Foundations of High Performance Polymers

Properties, Performance, and Applications

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Abbas Hamrang, PhD
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Edited by

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Gennady E. Zaikov, DSc, and A. K. Haghi, PhD
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LIST OF ABBREVIATIONS

AcAc	Acetiylacetone
ACA	Amino caproic acid
AChE	Acetylcholinesterase
AFD	Average fiber diameter
ANN	Artificial neural network
ANOVA	Analysis of variance
APPh	Ammonium polyphosphate
BSSE	Basis superpositional error
CA	Contact angle
$CaCO_3$	Calcium carbonate
CB	Carbon black
CCD	Central composite design
c-di-GMP	3′, 5′-Cyclic diguanylate
CDS	Clinical Diagnostic Station
CF	Carbon fibers
CHT	Chitosan
CMC	Cell membrane complex
CNT	Carbon nanotubes
CVD	Chemical vapor deposition
DAcA	Diacetonealcohol
DAQ	Data acquisition
DD	Deacetylation degree
DGC	Diguanylate cyclase
DLS	Dynamic light scattering
DMF	Dimethylformamide
DSC	Differential scanning calorimetry
DWNT	Double-walled carbon nanotube
ECG	Electrocardiogram
ER	Epoxy resin
FS	Fine suspensions
GTP	Guanosine-5′-triphosphate
HDPE	High density polyethylene
HP	High pass
ICD	Implantable Cardioverter Defibrillator
LBM	Lattice Boltzmann method

LMC	Low-molecular compound
LMCS	Low molecular weight chitosan
LP	Low pass
MFD	Mean fiber diameter
MWNTs	Multi-walled carbon nanotubes
NS	Nanostructures
ODE	Ordinary differential equation
PAN	Polyacrylonitrile
PCL	Polycaprolactone
PCM	Polymeric composite materials
PEO	Polyethylene oxide
PEPA	Polyethylene polyamine
PP	Polypropylene
RI	Relative importance
RMSE	Root mean square errors
RSM	Response surface methodology
SDS	Sodium dodecyl sulfate
SDS-PAGE	SDS polyacrylamide gel electrophoresis
SEM	Scanning electron microscope
SI units	System International d'unites
StdFD	Standard deviation of fiber diameter
SWNTs	Single-walled carbon nanotubes
TiO_2	Titanium dioxide
UCM	Upper-convected Maxwell
WSN	Wireless Sensor Networks
ZPVE	Zero-point vibration energy

PREFACE

Polymers have a significant part in human existence. They have a role in every aspect of modern life, such as health care, food, information technology, transportation, energy industries, etc. The speed of developments within the polymer sector is phenomenal and at same time crucial to meet the demands of life today and in the future. Specific applications for polymers range from adhesives, coatings, painting, foams, and packaging to structural materials, composites, textiles, electronic and optical devices, biomaterials, and many other uses in industries and daily life. Polymers are the basis of natural and synthetic materials. They are macromolecules and in nature are the raw material for proteins and nucleic acids, which are essential for the human body.

Cellulose, wool, natural and synthetic rubber, and plastics are well-known examples of natural and synthetic types. Natural and synthetic polymers play a massive role in everyday life, and a life without polymers really does not exist.

Previously, it was believed that polymers could only be prepared through addition polymerization. The mechanism of the addition reaction was also unknown and hence there was no sound basis of proposing a structure for the polymers. Studies by researchers resulted in theorizing the condensation polymerization. This mechanism became well understood, and the structure of the resultant polyester could be specified with greater confidence.

In 1941/1942 the world witnessed the infancy of polyethylene terephthalate or better known as the polyester. A decade later for the first time polyester or cotton blends were introduced. In those days Terylene and Dacron (commercial names for polyester fibers) were miracle fibers but still overshadowed by nylon. Not many would have predicted that decades later, polyester would have become the world's inexpensive, general purpose fibers as well as becoming a premium fiber for special functions in engineering textiles, fashion, and many other technical end uses. From the time nylon and polyester were first used there have been an amazing technological advances that have made them so cheap to manufacture and widely available.

These developments have made the polymers such as polyesters contribute enormously in today's modern life. One of the most important applications is the furnishing sector (home, office, cars, aviation industry, etc.) which benefits hugely from the advances in technology. There are a number of requirements for a fabric to function in its chosen end use, for example, resistance to pilling and abrasion, as well as dimensional stability. Polyester is now an important part of upholstery fabrics. The shortcomings attributed to the fiber in its early days have mostly been overcome. Now it plays a significant part in improving the life-span of a fabric, as well as its dimensional stability, which is due to its heat-setting properties.

About half century has passed since synthetic leather, a composite material completely different from conventional ones, came to the market. Synthetic leather was originally developed for end-uses such as the upper of shoes. Gradually other uses such as clothing steadily increased the production of synthetic leather and suede. Synthetic leathers and suede have a continuous ultrafine porous structure comprising a three-dimensional entangled nonwoven fabric and an elastic material principally made of polyurethane. Polymeric materials consisting of the synthetic leathers are polyamide and polyethylene terephthalate for the fiber and polyurethanes with various soft segments, such as aliphatic polyesters, polyethers, and polycarbonates for the matrix.

New applications are being developed for polymers at a very fast rate all over the world at various research centers. Examples of these include electroactive polymers, nano products, robotics, etc. Electroactive polymers are special types of materials that can be used, for example, as artificial muscles and facial parts of robots or even in nano robots. These polymers change their shape when activated by electricity or even by chemicals. They are light weight but can bear a large force which is very useful when being utilized for artificial muscles. Electroactive polymers together with nanotubes can produce very strong actuators. Currently research works are carried out to combine various types of electroactive polymers with carbon nanotubes to make the optimal actuator. Carbon nanotubes are very strong, elastic, and they conduct electricity. When they are used as an