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INTRODUCTION

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We deal what we are. This saying serves to introduce the discussions on polymers. A quantum leap in this area brought about the Industrial Revolution in the 19th century. Recognition should be given to Herman Staudinger, who, in 1922, proposed the first explanation that polymers contain long chains of relatively simple repeating units. This date marks a turning point in the history of polymers, for it was then that the term "macromolecule" was first used. Thus the word becomes self-explanatory when broken down: The word "poly" means many, and "meros" means parts. The macromolecular concept was formulated by Staudinger, who received the Nobel Prize in 1953. Polyethylene, for example, is a polymer that contains large numbers of [$-CH_2-CH_2-$] units. In 1970, the first experiments with polyacetylene took place. Polyacetylene is a long string of molecules chained together, with one unit of acetylene repeated over and over again. In 1977, the trio of Mac Diarmid, Shirakawa, and Heeger joined to focus in this arena to revolutionize electronics and received the Nobel Prize in the 21st century.

Polymers play an essential role in the emergence of the modern world. Though started in the middle of the last century, today, the uses of polymer systems are legion. Technology from commodities to rockets is based on productive research on polymers. The polymer industry developed as population growth created increased demands for natural products that could not readily be met because of their limited supplies. "Osmosis" and "reverse osmosis" techniques that regulate life in every aspect are based on polymers.

Abbe Nolet had observed the "osmosis" phenomenon in the year 1748 in pig bladders, with natural polymers. Later on, synthetic ones came to replace natural polymers.

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The history of the “reverse osmosis” membrane started at UCLA in 1959. Samuel Yuster and two of his students, Sidney Loeb and Srinivasa Sourirajan, produced a functional synthetic reverse osmosis membrane from cellulose acetate polymer. The ability to make high-quality biocompatible materials in the biomedical field is at the heart of this revolution.

Traditionally, people in the medical field view polymers as components of devices such as inhalers and catheters, inert bioprostheses, or transdermal patches. Polymers have also proactive role, i.e., they are used as integral parts of therapeutics. New drugs, as well as drug delivery systems based on polymers, have the potential to counter many diseases. The application of synthetic polymers for gene therapy has also been investigated. They may provide a safer way of gene delivery than use of viruses as vectors. Polymeric materials have also been used for biosensors, in testing devices, and for bioregulation.

Textile products made of polymers have always satisfied aesthetic requirements. Synthetic polymers replace natural polymers (e.g., wool and cotton) to help clothe growing populations. The success of aramid fibers has also spawned a variety of other polymer fibers based on nylon, terephthalates, and polyethylene, for example.

Polymers are also identified with insulation. This property has contributed to the enormous success of plastics in insulated shielding for wires and other safety functions. Polymers are also used in the conducting or semi-conducting fields for such things as plastic batteries, light emitting diodes, and sensors.

Polymers touch every aspect of our lives. The nylon toothbrush, the plastic bucket, or the polystyrene umbrella handle are all polymers. Knowingly or unknowingly, every individual today relies on polymers to meet his needs.

Though polymers are legion, sometimes they cannot fulfill the demand, depending on their properties. Improvements in polymers are tremendously important because they will widen the scope of application. There are two main approaches: construction of new molecules that are likely, from their molecular composition, to have the desired properties, and modification of properties of existing large-scale polymers.

Modification of polymers has received greater attention in light of the scarcity of starting materials required for the synthesis of new monomers to deliver better polymeric materials. In other words, modification is essential to meet various challenges, as it is very diffcult to get new polymers. The next generation awaits polymer modification as it opens up new possibilities. Surface and bulk properties can be improved easily by modifying conventional polymers. Sometimes, balancing of properties is needed, and this is possible only through modification of polymers.

Polymer modification is required to bring specific properties to the modified material, such as enhanced thermal stability, multiphase physical responses, compatibility, impact response, flexibility, and rigidity. Modifications make an insoluble polymer from a soluble one or vice versa. Thus polymer modification improves the processibility of the polymers. One of the recent directions regarding polymer modification is intended to avoid their nonbiodegradable nature.

We have already referred to giant molecules and indicated that they are very long molecular chains of carbon atoms, often literally “branched” like a tree or linked together crossways in various directions. These chains can be provided by nature, as in the case of cellulose, or are built up from single short molecules known as “monomers” by uniting them into a chain to give “polymers,” which is known as polymerization. When monomers of different kinds are united, the product is known as a “copolymer,” and the process of uniting different monomers is copolymerization. Depending on the alignment sequence of different monomers in a polymer chain, copolymers are diversified in their property profiles.

Copolymers with an alternate sequence of monomers are alternating copolymers, whereas random copolymers do not follow any definite sequence in alignment patterns of the constituent monomers. Rarely may we expect any property gain from such compositions. Block copolymers are composed of long sequences (blocks) of one monomer unit, covalently bound to sequences of unlike type. Depending upon the chemical nature of the monomers block copolymers may be di-, tri-, tetra-, or even multi-block.

Generally, blocks are spontaneously self-assembled into a diversity of mesophases with the size scale governed by the chain dimensions. Dissimilar blocks exist as microdomains and exert their properties in the system. Thus glassy microdomains serve to anchor rubbery segments permitting the material to be used as melt processable adhesives and rubbers, i.e., thermoplastic elastomers such as SBS or ABS. Block copolymerization is one of the keys to achieve polymeric products with the desired property profiles.

The prime techniques for polymer modifications are grafting, crosslinking, blending, and composite formation, which are all multicomponent polymer systems. Such materials have attracted considerable attention in the industrial field as they combine a variety of functional components in a single material. Micro- and macrophase separation directly affect the physical and chemical properties in such multicomponent polymers. Graft copolymers are branched macromolecules in which the branches are of a different type from the backbone. They have a variety of potential applications resulting from the wide range of properties available when different polymer chains are connected to form hybrid branched macromolecules.

Multidirectional chain extension of polymers leading to the formation of network structures may be defined as crosslinking and viewed as a stabilization process. Crosslinking may result either through the polymerization of monomers with functionality greater than 2 (by condensation mode) or by covalent bonding between preformed polymer molecules accomplished by irradiation, sulfur vulcanization, or miscellaneous chemical reactions. Crosslinking restricts chains from sliding past one another and generates elasticity in an amorphous polymer. It makes a polymer more resistant to heat, light, and other physical agencies, giving it a high degree of dimensional stability, mechanical strength, and chemical and solvent resistance. The effects of crosslinking on the physical properties of the polymers are primarily influenced by the degree of crosslinking, the regularity of the network formed, and the presence and absence of crystallinity in the polymer. For crystalline polymers there may be a reduction in crystallinity with a low degree of crosslinking as it hinders chain orientation, and the polymer may become softer, more elastic, and have a lower melting point. Crosslinking changes the local molecular packing and leads to a decrease in free volume. This is reflected in an enhancement of glass transition temperature. Improvement in creep behavior also results from crosslinking as it restricts the viscous flow. Hence for property synergism crosslinking is unavoidable in the present arena of polymers.

A macroscopically homogeneous mixture of two or more different polymers may be defined as a polymer blend. The blending of polymers provides a means of producing new materials, which combine the useful properties of all the constituents. Most of the polymers are immiscible. Hence the combination of two arbitrary polydispersed polymers (quasi-binary mixture) exhibits neither a true two-phase nor a single-phase structure. It may appear to have a two-phase morphological pattern whereby both phases contain a different and finite concentration of each polymer or it may have multiphase structure. In both the cases, no definite interface exists between the two adjacent phases. The relative concentration of the constituents in different phases depends upon their intensity of mixing and solubility parameters. The ultimate behavioral pattern of polyblends depends upon extent of phase separation, nature of the predominant phase, character of the dispersed phase, and interaction between the component polymers. Most useful blends have the characteristics of uniform dispersion, i.e., fine discrete particles of one component being uniformly dispersed through the matrix of the other component.

It would be advantageous if the size and size distribution of the domains of the dispersed phase remain practically unaltered over long periods of time, from the conditions of blending to the conditions under which the blend is to be performed. The two main objectives of making polymer blends are to maintain a proper cost performance ratio and reinforcement of properties, i.e., compensation of the demerits of a polymer by blending it with a second one that is rich in the aspects lagging in the initial one. The technology of blending is now advancing at a rapid pace. New blends are constantly being developed and characterized, and blends with metallocene resins, liquid crystal polymers, and biodegradable resins are now available. Blending technology is also proving to be of use in plastics recycling.

A composite, as its name suggests, is made by combining two or more dissimilar materials in such a way that the resultant material is endowed with properties superior to any of its components. These components neither take part in the chemical reaction nor do they dissolve or completely merge with one another. Nevertheless, they remain strongly bonded together while maintaining an interface between one another and act in concert to give a much improved performance. In polymer composites, polymers that are the major components contain different reinforcing materials such as glass fiber, carbon fiber, silica, or mica as minor components. Reinforcement results in increased tensile, flexural, compression, and impact strength; rigidity; size stability; fire retardancy; corrosion resistance; electrical properties; and processibility. Polymer composites have versatile applications from the construction sector to commodity materials.

The two predominant modes of polymer modifications—grafting and cross-linking—are primarily considered in this book. The basic theories and exploration of these techniques in different sectors of human life are described in the following chapters.