Polymers for Advanced Technologies

Volume Edited by

Menachem Lewin

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Macromolecular Division

In Conjunction with

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PREFACE

During the last two decades, significant changes have taken place in the general pattern of industrial developments throughout the world. Novel industrial enterprises have blossomed, based primarily on new scientific and technological achievements. The appearance of these advanced industries represents a growing partnership between scientists, engineers, and industrialists.

Three outstanding characteristics of the new technological trends are

1. The pace of development: The transition from concept, through laboratory and pilot plant, to practical application is highly accelerated.
2. The new developments are interdisciplinary in nature and require close cooperation between several fields of scientific as well as engineering skills. This is perhaps a major reason for the imaginativeness and unexpectedness of many of these developments.
3. These technologies are highly diversified; they branch out into many avenues of human activity and endeavor, meeting ever-increasing challenges of hitherto unsolved problems.

It is not surprising that a considerable part of these new technologies center around polymers. Seventy million tons of polymers, valued at over 140 billion dollars, were produced worldwide in 1986. The bulk of this production was relatively simple commodity polymers. Recently, however, a small but growing proportion of the polymers produced have been specially designed and tailor-made for specific, increasingly sophisticated applications. These spectacular achievements in polymer science led to a recent statement by Herman F. Mark that the time is close when "the potential of polymer chemistry will be limited only by the imagination and ingenuity of scientists."

It appeared to the organizers of the 1987 IUPAC International Symposium on Polymers for Advanced Technologies that the time was ripe for focusing the attention of scientists from academia and industry on recent developments and on several new aspects of polymer research and its impact on the emerging science-based technologies, in order to meet the challenges of the 21st century.

The Symposium took place at the Laromme Hotel in Jerusalem on the 16–21 of August, 1987, with 450 participants from 20 countries. The program consisted

of 26 lecture sessions, two poster sessions, and a panel discussion on Strategies for Advanced Polymers in the World.

The Symposium was opened by Professor Menachem Lewin, followed by a welcoming address by the Prime Minister of the State of Israel, the Honorable Yitzhak Shamir, who stated "Science and technology are a striking example of international cooperation in which gifted individuals from many countries reach out to each other across borders and beyond limitations in a joint effort to create knowledge in order to build a new, happier world, a safer future, and a permanent peace for all humanity." The opening lecture was given by Professor Herman F. Mark, who presented an overview on "Polymers for Advanced Technologies." This was followed by the plenary lectures by Professor E. Katchalski-Katzir on "Polymers for Biosystems," by Nobel Laureate Professor W.B. Merrifield on "The Solid Phase Approach to the Chemical Synthesis of Biologically Active Peptides," by Dr. D. Tanner on "Polymers for Advanced Structures," and by Professor A. Chapiro on "Polymers in Radiation-Related Technologies."

The Symposium, organized by Professor Menachem Lewin, was the third IUPAC Macromolecular Symposium held in Israel. The first took place in Rehovot in 1956 and was organized by the late Professor Aharon Katchalski-Katzir. The second symposium was held in Jerusalem in 1975 and was organized by Professor Alex Silberberg.

The Symposium, organized around three major topics (microsymposia) covered a large part of the work in the field: (1) Polymers for Biosystems, (2) Polymers in Radiation-Related Technologies, (3) Polymers for Advanced Structures.

Seventy-five out of the 135 lectures and posters presented at the Symposium are published in the two volumes of the proceedings. They include the plenary and sectional lectures as well as a number of selected contributed presentations by outstanding authors from 20 countries. These represent a wide diversity of subjects, approaches, and experiences and are truly representative of the present state and future trends of the field of polymers for advanced technologies.

One of the volumes, "Polymers for Biosystems," contains 26 chapters and is being published by Hüthig and Wepf Publishers, Basel. The present volume contains 51 chapters and deals with the two other Symposium topics: Polymers in Radiation-Related Technologies and Polymers for Advanced Structures. It is subdivided into nine parts. Part I deals with radiation-sensitive and radiation-modified and cured systems. Silicon-containing resist polymers for bilayer applications and image-selective silylations for single layer schemes are described by *J.M. Pearson, S.P. Hersh, S. Brock, P.L. Grady,* and *J.J. Wortman* compare the ion irradiation method for enhancing permanent conductivity of a number of highly insulating polymers to chemical doping. Modification of polymers by high-energy radiation resulted in highly sophisticated devices applied in fields such as wires, cables, packaging materials, automobile tires; breakthroughs are expected in electronics and biomedical devices (*A. Chapiro*). The state of the art

of industrial applications of ultraviolet (uv) lamps and low-energy electron accelerators for instant polymerization of radiation-curable chemicals is critically reviewed by *J.R. Seidel*. Such systems are exemplified by photo-crosslinking of EPDM elastomers in a multi-step reaction with photoinitiated uv crosslinking of polyethylenes and polyesters (*B. Ranby, C.Y. Lie, Q.B. Jun,* and *S.W. Feng*). An electron beam radiation grafting of *p*-styrene sulfonic acid on ethylene-vinyl alcohol is also presented (*A. Mey-Marom* and *S. Shkolnik*). Recent developments in solar energy collection technologies have brought about considerable progress in designing and modifying polymers in order to obtain the desired properties and predicted performances in service. Of particular importance are the optical, thermomechanical, and diffusion barrier behavior properties, as well as environmental aging effects (*H. Neidlinger* and *P. Schissel*).

Part II describes systems of photo-electro conductive and piezo-electric polymers. Photoconductivity of homogeneous and heterogeneous systems with particular emphasis on materials based on poly(N-vinyl carbazole) is discussed by *M. Kryszewski*. *M.A. Abkowitz* and *M. Stolka* describe the electrophotographic process and discuss the electronic transport phenomena in polymeric photoreceptors with emphasis on polysilylenes. A study on the contact resistance and interfacial properties of *p*-Si/conducting polymer interface for solar cell applications is presented by *G. Nagasubramanian, S.D. Stefano,* and *J. Moacanin*. Phthalocyanine-based Langmuir gas sensors are reviewed by *E. Rickert*.

Three chapters deal with electrical phenomena in poly(vinylidene fluoride) (PVDF) as a piezoelectric and pyroelectric polymer: *J.B. Lando* discusses the relationship between crystallization and the poling behavior of the polymers. He also discloses a way to produce bulk poly-(fluoroacetylene) from PVDF. *J.H. Wendorff* and *O. Jungbauer* report on nonlinear piezoelectricity obtained when uniaxially stretched and poled PVDF was stressed or strained perpendicular to the stretching direction. *J. Fuhrmann, U. Jahn,* and *H. Strum* show that the ferroelectric behavior of PVDF is frequency dependent, due to the dynamic cooperative dipole effect. *M. Aldissi*, in a contributed paper, discusses intrinsic anisotropy in electric and optical properties of conducting polymers obtained by macroscopic and chain orientation of the material. New information is reported on triboelectricity of keratin fibers by *J. Jachowicz, G. Wis-Gurel,* and *M. Garcia*. A comparison of the alpha particle penetration range of several polymers used in the microelectonics industry—poly-*p*-xylylene, polyimide, polyester, and plasma polymerized hexamethyldisiloxane—is reported by *G. Kennedy, E. Sacher, and M.R. Wertheimer*.

Parts III–VIII of the present volume deal with polymers for advanced structures, which are defined by *D. Tanner, V. Gabara,* and *J. Schaefgen* in their overview "as systems of materials which meet unusually high performance requirements" in, for example, aircraft, aerospace, automotive, ballistics, and protective clothing applications. In his overview, *H.F. Mark* discusses recent developments in

advanced polymers and regards "competition and cooperation of polymers with metals and ceramics" as a major trend in future developments. This relates to efforts being made to synthesize polymers with properties approaching those of metals and ceramics. In addition, materials composed of polymers combined with metals or ceramics are emerging.

Parts IV and V deal with high-performance polymers. *Dr. Stephanie Kwolek*, who was the first to establish the existence of lyotropic liquid crystalline (LC) solutions of polymers, reviews recent work on aramide LC polymers and fibers and discusses a new vapor phase polycondensation process. *M. Jaffe* and *H.N. Yoon* discuss structure-processing relationships of nematic thermotropic copolyesters. *W.J. Jackson* compares effects of composition and fiber processing conditions on the tensile properties of LC polymers prepared from aromatic copolyesters containing flexible spacers and wholly aromatic copolyesters. *R.W. Lenz* discusses the effect of both main chain and pendant flexible spacers on the LC properties of thermotropic polyesters. *J.H. Wendorff* reports on the effect of local structural variations induced in LC domains by external fields, on the local variation of the refractive index, and on birefringence and its use for reversible information storage.

Materials prepared from polyacrylate and polysiloxane LCPs showing both thermotropic and photochromic mesophases are described by *I. Cabrera*. Novel condensation systems for producing high molecular-weight polyamides and polyesters are presented by *N. Ogata*.

D. Prevorsek discusses factors influencing strength and modulus of high tenacity–high modulus polyethylene fibers. *A. Ziabicki* compares development of structure in processing of polymers built of rigid versus flexible macromolecules. Preparation of single crystal fibers by solid state polymerization of monomeric single crystals of substituted diacetylenes and their properties is presented by *R.J. Young*. *H.D. Wagner* discusses the effect of size on ultimate properties such as strength and lifetime of fibers and whiskers.

Recently, there has been considerable interest in multi-component polymer blends and in their application to the engineering, space, biomedical, electrical, and electronic industries. Understanding the morphology and behavior of various polymer blends and networks is in its beginning stages; nevertheless, the wide possibilities for obtaining materials and devices with improved and novel properties are already widely realized.

Parts VI and VII of this volume contain eight papers on polymer network and blends. *L.H. Sperling* reviews recent work on interpenetrating polymer networks (IPNs), with emphasis on domain size assessment with small angle neutron scattering phase separation and on sound and vibration damping. *S.R. Jin, J.M. Widmayer*, and *G.C. Meyer*, in a contributed paper, report on the formation kinetics of a acrylic network phase in the presence of an already fully-formed polyurethane network, followed by Fourier transform infra red (FTIR) spectroscopy. *Sung Chul Kim* reports on an IPN membrane composed of the hydrophylic

polyurethane and the hydrophobic polystyrene for pervaporation of ethanol–water mixtures. Water-swellable ionic polymeric networks composed of polyacrylamide and polyacrylic acid and their swelling kinetics are discussed by *S.J. Candau.*

Four chapters are devoted to polymer blends. *E.M. Pearce, T.K. Kwei,* and *Ling-Yu-He* discuss thermal degradation of blends of poly(vinylacetate) and PVDF. Mechanical spectroscopy is applied for the study of the structure of ethylene–propylene-based polymer blends in a study by *J.F. Pierson. R. Kosfeld* describes the thermal behavior of blends of polycarbonate with semiflexible thermotropic copolyesters from poly(ethyleneterephthalate) (PET) and *p*-hydroxybenzoate. *G. Groeninckx* reports on the miscibility behavior, morphology, mechanical properties, and deformation modes of blends of a rubber containing modifier with a random terpolymer mainly based on styrene and maleic anhydride and PVC.

The intensive studies being conducted in many laboratories on composites and adhesives are reflected in the five papers of Part VIII of this book. In a contributed paper by *I.K. Varma*, studies are reported on the thermal behavior of bismaleimide resins with a series of additives. *G. Tesoro* reports on a new system for chemically modifying the surface of Kevlar® fibers to improve composite properties. *F. Tüdos* and *B. Pukanszky* describe the role of the interface in PP composites containing different inorganic fillers. *I. Shapiro* reports on the chain length development in epoxy-amine matrices. *H. Dodiuk, A. Buchman,* and *S. Kenig* describe polyurethane adhesive with silane coupling agents.

Part IX of this volume is devoted to elastomers and several special topics. *C. Garbuglio* reviews recent work on structure and properties of fluoroelastomers—for example, copolymers vinylidene fluoride (VDF)/hexafluoropropene (HFP), and terpolymers VDF-HFP-tetrafluoroethylene. *H.J. Cantow, B.C. Auman, W.A. Jishan, V Percec,* and *H.A. Schneider* report on a new temperature-resistant thermoplastic elastomer composed of aromatic polyether sulfone with incorporated poly(dimethylsiloxane). *R.B. Seymour* describes the synthesis of block and graft copolymers from macroradicals. *B.J. Bulkin* and *M. Lewin* discuss new developments in Raman spectroscopy of polymers which enable the direct determination of a number of properties. *R. Hosemann* describes microparacrystals and their equilibrium state. *H. Craubner* presents a statistical thermodynamic theory of polymer precipitation.

The Symposium would not have been possible without the sponsorship and financial support of the following institutions: IUPAC, Israel Academy of Sciences and Humanities, Israel Chemical Society, Ministry of Science and Development, Ministry of Industry and Trade, Hebrew University, Ben-Gurion University of the Negev, Tel-Aviv University, The Weizmann Institute of Science, and the Technion-Israel Institute of Technology.

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Radiation-sensitive, Radiation-modified, and Cured Polymers

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