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Polymer Science in Australia I. Sydney and Canberra

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Centers of Polymer Research

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Australia is a country of about 3 million square miles and 17.5 million inhabitants. It is devided into 6 states, New South Wales (NSW), Victoria, Tasmania, South Australia, West Australia, Queensland and two territories, Northern Australia and the capital district of Canberra. A substantial part of the population lives in several large coastal cities.

The indigenous people of Australia, the Aborigenes, are thought to have migrated from southern Asia some 70,000 years ago. The European settlement of Australia was begun in 1788 with the landing of the First Fleet in Botany Bay near Sydney. Sydney, the cultural and business center of Australia is a metropolis of about 4 million people with a fabulous harbor. In the year 2000 the Olympic Games will be held in Sydney.

Circular Quay, Sydney

Canberra was designated the capital of Australia in 1908 and it has since been built in a highly organized manner. The Australian National University and the Australian Academy of Science are located in Canberra.

In this article we will be describing the activities in Polymer Science and Technology in the central part of Australia, basically in New South Wales. Much of the teaching and research in this region is done at the University of Sydney and at the University of New South Wales.

The University Of Sydney

The University of Sydney is the oldest university in Australia, having been established by an act of parliament in 1850. A Professor of Chemistry was among the five Founding Chairs. Alumni include Sir John Cornforth, Nobel Laureate in Chemistry. Currently, the University has a student population of over 28,000 drawn mainly from the state of New South Wales.

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University of Sydney

Polymer Science at the University of Sydney is investigated at the School of Chemistry, especially at the Sydney University Polymer Center.

School of Chemistry

The first polymer studies were carried out by Professor A. E. Alexander and Dr. A. G. Parts. These studies have been continued by Donald H. Napper, current Professor of Physical Chemistry, and a student of both Alexander and P. J. Flory. He has investigated, for a number of years, polymer emulsions and latices. His current interests lie in three areas :

a.) Polymerization of Self-assembling Systems: Many surfactants undergo self-assembly spontaneously in water, both in the presence and absence of monomer. If the surfactants are polymerizable, then the group polymerization process may be very different from that observed when the monomers are dispersed. If monomer is added, it may be polymerized under unusual conditions to generate polymers with unusual properties.

b.) Properties of Single Chain Glasses: Microemulsion polymerization generates polymers as single chain glasses. In these, the polymers adopt a globular conformation rather than the more ubiquitous random coil. There is now spectroscopic and thermal evidence to suggest that these single chain glasses have properties different from multichain glasses, the reasons for these differences are being studied.

c.) Studies of Coil to Globule Transition Interfaces : Poly (n-isopropylacrylamide) undergoes a coil-to-globule transition when attached to the surfaces of latex particles. The general features of this transition, and its dynamics are being studied and compared with theory of n-cluster formation developed by de Gennes. These systems provide insights into the knotting of polymer chains.

Sydney University Polymer Center

The Center has the dual objective of fundamental research in polymer science and providing active collaboration with the polymer industry and is under the direction of Robert G. Gilbert. The goal with individual collaboration is to use scientifically based practical knowledge and problem-solving to produce rational polymer design for improvement and innovation in commercial processes : to provide the means of improving and changing "mature technologies", assistance in customer service (both short- and long-term), and assistance in the development of new technologies. Staff and affiliates have expertise in a wide range of polymerization processes and polymer products, including : Emulsion Polymerization and Emulsion Polymers, Analysis of Polymer Systems, Colloid Science, Modelling of Polymer Systems and Processes, Polymerization Kinetics, Polymer Thermodynamics.

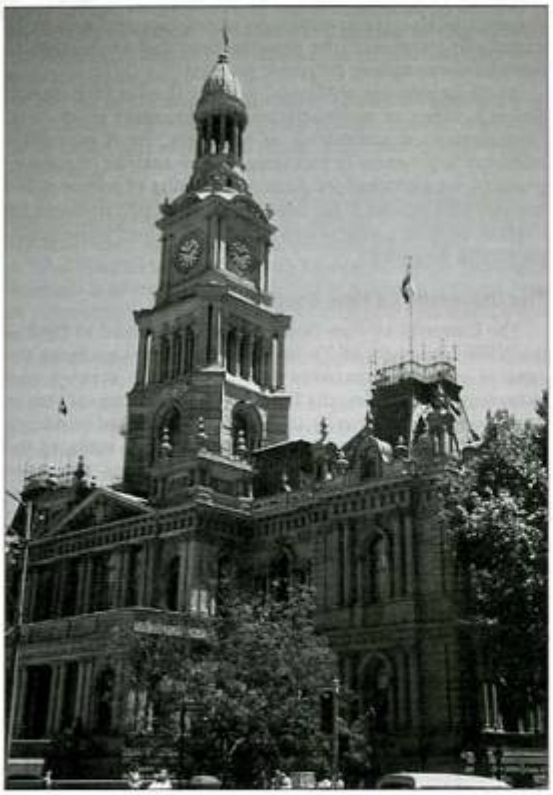
University of Sydney, School of Chemistry

The general research interests of the Center include : Basic mechanisms of free radical polymerization, emulsion polymerization products and processes. Other more applied interests are : Organic and water based paints, other surface coating materials, adhesives, plastics, rubbers, latexes and flocculants.

The Sydney University Polymer Center has experience in applying current research knowledge for the improvement and

development of both mature and state-of-the art products and processes. This can provide expertise, laboratory space and equipment which may not be available in a company. The Center performs a.) Contract and Consutancy Work - the SUPC is a registered research agency ; contract and consultancy work with the SUPC qualifies for the 150% tax incentive for R & D collaboration within Australia; b.) Collaborative Research and Development Projects, e.g. through the IRD scheme. c.) Collaborative Fundamental Research Projects, e.g. industrial ARC; d.) Sponsored Research Students, e.g. APRA (Industry); e.) Seminars, Courses and Workshops (employee training) - in polymer science, research efficiency and the use of consultants; f.) Customer Servicing for Special Problems.

Members of the Center have technical expertise in a.) Polymerization Process Design and Optimization - including the formation and properties of polymers and polymer colloids, especially using free radical polymerization, and including any method of heterogeneous polymerization, emulsion, dispersion and suspension polymerization; b.) Development of High Value-Added Products; c.) Troubleshooting in Polymerization Processes; d.) Analysis of Polymer Product and Polymerization Processes in Laboratories of the Center; e.) Design and Characterization of Polymer Latexes; f.) Courses and Seminars.



City Hall, Sydney

Opera House, Sydney

Robert G. Gilbert, Professor of Chemistry is interested in two major areas : a.) Basic Mechanism of Free Radical Polymerizations and b.) Emulsion Polymerization Products and Processes. In the first area he is involved with the experimental and theoretical studies of the important kinetic events in free radical polymerizations: propagation, transfer, termination, chain-branching and reactivity ratios. How these rate coefficients can be obtained from and how they effect, rates and molecular weight distributions. The knowledge gained can be used to control and improve polymer properties and production. On the second subject, Gilbert is investigating the mechanisms controlling the production of latexes and formed polymers in emulsion polymerizations : initiator efficiency, radical desorption, aqueous-phase kinetics (e.g. oligomer production), particle nucleation, secondary particle formation and particle size distribution.

Ian A. Maxwell is investigating a.) Polymerization Kinetics : Understanding basic mechanisms of polymerization and copolymerization in both bulk and heterogeneous systems; b.) Polymer-Solvent Thermodynamics: Development of models that predict solvent partitioning in heterogeneous systems, including polymer latex particles and vesicles; c.) Polymer Technology : Development and modification of polymer products; Maxwell is also interested in colloid science, flocculants and flocculation, membrane technology, surfactant science, surface coating technology, instrumentation and methods for particle sizing. Anthony P. Lang, Lecturer in Physical Chemistry is studying a.) mechanisms of polymerization, especially the examination of free radical copolymerization; b.) Degradation of Polymers, the effects of high energy ionizing radiation on polymers, especially on copolymers and their structure and composition; c.) Organoferromagnetic Materials, small molecule stable radicals and their incorporation onto polymers and the examination of the relationship between their chemical structure and their magnetic behavior.

David F. Sangster is interested in application of radiation techniques in the polymer field: Initiating species - characterization, rates of reaction. Emulsion polymerization -

Harbor Bridge, Sydney

observation of relaxation and approach-to-steady-state phenomena to determine kinetic parameters and mechanisms. Macroradical reactions - studies of macroradicals formed by radiation. Radiation grafting - suppression of homopolymerization, biocompatability. Irradiation of polymers - degradation and crosslinking mechanisms. Radiation processing - industrial applications of high energy radiation.

Department of Mechanical Engineering

In the Department of Mechanical Engineering, Professors R. I. Tanner and N. Phan-Thien have an extensive program to study the rheology of viscoelastic fluids, such as molten polymers and polymer solutions, especially as they relate to polymer processing. Much of this work involves computational fluid mechanics. In the same department, Professor Y. M. Mai is studying the fatigue and fracture of polymers, polymer alloys and novel interpenetrating networks. Studies are also being performed on the friction and wear behavior of metals sliding on polymers. The role of fracture and fatigue, as well as the effects of organic solvents on wear, are being studied.

Eastern grey kangaroo

University Of Technology, Sydney

At the Department of Chemistry, Gary Norton, Associate Professor and Department Head is interested in the a.) Chemical Modification of Polymers for use as corrosion inhibitor and light weight aggregate in concrete; b.) Synthesis of Conducting Polymers, and their evaluation as a function of structure especially the continuing synthesis of conducting polymers. c.) Evaluation of Polymers in Use, the investigation of polymer performance in various applications, the development and evaluation of formulations containing polymeric products.

At the Department of Material Science, Gordon M. Renwick, Senior Lecturer in material science is interested in analysis, characterization and testing of polymers. He is especially interested in polymers in packaging, failure analysis of polymer products, durability and accelerated weathering of polymers. His research activities are in the characterization of polyurethanes for implant materials, degradation of polymers and intrinsically conducting polymers.

The University Of New South Wales

The University of New South Wales was founded in 1949 as the NSW University of Technology, the name signifying the special emphasis that was to be placed on science and technology. To this day, the University's special strength are in this area. However, even by 1958, the University had broadened its discipline base to such an extent that it was renamed the University of New South Wales. It has founded two other Universities, at New Castle and Wollongong, and has a campus in Canberra, the Australian Defence Force Academy, where it teaches officer cadets in all three services to first degree level. Its current student population is 29,000.

Polymer Science and Engineering Group

The research interests of the Department of Polymer Science cover a number of new areas of polymer chemistry and engineering which links with industries and universities within Australia and Overseas.

Investigations of the homogeneous Ziegler-Natta polymerization have resulted in the establishment of a mechanistic model. The investigations have also been extended to include heterogeneous and rare earth catalyst systems. Polymerization of propylene is also being investigated with

emphasis on particle development and characterization.

The synthesis and characterization of polymer blends and networks has been extensively studied. Some composites comprise crosslinked elastomer dispersed in a second rubbery or plastic matrix, with the interface being controlled. Other systems comprise continuous cross-linked phases (for example an elastomer or thermoplastic elastomer) interpenetrating into a stiff thermoplastic. Rigid-rod polymer blends are also being investigated. Studies of fracture toughness, morphology by electron-microscopy and thermal behavior by dynamic mechanical analysis are in progress.

Fracture morphology and toughness of a wide range of polymers are being measured, including thermoplastics prone to environmental crazing, rubbers and rubber/plastics blends. This work has concentrated on crystalline polymers including nylons, polyethylene and polypropylene. Polypyrroles are also being synthesized and optimized for durability and potential improvement of existing materials including membranes.

Polymers suitable for hydrogels and other biomedical applications are being tailored. In particular, two phase systems with micropores suitable for gas and water transmission are being developed.

Polymers and polymer networks with either linear or non-linear optical properties have been synthesized and characterized. Specific objectives include the increase in fracture toughness of homogeneous polymer networks and a study of ring opening metathesis polymerization techniques to prepare polymers with extensive conjugation.

The use of UV and EB radiation to prepare coatings and graft copolymers have been extensively studied. Specific objectives include the preparation of tough, hard coatings for optical applications.

Ab initio molecular orbital calculations are being applied to free-radical polymerizations in an attempt to predict reactivity and understand remote unit effects in copolymerizations.

The synthesis and characterization of novel hydrogen materials is of current interest. A part of this work is the analysis of water structure in the materials by dielectric spectroscopy and DSC.

An interdisciplinary Center for Applied Polymer Science is currently being established at UNSW. The Center will bring together expertise in biomedical polymers, contact lens materials, textiles, engineering polymers and their architectural applications together with mainstream disciplines of polymer chemistry and physics.

Robert P. Burford, Associate Professor and Head of the Department is studying a.) The diene polymerization with supported Ziegler-Natta catalysts and the preparation and characterization of the elastomers. b.) Fracture Processes, the environmental stress cracking and crazing and interfacial properties. c.) Synthesis of semi- and full interpenetrating networks and polymer blends. Thermal and fracture toughness properties and blend morphology. d.) Electrically conducting polymers, especially the use of polypyrroles membranes, factal growth.

Rodney P. Chaplin, Senior Lecturer is investigating a.) Optical Polymers: The preparation and properties of interpenetrating polymer networks for optical applications, development of synthetic methods for the preparation of polymers with large 3rd order optical nonlinearities for use as optical fibers. b.) Organic/Inorganic Hybrid Polymers: Development of synthetic techniques for the preparation of hybrid network polymers and the evaluation of their mechanical and optical properties; c.) Graft Polymerization: Study of the effect of grafting conditions on the rate and mechanisms of grafting reactions to include free radical (UV and ionizing radiation), anionic and cationic mechanisms; d.) Polymerization Reactions: Study of Ziegler-Natta catalyst systems for the polymerization of vinyl monomers, mechanisms and reactor design. Computer programs are also being developed to aid in the teaching of experimental design. Tom Davis, Senior Lecturer, is investigating free radical polymerization thermodynamics and kinetics, hydrogels and biomaterials, molecular modelling of polymers, radiation crosslinking, novel synthetic routes to polymers and acrylic materials.

At the School of Chemical Engineering and Industrial Chemistry, John L. Garnett, Emeritus Professor is interested in a.) Radiation Chemistry, especially the relationship between mass spectrometry and radiation chemistry and the role of positive and negative ions, free radicals and energy transfer processes in radiation chemistry; b.) Radiation Polymerization, Curing and Grafting: Novel methods for synthesizing oligomers, grafting and curing of monomers/oligomers to backbone polymers using ionization radiation and UV radiation. c.) Radiation Processing: Development of new commercial processes in surface coatings, inks, composites and flame retardancy using UV and electron beam curing and cross-linking reactions.

Srikanta Bandyopadhyay, Senior Lecturer is investigating a.) Micromechanics of deformation and fracture in engineering plastics and structure property correlations; b.) Toughened epoxies/toughened plastics; c.) Stress cracking of polymers and d.) Polymer-matrix composites, metal-matrix composites and ceramic-matrix composites. Darrell J. Bennett is involved in a.) Hydrogel polymers, the nature of water in hydrogels, with particular attention to free and bound water and its effect on the mechanical properties of the polymer. Methods of increasing the water content of hydrogels without adversely affecting their properties.; b.) Solid state NMR spectroscopy to probe the molecular motions occuring in polymers.

University Of Wollongong

At the Department of Materials Engineering, Geoffrey M. Spinks is involved in the investigation of a.) Mechanical properties of polymers with emphasis of fracture, fatigue and indentation behavior of thermosetting polymers and blends; b.) Adhesion and the characterization of the polymer- metal "interphase"; The determination of the strength of structural adhesive joints and the correlation to the interphase structure. Adhesion of paints to coated steel, with relevance to corrosion protection; c.) Conductive polymers: processing, morphological structure and mechanical properties of electrically conducting polymers, work that is carried out in conjunction with the Intelligent Polymers Research Laboratory.

Professor Gordon Wallace has rapidly build up a large group in the Intelligent Polymer Laboratory. The idea is to tailor-make polymers which will respond in some fashion to the environment, thus allowing their use in e.g., sensors and control devices. Conducting polymers have been a special focus to allow the construction of electrochemical sensors.

Considerable amount of research on polymers is also being carried out at the Research and Technology Center of BHP Steel. The BHP Steel -Sheet and Coil Products Division is one of the largest coil coating organizations in the world. The Polymer Research Group is involved in the evaluation and development of polymer surface coatings and is concerned with both bulk and surface properties of such coatings. Malcolm R. Binns' research interests are a.) Synthesis of model coating systems; b.) Investigation of UV induced polymer degradation mechanisms; c.) Development of improved, more reliable accelerated weathering procedures; d.) Investigation of adhesion at polymer-metal, polymer-pigment and polymer-polymer interfaces. Christopher A. Luckey is investigating new methods for the early detection of paint film degradation. He is also studying the development of predictive weatherability tests based upon these methods, new durable resins for coil-coated steel applications, pigment-resin interactions and their effect on durability and new curing technologies and their application to coil coated steel.

The Australian National University

The Australian National University was founded in 1946 as a purely research university but in 1960 it was amalgamated with the Canberra University College, which had taught at the undergraduate levels since 1930. The historical divisions live on in the two quite distinct parts of the University: research-oriented Institute of Advanced Studies and the more teaching oriented Faculties, which also undertake research. The University has a student population of some 10,000 students, who are drawn from all over Australia.

Polymer science at the Australian National University is located in the Faculty of Engineering and Information Technology, specifically in the Department of Engineering. Much is concentrated in the Materials and Manufacturing Group.

Materials and Manufacturing Group

The prime research focus of this group is fabrication and mechanical properties of composite materials and polymers. The strength of the Materials and Manufacturing Group lies in the combination of traditional material engineering and science with modelling and process simulation. This allows for an approach to materials through modelling and an approach to modelling and simulations that has a sound base in materials science.

Graphite fiber/polymer composites are materials of the future because of their light weight to high strength properties. Their potential lies in many areas, including transport, communication equipment, medical devices, sporting goods and light air craft.

With a major emphasis on polymers and composite materials, the group has a certain uniqueness in Australia. The research agenda emphasises programs that are multi-disciplinary in nature and have high potential to provide Australia with a more competitive manufacturing basis.

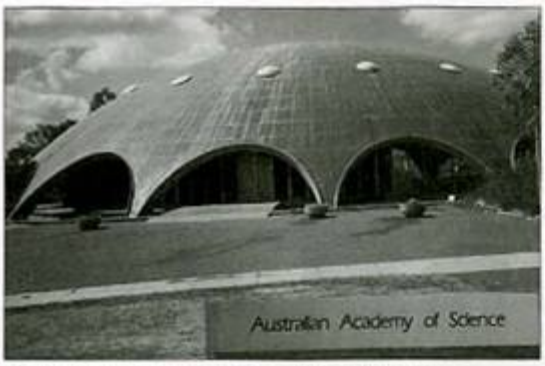
The research activities include: Real time simulations of materials processing in blow molding operations; solidification of polymers; particle coarsening in polymer blends; transparency and kinetics of crystallization in polymers; pultruded fiber reinforced materials and shaping technology; relationship between chemistry and mechanical properties of matrices and composite materials; influence of fiber/matrix interface on microstructure of modified epoxy resins; influence of graphite fiber/epoxy matrix interface on the adjacent microstructure; fracture resistance and damage tolerance of FRC with process control and engineered interfaces; ultra-micro indentation studies of modified epoxies; fracture toughness and fatigue life of advanced composite materials for marine applications.

Zbigniew H. Stachurski

Zbigniew H. Stachurski, Reader at the Department of Engineering has his research interests in a.) Solidification of polymers: crystallization, gelation and vitrification; kinetics, diffusion and microstructure; b.) Mechanical properties of polymers, viscoelasticity theory of yield in amorphous polymers, toughness of laminated films, design; c.) Interactive modelling of materials and processes, kinetics of epoxy curing, graphite-epoxy interface. Jang-Kyo Kim is primarily working on Composite Interfaces/Interphases: Characterization of failure mechanisms, correlation between the microscopic interface properties and the gross mechanical performance of composites, reliable theoretical models of single composite tests and optimize the strength/stiffness properties and fracture resistance/damage tolerance of composites. P. Y. Ben Jar's interests are in crystallization and morphology of semi-crystalline polymers and in the characterization of fiber-reinforced polymer composites.

Australian National University, Canberra, Department of Material Science

Old Parliament, Canberra



Becker House, Australian Academy of Science, Canberra

The Australian Academy Of Sciences

The Australian Academy of Sciences was constituted by Royal Chapter presented to the first Council by the Queen of Australia Elizabeth II, of February 16, 1954. The Academy is housed in two buildings on adjecent sites in Canberra, the national capital. The more architecturally distinctive of the two buildings is Becker house (or The Dome as it is affectionally known), which provides a large conference chamber (the Ian Wark Theatre) suitable for scientific meetings. It is also here that the Fellows of the Academy meet annually to transact the formal business of the Academy, including the election of new Fellows. The current membership of the Academy runs to some 280 Fellows (including 20 non-Australian corresponding Fellows resident overseas.

The Fellows of the Academy represent a wide range of disciplines: Mathematics, computer science, physics and astronomy, chemistry, earth and planetary sciences, zoology, botany and microbiology, biochemistry, molecular biology and immunology, agriculture environment, medical and veterinary sciences, as well as physical sciences, such as engineering, materials sciences, information technology and industrial innovation. The latter areas abut those covered by a complementary learned society, the Australian Academy of Technological Sciences and Engineering, with which there is a significant overlap by the Academy of Science, it is perhaps not too surprising that currently only three Fellows, Professors D. H. Solomon (Melbourne), D. H. Napper and R. I. Tanner (both Sydney), are active in the field of synthetic polymer science, although a number of other Fellows study biopolymers.

The stated role of the Academy is to promote science in Australia and to recognize outstanding contributions to the advancement of science. One method by which the Academy promotes science is by fostering its teaching, especially at the school level, through curriculum development and the publication of appropriate texts. Currently it is actively involved in developing the teaching of elementary science in the junior school program. The Academy is also involved in science policy issues. Its location in the seat of the national parliament gives it ready access to those who hold the reins of power. The Academy also fosters science in Australia through being the focal organization that interacts officially with the International Scientific Unions, like IUPAC, and other international groups. In this role, it is an official sponsor of international polymer meetings held in Australia, such as the Pacific Polymer Conferences and the IUPAC MACRO conferences.

National Library, Canberra

Marquarie University

At the School of Chemistry, Jacob S. Shapiro, Senior Lecturer in chemistry is investigating a.) Conductive polymers, the effect of synthesis conditions on the morphology of conducting polymers to yield copolymers of polypyrrole and poly(3-alkylthiophenes); b.) Modification of polymers for recycling, grafting of water-miscible polymers on commodity polymers to yield copolymers for horticultural applications; c.) Thermal decomposition and stabilization of polymers; decomposition of PVC and substituted polydiacetylenes with special emphasis on the effect of crystallinity of the polymer on the kinetics and the products of the decomposition, but also the mechnism of stabilization of PVC.

Acknowledgments

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