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Polymer Science in Academy Institutes in Northern China (North of the Yangtze) Part II: Changchun

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Changchun, a city of 1.3 million people, is located in the heart of the three northeastern provinces of China (Manchuria). It is the capital city and the economic, cultural, and railway center of Jilin Province.

Changchun Institute of Applied Chemistry

Changchun Institute of Applied Chemistry is the oldest and largest of the 15 chemistry research institutes of the Chinese Academy of Sciences (Academia Sinica). It acquired the present name after the merger in 1953 of two institutes: The Institute of Physical Chemistry of the Academy from Shanghai and the chemistry section of the former General Research Institute which had been placed under the jurisdiction of the Academy a year earlier. The General Research Institute had been founded at the end of 1948, right after the liberation of the northeastern provinces. Before becoming part of the Academy of Sciences the Changchun Institute had been called Northeastern Institute of Scientific Research and was under the administration of the then Northeastern Ministry of Industries.

The Changchun Institute of Applied Chemistry has now, a staff of about 1,000 people, more than 600 research staff, the rest are service people; scientific women workers are 40% of the work force. The Institute consists of four centers: Polymer Science, Physical Chemistry, Inorganic Chemistry, and Analytical Chemistry.

The Center of Polymer Science now consists of nine laboratories; it has 30 professors and associate professors, about 100 research associates, 140 junior scientists and assistants. Currently, there are about 20 graduate students working for a three-year M.S. degree and four for a Ph.D. degree; 30 students have already received M.S. degrees in

Polymer Science since the restoration of the graduate school system in China in 1978. Work in the two broad fields of polymer synthesis and polymer physics are interwoven through cooperation between individual laboratories.

I. Polymer Synthesis

1. Coordination Polymerization

Professor Jung Ouyang, Fosong Wang, Bincai Li (now at Southern China College of Engineering), Xueming Tang (to move to Shandong College of Chemical Engineering), Zhiqun Shen (now at Zhejiang University), Hongzuan Xie (now at Hubei Chemistry Institute) and others have been involved



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since the early 1960's in the stereospecific polymerization of butadiene with transition metal (Ti, Co, Ni) compounds. Cis-1,4-Polybutadiene based on a Ni-catalyst was developed in the Institute and since the early 1970's has been in production in five plants.

Rare-earth initiators for the diene coordination polymerization were first discovered in Changchun Institute in 1963; polymerization techniques were later developed for both isoprene (Professor Fosong Wang's group) and butadiene (Associate Professor Zhenya Hu, Research Associate Lian-sheng Jiang and their associates) polymerizations. Both polyisoprene and polybutadiene (also in the oil extended form) are being further developed for application in cooperation with industrial laboratories. The structure of the active species and the polymerization mechanism of rare-earth initiators have been and are being studied by Professor Jun Ouyang, Fosong Wang and Associate Professor Enli Pan and their groups. Rare-earth coordination catalysts have also been developed for the butadiene-isoprene copolymerization and for the random and block copolymerization of ethylene and butadiene. The work on the development of elastomers is coordinated with the group responsible for the processing studies (Associate Professor Yadong Liu's group) and aging studies (Associate Professor Zhonghan Chen's group) of these rubbers.

After reorganization of the work on coordination polymerization in 1978, research is now carried out in two laboratories. The Laboratory of Rare-Earth Polymerization is now under the direction of Professor Fosong Wang and Associate Professor Zhenya Hu. The Laboratory of Coordination Polymerization with Transition Metals is headed by Professors Baotong Huang, Zeuming Tang and Associate Professor Zhonghan Chen. Professor Xueming is also working on the development of new molybdenum initiators for the 1,2-polymerization of butadiene. New vanadium catalysts modified with activators for the preparation of ethylene/propylene terpolymers was developed by Professor Baotong Huang's group. Professor Baotong Huang's recent work involved also the study of multiphase polymeric systems prepared with Ziegler-Natta type coordination initiators.

A new project on the polymerization of acetylene with rare-earth and other coordination initiators for the preparation of organic metals and the study of their structure, morphology and properties was started in 1981 by Professor Fosong Wang.

2. Multiphase Polymers

Professor Baotong Huang and his group are now engaged in the synthesis and characterization of physical and mechanical properties of ethylene/propylene block and graft copolymers as possible thermoplastic elastomers, or as compatibilizers for polymer blends. The thrust in his area of research is the investigation of block polymers with Ziegler-Natta type coordination catalysts, especially when the polymerization is carried out in the slurry. Attempts are also made to synthesize isotactic propylene/ethylene-isotactic propylene/atactic propylene, atactic propylene/ethylene and other block copolymers.

Well-characterized graft copolymers from allyl-terminated polystyrene macromers, terpolymerized with ethylene and propylene were prepared and the morphology properties of

these polymers was investigated. Blends of ethylene/propylene terpolymers with polypropylene as thermoplastic elastomer and of ethylene/propylene copolymers with long ethylene or propylene sequences are also under investigation. Comb-shaped polybutadienes which are not multiphase polymer systems were prepared and characterized; they serve as models for the study of graft polymers and polymers with long chain branches.

Associate Professor Zhiliu Feng, Head of the Laboratory of Polymer Structure, is investigating the relationship between morphology and properties of toughened polypropylene. He is studying the blending of polypropylene with elastomers and is investigating the effect of compatibilizers on blends.

Sequential block copolymers based on polyether-sulfones and triblock polymers of alternating copolymers are being investigated by Research Associates Guodong Zheng and Xiaozu Han respectively.

Aging of polymers and polymer stabilization is studied by Associate Professor Zhonghan Chen in the Laboratory of Coordination Polymerization. His interests include: (1) preparation of photodegradable low density polyethylene films, and (2) study of the effectiveness of hindered piperazines on the photostabilization of polyethylene or polypropylene as a function of the chemical structure of the hindered piperazines.

3. Specialty Polymers

For years the Specialty Polymer Laboratory, now headed by Associate Professor Kejing Liu and Jiping Xu, worked on high temperature polymers, polyimides and poly(amide-imides) and engineering plastics, polyarylsulfones. New types of extrudable polyether-imides have now been developed by Associate Professor Xinye Liu and Research Associate Mengxian Ding.

Associate Professor Kejing Liu has been working on the cyclotrimerization of acetylene-terminated arylether-sulfone/ketone oligomers and their laminates and heat-resistant polymers.

In recent years, increasing emphasis has been placed on Functional Polymers. Associate Professor Kejing Liu and her group work on polymeric catalysts containing Pd and other metals for cyclotrimerizations. Associate Professor Jiping Xu and his colleagues prepared crown ether-containing polymers and studied their selective complexing properties; they also developed chelating resins with macrocyclic mercaptal group which was highly selective for the complexation of Hg^{2+} and CH_3Hg^+ . Work on electron-transfer reactions on a polymeric pyridinium chloride resin is also being carried out.

Research Associate Zhenghai Liu has been responsible for thermal analysis. He is using thermogravimetry, differential thermal analysis, differential scanning calorimetry for the evaluation of the thermal and thermal-oxidative stability, of heat-resistant polymers synthesized in this Laboratory.

4. Polymer Radiation Chemistry

The Laboratory of Polymer Radiation Chemistry, the only one of its kind in any of the Institutes of the Academia Sinica is equipped with a 60,000-curie ^{60}Co -radiation source and a 2MeV Van de Graeff accelerator.

Professor Zicheng Zhang, head of the Laboratory of Poly-

mer Radiation Chemistry, and his colleagues, have been working on the radiation crosslinking of polyethylene and the homo- and copolymerization of trioxane; they are now working on the radiation crosslinking of nylon 10,10.

Associate Professor Jiazhen Sun is studying the radiation crosslinking of fluorocarbon polymers, and the development of methods for the determination of molecular weights of polymers of low solubility. He is also interested in the crosslinking of polyimides and of silicone rubber blends and radiation grafting of polymers, emulsion polymerization of styrene and vinyl acetate by radiation, and the theory of random crosslinking.

Associate Professors Hansheng Xu and Qian Li are involved in radiation polymerization and copolymerization of solid or aqueous solutions of acrylamide to be used as aqueous gels or as flocculants. Associate Professor Shuzhen Xu's group is working on the sensitized radiation crosslinking and degradation of poly(vinyl alcohol).

Associate Professor Jie Chen has been carrying out studies on the plasma polymerization of ethylene, propylene, fluoromonomers, styrene and silicon containing monomers, and the mechanism of plasma polymerization. He has used ESCA extensively to study the structure of these polymers.

5. Oligomer Chemistry

The Laboratory of Oligomer Chemistry, headed by Professors Mingshi Ji and Qingyu Zhang, are involved in the development of adhesives, potting materials, protective coatings for special purposes, and materials of national interest.

Professors Mingshi Ji, Qingyu Zhang and their colleagues have been working on the synthesis of oligomers by free-radical or ionic polymerization or by degradation of polymers; they are also investigating the curing of these oligomers. Professor Zhang is also studying the effect of molecular weight and molecular weight distribution on the preparation of telechelic oligomers.

Interpenetrating networks based on oligomers are being investigated by Research Associate Donghua Zhang.

6. Organometal Chemistry

The development of rare-earth chemistry in the Institute of Applied Chemistry required the creation of research programs to investigate broadly the synthesis of new rare-earth organometal compounds; consequently, the Laboratory of Organo-Metal Compounds was organized in 1980.

Associate Professor Wenqi Chen's group is now involved with the synthesis of rare-earth compounds of the type $R\text{LnCl}_2$ where R=indenyl, cyclopentadienyl, phenoxy, alkyl- or chloro-substituted phenoxy, complexed with THF and/or HCl. The polymerization (and the kinetics of polymerization) of butadiene with rare-earth compounds (after reaction with aluminum alkyls) is being studied. The following compounds: $\text{C}_5\text{H}_5\text{NdCl}_2$, $(\text{C}_5\text{H}_5)_2\text{NdCl}$, $(\text{C}_{10}\text{H}_7)_3\text{Nd}$ and $(\text{C}_6\text{H}_5)_3\text{Nd}$ (or Gd) and their complexes with nLiCl or THF have been prepared.

Research Associate Qi Shen is synthesizing rare-earth substituted-dicyclopentadienyls and compounds with N- or P- containing ligands; he is also investigating the catalytic activity of these compounds in homogeneous catalysis.

Associate Professor Guozhi Liu, Head of the Laboratory, concerned with the synthesis of new organo-iron compounds

in connection with the investigation of polymerization with organo-iron catalysts.

Research Associate Rizhen Jin's group is studying the synthesis and function of metal tetraphenylporphyrins.

II. Polymer Physics and Physical Chemistry

1. Polymer Physics

Professor Baogang Qian was former Head of the Laboratory of Polymer Physics and one of the Deputy Directors of this Institute; he is now Head of the Wuhan branch of the Chinese Academy of Sciences in Central China. His interest is in transitions of polymers and in the crystallization rate of polymers; he had been responsible for the organization of the research activities in Polymer Physics and Physical Chemistry. Especially in the last decade the characterization of polybutadienes and polyisoprene prepared with rare-earth and other transition metal initiators was undertaken.

The new Laboratory Head, Associate Professor Fusheng Yu, and his colleagues are continuing the study of polymer transitions and of damping properties of polymers with their potential use as damping materials. They are also investigating the mechanism of entanglement in polymer chains and the effect of branching and molecular weight distribution on stress-relaxation and the dynamic properties of polymer systems. The group of Fusheng Yu is now working on the correlation of yield stress with the molecular weight for various elastomers.

Professor Rongshi Cheng, Associate Professor Zhiduan He and their colleagues have long been working on the solution properties of polymers, gel permeation chromatography (GPC) and laser light-scattering techniques. Professor Cheng has developed a unified theory for the calibration of GPC curves. He is also working on long-chain branching in polybutadienes and its effect on their mechanical and rheological properties.

Associate Professor Wen Qing is studying the rheology of cis-1,4-polybutadienes, 1,2-polybutadienes and ethylene propylene terpolymers. Rheological studies on other polymer systems are also being carried out in other research groups.

Associate Professor Donglin Chen's interests are the thermal properties of blends and block copolymers and the thermal properties of fluorocarbon polymers after radiation.

2. Polymer Structure

To meet the ever increasing demand for better understanding of structure/property relationships, the Laboratory of Polymer Structure was organized in 1979, with Associate Professor Zhiliu Feng and Bingzheng Jiang as Laboratory Heads.

Associate Professor Zhiliu Feng, formerly engaged in studies of mechanical properties of polymers, is now involved in work using light and electron microscopy, dynamic mechanical measurement, differential scanning calorimetry and small angle light scattering to study the compatibility of different elastomers with polypropylene; he is also looking into the used compatibilizers and the structure and properties of blends. Phase formation and morphological structure of segmented copolymers as a function of molecular parameters is being investigated.

Centers of Polymer Research

Associate Professor Bingzheng Jiang is studying structure and morphology of polymers by means of scattering techniques, such as small angle light scattering, small angle X-Ray scattering, and small angle neutron scattering. The effect of temperature and stress on the spherulitic structure and the mechanism of melting of some crystalline polymers is now being studied. The process of separation of polymers into two phases is also being investigated.

Associate Professor Xingmao Zhou is interested in the structure of rigid rod polymers, especially the mesophase transformation of such polymers.

Another group headed by Research Associate Xiabing Jing is studying chain structures of polymers: the microstructure and sequence length distribution is studied by chromatography/mass spectroscopy, ^{13}C NMR or IR spectroscopy. The isomerization of polyacetylenes and the change of structure on doping is also being studied. Future work will include the investigation of the configuration and the conformation of polymers by NMR, IR, Raman and mass spectroscopy. In this group Research Associate Zinan Zhou is responsible for NMR studies for the determination of the

microstructure and for conformational analyses of the macromolecular chain structure.

In the separate Testing Center of the Institute, Associate Professor Enle Zhou and Research Associate Zhishen Mo are studying the morphology and crystallization rate of *cis*-1,4-polybutadienes. These measurements are done as a function of changing structural parameters and the interatomic distance of the polymer chains; the necessary distribution functions have been derived from electron diffraction measurements. Research Associate Zhishen Mo is studying fluorocarbon polymers and polyolefin block copolymers prepared in other laboratories of the Changchun Institute by wide angle X-ray diffraction.

It must be emphasized that commercial instruments have now become available in the Institute. Many instruments in the polymer laboratories, for example, torsion pendulum, torsional braid analyzer and its computerization, but also, small-angle light scattering instruments are computerized. Stress relaxometer, automatic viscometer, and instruments for measuring linear expansion and varying speed Mooney viscosity, were designed and constructed in the Institute.