellulose. Today there are several research groups covering the undergraduate and graduate education which is reflected in many course requirements and research programs in polymer science and engineering. Much of the work is devoted to synthesis, characterization, processing, polymer blends and composites and the degradation and stabilization of polymers. This Department also possesses good facilities for the study of conducting polymers.

In addition to the standard equipment for organic synthetic work, a number of special equipment is available like gel permeation chromatography, IR, UV, ¹H-NMR spectroscopy, thermal analysis equipment for the measurement of mechanical properties, and a substantial number of computers. The Faculty also has good connections with other similar research organizations in Zagreb like the Rudjer Bošković Institute, the INA-Research and Development Department, the Faculty of Mechanical Engineering, which allows them to use other types of equipment, such as: ¹³C-NMR spectrometers, scanning microscopes, EPR spectrometers, microcalorimeters, Laboratory extruders, Polymer rheology equipment, etc.

Some of the current research activities of members of the department will be described in the following section.

Copolymerization and Copolymers of Brominated Vinyl Monomers:

Professor Zvonimir Janović. Reaction mechanisms and kinetics of copolymerization, terpolymerization and grafting of some brominated monomers, namely aliphatic and aromatic acrylic and methacrylic esters, brominated styrenics as well as brominated N-phenylmaleimides with a number of conventional vinyl monomers, by free radical initiations are being studied. In addition, specific characteristic properties of these copolymers, particularly molecular weight and molecular weight distribution, glass transition temperatures, thermal and flammability behavior are also being investigated.

It was demonstrated that the rate of copolymerization is much faster for acrylates than for the corresponding methacrylates and that it increases as the polarity of the brominated monomer increases. Terpolymerization parameters of these brominated (meth)acrylates with styrene and acrylonitrile were investigated and the grafting of tribromophenyl acrylate onto polybutadiene is being studied. Copolymerization kinetics of the polymerization of tribromostyrene with styrene, acrylonitrile and (meth)acrylate

is studied and some of the properties of these copolymers were examined. Brominated N-phenylmaleimides gives alternating copolymers with styrene, butadiene and vinyl acetate and random copolymers with acrylonitrile and (meth)acrylates. These copolymers show considerable increase of thermal stability and appreciable flame-retardant properties.

Electrically Conducting Polymers. **Professor Ljerka Duić.** This group started research on electronically conducting polymers in 1988 with the electrochemical synthesis of polyaniline. The research activities cover the investigation of the reaction mechanism and the influence of different experimental parameters on the reaction path. The application of polyaniline as a potential catalytic electrode material in oxidation and/or reduction of different compounds is being evaluated. The polymers are characterized by scanning microscopy, EPR spectroscopy and conductivity measurements.

Degradation and Stabilization of Polymers. Degradation, aging and stabilization of polymers plays an important role in the research activities of the Department of Chemical Engineering and Technology. The aging of different rubbers and thermoplastic elastomers is being studied by **Professors Mladen Bravar and Jasenka Jelenčić.** Most of their work is devoted to investigation of the ultraviolet degradation of natural rubber latex films in inert media or in the presence of oxygen. These materials had been vulcanized with different accelerators which gave polymer networks of different structures and crosslink densities which, in turn, causes different behavior to UV irradiation.

The interdependence between the properties of synthetic rubber vulcanize and their molecular structure is also being elucidated. It was shown that acrylonitrile-butadiene copolymer alone or as a blend with PVC, or as a blend with polychloroprene can attain a substantial degree of resistance towards its swelling behavior by organic solvents only if appropriately cured. With EPDM vulcanizates the values of the crosslink densities are highly dependent on the particular method applied.

The analysis of the influence of aggressive media on polymeric materials like rubber reinforced polymers, e.g. high impact polystyrene is being investigated by **Professor Drago Hace.**

Professor Vjera Kovačević and her research team are investigating the properties of structural adhesives of polymeric composites, elastomers and leather.

Professor Vesna Rek is studying the interrelation between processing, structure and properties of polymeric materials, particularly of polyurethane's (PUR) The research is focused on: stability, degradation and annealing processes and of new PUR materials. It was found that structure and composition of PUR effect significantly the course and the degree of the chemical, photooxidative and thermooxidative degradation of these materials. The degree of the structural changes, especially of the change in the morphological structure of PUR and its mechanical and thermal properties was determined. Annealing/quenching processes influence the morphological structure of PUR. Segments reordering, mechanical properties and viscoelastic function was found to be interrelated. Novel PUR materials, particularly PUR foams based of polyols and PUR with high thermal stability using a polyvinyl moiety in the polyol component has also been studied.

The research group of **Professor Branko Kunst** is primarily

Centers of Polymer Research

interested in polymer membranes. The formation, structure and the properties of asymmetric reverse osmosis and ultrafiltration membranes are being investigated. The mechanism of the formation of the asymmetric structure during the precipitation process of passing the thick polymer solution into the non-solvent and the phase separation that occurs during this process is being studied. The experience from the more traditional processes has been applied to the membrane preparation from various polymeric materials. The porous structure of the membrane's skin has been carefully examined and the exact structure has been related to the membrane's performances.

The research of the group of **Professor Helena Jasna Mencer**, the Vice President of the University of Zagreb, is concerned with:

- 1) *Hydrodynamic and thermodynamic properties* (solubility, miscibility, phase separation) of polymer solutions; the mechanism and the efficiency of some polymer separation methods (GPC, fractionation methods); the correlation between molecular weight distribution of polymers and their macroscopic properties.
- 2) *Kinetic analysis of polymerization reaction* of thermosetting resins (epoxies and unsaturated polyester-resins) and their composites, the chemorheology of thermosetting resins and modelling of their curing kinetics.
- 3) *Studies of the correlations of the process parameters* in solution and emulsion copolymerizations and their product properties (molecular weight distribution, composition drift, thermodynamic behavior).

Faculty of Mechanical Engineering and Naval Architecture

The beginning of the education in polymer processing at the University of Zagreb started at the Faculty of Mechanical Engineering and Naval Architecture. Polymer processing curricula started back in 1971, and, by now 220 Dipl.-Ing. have

been granted. The students in the Departments of Production, Industrial and Material Engineering are also educated in this field. Education in Polymer Processing provides a profound knowledge in designs using polymeric materials, in testing of polymers, in the production of polymeric parts, in understanding equipment, mold design, reactive processing and other important functions of polymer fabrication.

Scientifically, Polymer Engineering and Processing is covered by the Chair of Polymer Processing and Materials Engineering. The Chair of Polymer Processing was established in 1974 and is now headed by **Professor Igor Čatić**. He is assisted by **Associate Professor M. Šercer** and three assistants. The main fields of scientific interest of Chair can be summarized as follows: Calculation of mold elements, heat exchange in molds for injection molding of thermoplastics, rubber compounds, thermoset, PS-E and thermoforming, design of runner systems for injection molding of rubber compounds, trend regulation of injection molding processes, development of expert systems for the elimination of visibly faults in the moldings, CAD in mold design, recovery of polymeric parts, development of new injection molded polymeric products, reactive cyclic polymer processing with the mold as a batch reactor, systemic analysis of injection molding of polymer materials, compression molding of thermosets, thermoforming, extrusion coating and coextrusion, film extrusion and welding of polyethylene films.

The newest field of this research is the application of the conception of the factual entrepreneurial culture in the field of polymer processing, particularly in injection molding shops.

The chair for Material Engineering with emphasis on the field of Engineering of Polymeric Materials was created in 1959. At the present time, it consists of two **Associate Professors, J. Indof and Z. Smolčić-Zerdik** and three assistants. The main areas of interest are: Characterization of polymeric materials and polymer-based composites and correlations between structure and properties, mechanical, chemical and thermal properties.

THE UNIVERSITY OF SPLIT

The University of Split, established in 1974, is based on the foundations of the cultural, educational and scientific heritage of Dalmatia, which represents 25% of Croatia's territory and has a population of around one million. Academic instruction in Dalmatia has a long tradition, reaching back into the middle ages. In 1396 a school of theology and philosophy was founded in the Dominican monastery in Zadar, with the right to give the title of Doctor Philosophiae. This Academy functioned until 1811.

Today, the University of Split consists of 9 Schools, including a school of Philosophy in Zadar, of Natural Sciences, Mathematics and Teacher Training in Split and of Electric and Electronic Technology, Engineering and Shipbuilding, Technology, Construction, and Law also in Split.

The University of Split has about 10,000 students. It has a regional and multi-center structure with branches in Split, Zadar and Dubrovnik.

Faculty of Technology

This Department of Organic Chemical Technology was established in 1960. Polymer research started in 1963, when **Dr. Urban Roje** was appointed Professor. Today **Professor T. Kováčik** is the head of the Department assisted by **Dr. I. Klarić**.



Part of Old Rampards, Zagreb



Split

This research team is mostly involved in the investigation of the effectivity of the actions of plasticizers, specifically on the mechanisms and kinetics of plasticizers action in PVC, and the thermal stability of those mixtures. In addition, a number of PVC blends with other polymers, particularly those of more practical interest such as ethylene-vinyl acetate copolymers, chlorinated polyethylene, thermoplastic polyurethane, ABS, graft copolymer of methylmethacrylate-co-styrene onto polybutadiene are being investigated. Thermal degradation processes of some of these blends are being studied by isothermal and nonisothermal thermogravimetry and by applying different kinetic models for the mechanisms of degradation.

The Universities of Rijeka and Osijek

The University of Rijeka, established in 1973 consists of ten schools, a School of Medicine, a School of Technology, a School of Economics and the Hotel Management College. The University has about 10,000 students. The Josip Juraj Strossmayer University of Osijek, established in 1975 has now 6,500 full-time and 1,000 part-time students enrolled. Neither of these two Universities has any research or teaching in Polymer Science and Technology.

SCIENTIFIC INSTITUTIONS IN CROATIA

There are currently 23 scientific institutes and 55 colleges in Croatia. In the natural sciences there are 3 institutes with about 300 scientists; in the technical sciences there is one Institute with about 350 scientists.

The Institute Rudjer Bošković

The Institute Rudjer Bošković IRB is the largest scientific institution in Croatia which is engaged in basic natural sciences. The RBI was founded in 1950 by Professor Ivan Supek; today

the General Director of IRB is Dr. Mikola Zovko. Since 1953 the Institute is committed to graduate studies. At present, the Institute employs 730 people, 390 of these are research scientists and 105 are graduate students in all areas of research. The Institute consists of 5 departments: Department of Physics, Department of Chemistry, Department of Biology and Medicine, Center for Marine Research and Center for Laser and Atomic Research and Development covering the following areas of research: theoretical and nuclear physics nuclear chemistry, solid state physics, atomic and molecular physics, laser physics, preparative organic and inorganic chemistry, theoretical chemistry, biology and medicine, spectroscopy, physical and structural chemistry, marine sciences and computer sciences. Forty percent of all scientific output in Croatia comes from the IRB. Polymer sciences is a small

part of the overall research activities and involves 10 scientists.

Polymer research at the Institute began in 1964 in the field of radiation chemistry and was followed with the application of spectroscopic methods to natural and synthetic polymers with the objective of determining structure and dynamics of polymers.

The investigation of polymers at the IRB is predominantly of a fundamental nature but the existing experience and the instrumental capabilities are also utilized for applied problems. The current research activities are described in the following sections.

Radiation chemistry of polymers. F. Ranogajec—The investigations involve the studies of the chemical and physical effects of ionizing radiation in polymers, radiation modification of polymers by grafting to increase the persistence of a stabilizer



Institute "Rudjer Bošković"

Centers of Polymer Research

or other additives by bonding them chemically to the polymer chain. Radiation induced crosslinking and radiation polymerization is also carried out. Calorimetric investigation of high conversion polymerization aims to better understand the polymerization mechanisms in heterogeneous media and/or in the cases where the gel effect is involved. This data is important for the control of industrial processes.

Characterization of Polymers. Z. Vekšli, M. Andreis, M. Topić—The investigation of polymer structures and relaxation processes in polymer structures is being studied by combination of spectroscopic methods: magnetic resonances (NMR, ESR), IR Raman spectroscopy, X-ray methods, dielectric and thermally stimulated depolarization current measurements. At present, the research is primarily concerned with the matrix morphology of polymers and polymer mixtures, phase separations in the glassy state and in solutions of copolymers, local orientation of block copolymers and the investigation of the compensation phenomena in the relaxation processes in order to understand property-structure-dynamic relationships. A potential of the double modulation ESR (DMESR) method recently developed in the Institute is being investigated in the range of slow molecular motion of polymers and copolymers. The method appears to be very sensitive to small free volume changes imposed by degradation, local orientation and phase separation.



In Zadar



Dubrovnik

The scientists at the Institute are extensively involved in international cooperation, have good collaboration with the industry and universities and participate in the graduate programs in the field of polymers.

THE CROATIAN ACADEMY OF ARTS AND SCIENCES

The Croatian Academy of Arts and Sciences is the highest-ranking scientific and artistic institution in the Republic of Croatia. It is the legal successor of the Yugoslav Academy of Arts and Sciences, established in 1866 as the highest-ranking scientific institution of the Southern Slavs. The Croatian Academy of Science initiates and organizes scientific activities and it is responsible for the implementation of their results. The Sabor (Parliament) of the Republic of Croatia controls the legality of the Academy's activities. The Academy has regular, honorary and corresponding members, as well as associate members. The maximum number of regular members is 160.

The Academy cooperates also with great interest with its foreign counterparts.

THE CROATIAN INDUSTRY

Much of the production of the petrochemical and polymer chemistry is in the largest company of Croatia, Industrija Nafta D.D. Zagreb (INA). In addition, there are smaller production capacities of polymer latexes based on vinylacetate and acrylic copolymers in two chemical companies, "Karbon" and "Chromos" both located in Zagreb. In fact the history of polymer industry in Croatia started in 1946 at Chromos by the production of phenolic resins.

INA Industrija Nafta D.D. Zagreb (INA)

INA Oil Company is a conglomerate company and the largest Croatian company. The value of its products and its financial potential make up almost one third of the national economy. INA, with its 26,000 employees is involved in the production of oil and gas, in processing of crude oil and trade and in transport of oil products in Croatia and abroad. The company produces petrochemicals, organic chemicals and mineral products. INA is among the ten largest petrochemical companies in Europe.

In 1992 the organic petrochemical industry exported over 80% of its annual production volume all over the world. The value of foreign trade transactions amounts to 1.3 billion US dollars.

INA is basically an oil company and consists of about 30% in refining, about 40% of oil exploration and production and about 30% in petrochemicals and polymer industry.

Polymer production in INA includes polystyrene, low density polyethylene and PVC by suspension, emulsion, and bulk polymerization. The total production amounts to 350,000 tons/year. In addition there are smaller production capacities for polyester fibers of about 16,000 tons/year and acrylic ester copolymers as viscosity index improvers for motor oils at about 8,000 tons/year.

The research activity in polymer chemistry is entirely related to the production programs but some special fields are also being studied. The polymer research group, consisting of 25 scientists and technical staff, is located in the central research organizations INA-Research & Development in Zagreb, which employs 150 researchers, 55 are University graduates.

INA-R&D was founded in 1963 by **Dragotin Fleš** and **Franjo Flajšman** as the Research Institute for the first petrochemical complex in this part of Europe.

Prior to the establishment of this Institute there was some individual activity in the polymer field in Croatia on cellulose, based on the good tradition in organic and physical chemistry at the University of Zagreb. Although most of the activities in the early phases of the existence of the Institute was related to production problems including the detailed characterization of polymers, some fundamental research was also carried out by D. Fleš, Z. Janović, V. Jarm, V. Seke, R. Vuković, V. Kurešević. It involved the synthesis of optically active polymers of optically active compounds such as substituted β -propiolactones.

Polymer synthesis was an active part of these investigations. It included the stereospecific polymerization of olefins, copolymerizations based primarily on styrene monomer with the objective of developing commercially interesting and useful copolymers (SAN, ABS, copolymers with α -methylstyrene). The synthesis of alternating copolymers based on derivatives of styrene as electron donor monomers with electron acceptor monomers like maleic acid anhydride and N-substituted maleimides was investigated by D. Fleš, Z. Janović, R. Vuković and V. Kurešević. These studies also included the synthesis of functional polymers, specifically, the preparation of hydroxy- and carboxy-terminated polybutadiene by anionic and free radical polymerization carried out by F. Flajšman, T. Kovač and B. Jerman.

Most of the research activities of INA R&D was related to production problems. Such work included suspension polymerization of styrene with the emphasis on the stability of the polymerization system and the control of particle size distribution. As an important practical problem, the study of the flammability of the polystyrene foam was of special interest. It resulted in the development of resins with substantially decreased flammability which complied with the highest standards regarding the application of material in civil engineering particularly in housing construction by Z. Janović and K. Šarić.

Investigation on polyethylene was the subject of extensive studies including UV-stabilization, controlled thermooxidative degradation to produce polyethylene-waxes, and the

modification of polyethylene with starch for UV biodegradable material.

The degradation of polymers were studied by gas chromatography, by mass spectrometry and other specific methods by D. Đur-Sitar, V. Švob and F. Flajšman.

Extensive studies were carried out at INA-R&D for the development of new polymeric materials based on polymer-polymer mixtures. Mixtures of polystyrene with poly(2,6-dimethyl-1,4-phenylene oxide), ABS/PVC—and others blends were studied. Polystyrene was used as the base blending polymer with various other polymers to prepare mixtures to produce polymer blends with new and useful properties. The effect of the structure of the component polymers on the miscibility and the phase behavior of polymers was investigated. The entire research activity at INA-R&D over the last 30 years resulted in about 380 publications and patents and a number of innovations were introduced in the production plants.

Chromos—Chemical Industry Research, Zagreb

Polymer research and development work in these industrial organizations started some 50 years ago, proceeding the first industrial production of plastics in this part of Europe. A group of young engineers, coming straight from the Technical Faculty of the University of Zagreb, without any industrial experience and with scarcely available technical or scientific literature and instruments immediately after the second World War started this enterprise: the first domestic production of synthetic plastic materials, namely phenolic resins and molding materials. In later years, always hiring the best young graduates and promoting team-work, but under the supervision of the best professionals (**A. Kostial**, **V. Doerner**, **T. Dobronić**), other synthetic polymers were produced. They included alkyd resins, urea- and melamine-formaldehyde resins as adhesives, coating resins and molding materials, unsaturated polyester resins, aqueous polymer dispersions of vinyl acetate and acrylic monomers and their copolymers, polyurethane coatings and adhesives, epoxy resins.

In the beginning, the main objective for this kind of polymer research was to follow, as closely as possible, the developments in the known fields of direct interest for the industrial production of paints, adhesives, molding materials, binders, etc. Later, starting in the middle seventies, it appeared as obvious, that the



Academy of Sciences, Zagreb

Centers of Polymer Research



INA—Central Office

next step forward in the R&D work should be, not only to follow its advancement, but to be a creative part of it on the international level.

To achieve such a goal, a special organizational unit had been formed, namely Chromos—Chemical Research Center was established by Dr. Zvonimir Katović. The main objective for such an industrial institution was to bridge the gap between applied and fundamental research, so characteristic for that time and especially for countries on a similar level of development. This was tried through the purchase of the most modern instrumentation, hiring established scientists from the

universities, and similar scientific institutions and very close cooperation with these institutions. At that time the cooperation with scientists of the Institute Rudjer Bošković (M. Topić, Z. Vekšli) was very fruitful. This was achieved by the development of a more or less informal permanent interaction and an exchange of scientific and technological information by engaging the research scientists in professional international organizations in scientific meetings, conferences and exhibitions.

The research topics covered included work on phenol-formaldehyde resins (the role of hydrogen bonding in the curing processes and miscibility with other polymers); on epoxies (the chemistry and the mechanisms of resin formations, modification and co-reactions with other monomers and resins, on polyesters (the influence of the microstructure of unsaturated polyester and alkyds on their properties and performance). Of special attention was the synthesis, separation and characterization of oligomers formed during resins formations, like phenolic, amines, polyesters and epoxies, using various chromatographic methods, thermal analysis, SEM and spectroscopy techniques.

Acknowledgement

We would like to express our appreciation to Igor Čatić, Faculty of Mechanical Engineering and Naval Architecture, Zorica Vekšli, Institute Rudjer Bošković, Urban Roje, Faculty of Technology, University of Split and Zvonko Katović of Chromos for their contributions of information to this article and to Meifang Qin for her help during the preparation of this article.