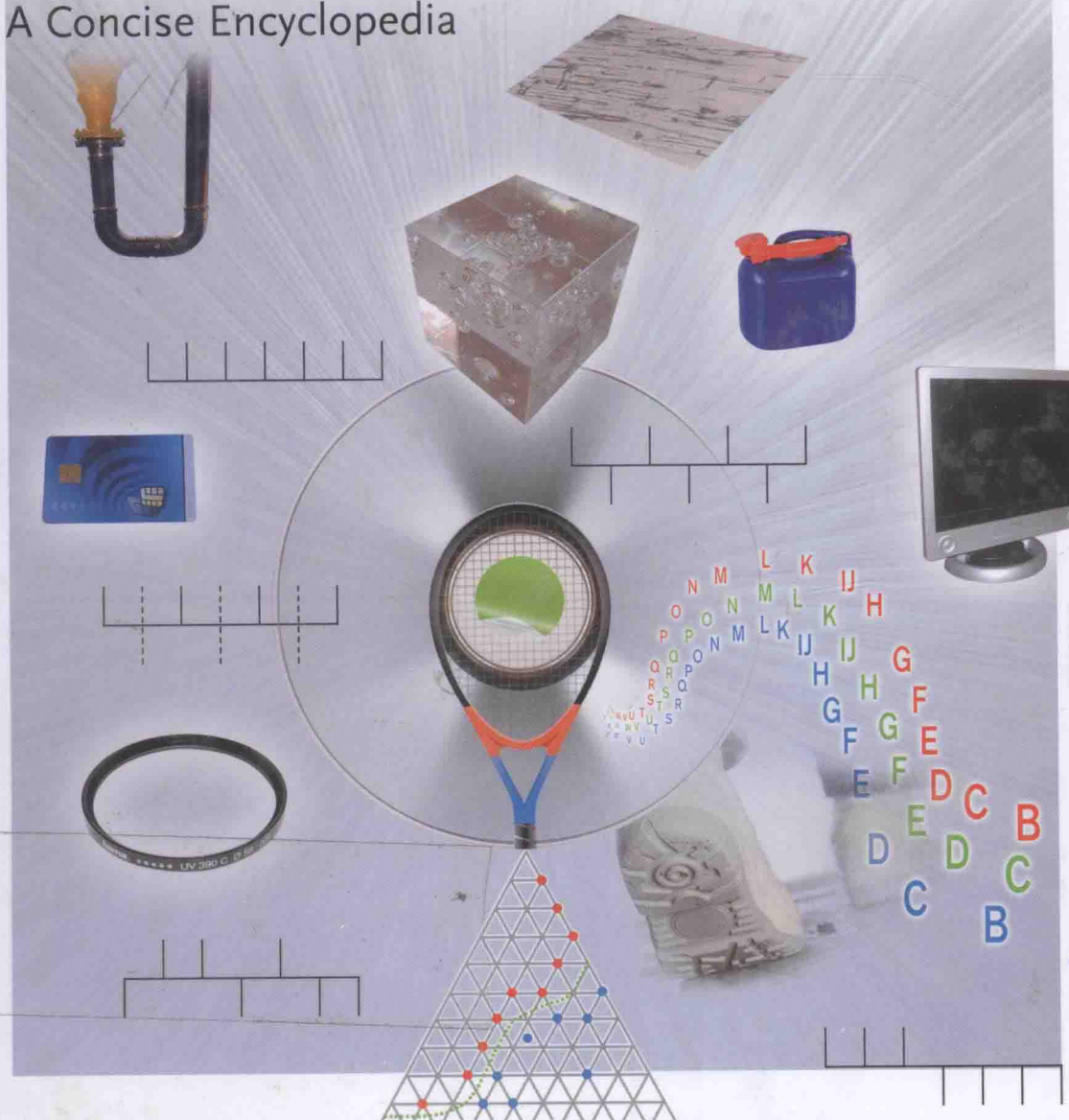
Leno Mascia

WILEY-VCH

Polymers in Industry from A-Z

A Concise Encyclopedia



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Dedication

To my grandchildren and their future

Preface

Polymers are a well-established class of materials both in the commercial sector and in educational curricula. Polymers are the main component of commercial products known as plastics, composites, rubber (or elastomers), surface coatings, fibres and adhesives.

Although many books have been published over the past 50 years or so to satisfy the demands of those concerned with the scientific and technological aspects of the subject, the author feels that there is a need for a reference text that can provide easy access to brief and concise information on the terminology, concepts, principles and industrial practice related to the constitution, manufacture and properties of polymer materials.

A compact encyclopaedia provides the easiest and most rapid route for retrieving both specific and general information about the subject of interest. This is particularly valuable when the reader is interested primarily in the basics of the subject.

Although the central focus of this book is on aspects concerned with the constitution, properties and processing of polymer-based materials, the treatment extends into related areas, including synthesis and characterization. The amount of information and details provided for each entry, therefore, varies according to the anticipated needs and interests of the potential reader within the core areas.

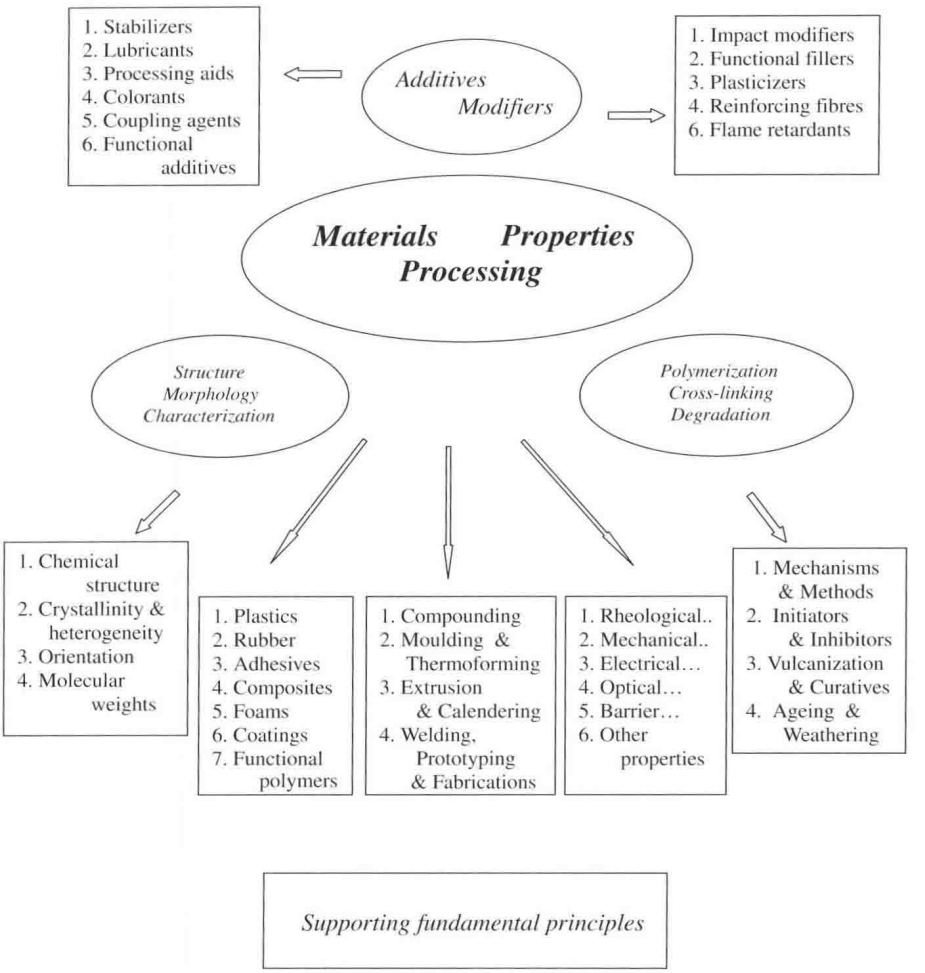
The contents covered by the text have been derived with the view that the field spans various disciplines and branches of industry and, therefore, the needs of the potential reader beyond the boundaries of these areas are served by complementary texts related to other sectors, such as the petrochemical industry and specific manufacturing concerns.

The information is presented in two sections. The main part of the book consists of an "A to Z encyclopaedic outline", which enables the reader to search directly for a particular topic or item of interest. This is complemented by the preliminary section "Overview" and "Search Guide", which should assist the reader to identify the specific topic or term for the search. All the terms that appear in the "Overview" and "Search Guide" are identified as individual entries in the main part of the book that follows, so that the reader can scan the entire field and select the topics and aspects of the subject that are of interest.

Acknowledgements

A book that covers such a wide field could not have been written without the contribution of very many authors over a large number of years. Although credit has been given to authors and publishers, there have been a few occasions where the original source could not be ascertained. Some of the diagrams used in the text have been taken from personal lecture notes produced as early as 1970. Many of these were extracted from the immensely rich literature provided by the industrial sector, whose identity was not recorded at the time. The author wishes to thank these anonymous contributors and hopes to be able to overcome any such deficiency in any future editions, if the required information is brought to his attention or is otherwise obtained.

Overview


1. Stabilizers
2. Lubricants
3. Processing aids
4. Colorants
5. Coupling agents
6. Functional additives
Additives
Modifiers
1. Impact modifiers
2. Functional fillers
3. Plasticizers
4. Reinforcing fibres
6. Flame retardants
Materials
Properties
Processing
Structure
Morphology
Characterization
Polymerization
Cross-linking
Degradation
1. Chemical structure
2. Crystallinity & heterogeneity
3. Orientation
4. Molecular weights
1. Plastics
2. Rubber
3. Adhesives
4. Composites
5. Foams
6. Coatings
7. Functional polymers
1. Compounding
2. Moulding & Thermoforming
3. Extrusion & Calendering
4. Welding, Prototyping & Fabrications
1. Rheological..
2. Mechanical..
3. Electrical...
4. Optical...
5. Barrier...
6. Other properties
1. Mechanisms & Methods
2. Initiators & Inhibitors
3. Vulcanization & Curatives
4. Ageing & Weathering
Supporting fundamental principles

Search Guide

1. Materials

1.1 Plastics

Thermoplastics

Acetals: Oxymethylene polymer, Polyoxymethylene, Poly(methylene oxide) (PMO)

Acrylics: Poly(methyl methacrylate) (PMMA), Methyl methacrylate–butadiene–styrene (MBS)

Barrier polymers: Phenoxy, Poly(vinylidene chloride) (PVDC), Ethylene–vinyl alcohol copolymer (EVOH)

Cellulosics: Cellulose acetate, Cellulose acetate butyrate, Cellulose nitrate, Cellulose propionate

Fluoropolymers: Perfluoropolymer (PFA), Polychlorotrifluoroethylene (PCTFE), Polytetrafluoroethylene (PTFE), Poly(tetrafluoroethylene–ethylene) copolymer (PETFE), Poly(tetrafluoroethylene–hexafluoropropylene) copolymer (FEP), Poly(vinylidene fluoride) (PVDF or PVF_2)

High-temperature polymers: Polybenzimidazole (PBI), Poly(ether ketone) (PEK), Poly (ether ether ketone) (PEEK), Polyketone, Poly (phenylene oxide) (PPO), Polysulfone (PSU), Poly(ether sulfone) (PES), Poly(phenylene sulfide) (PPS), Poly(ether imide) (PEI)

Polyamides: Nylon 6 (PA 6), Nylon 4,6 (PA 4,6), Nylon 6,6 (PA 6,6), Nylon 11 (PA 11), Nylon 12 (PA 12)

Polyesters: Caprolactone polymer (PLC), Poly(butylene terephthalate) (PBT), Polycarbonate (PC), Poly(ethylene terephthalate) (PET), Aromatic polyester

Polyolefins: Chlorinated polyethylene, Chlorosulfonated polyethylene, Coupled polypropylene, Ethylene–carbon monoxide copolymer (ECO), Ethylene–ethyl acrylate copolymer (EEA), Ethylene–methyl methacrylate copolymer (EMA), Ethylene–vinyl acetate copolymer (EVA), Ethenoid polymer, Polyethylene (LDPE, VLDPE, LLDPE, MDPE, HDPE, UHMWPE), Polypropylene (PP), Polybutene, Poly(4-methyl pent-1-ene)

Styrene polymers: Acrylonitrile–butadiene–styrene terpolymer (ABS), Acrylonitrile–acrylate–styrene terpolymer (ASA), High-impact polystyrene (HIPS), Polystyrene (PS), Styrene–acrylonitrile copolymer (SAN), Styrene–maleic anhydride copolymer (SMA)

Vinyl polymers: Chlorinated PVC, Poly (vinyl acetate) (PVAc), Poly(vinyl alcohol) (PVA), Poly(vinyl alkyl ether) (PVME), Poly(vinyl butyral), Poly(vinyl carbazole), Poly(vinyl chloride) (PVC, PVC-U), Poly (vinyl fluoride) (PVF), Polyvinylpyrridine, Polyvinylpyrrolidone

Thermosets

Amino resins: Melamine formaldehyde (MF), Urea formaldehyde (UF), Casein

Epoxy resins: Bisphenol-A (DGEBA), Cycloaliphatic, Epoxidized novolac resin, Tetraglycidoxylmethylene *p,p'*-diphenylene diamine (TGDM)

High-temperature resins: Cyanate ester, Diallyl phthalate, Furan resin, PMR, Polyimide, Polybismaleimide

Phenolics: Bakelite, Novolac, Resole

Unsaturated polyesters: Resins for composites, Bulk moulding compound (BMC), Sheet moulding compound (SMC), Vinyl ester

Other Aspects

Gel, Recycling, Polymer blend, Thermoreversible gel, Vitrification

1.2 Rubber

Vulcanized/Cross-Linked Elastomers

Acrylates: Ethylene–ethyl acrylate terpolymer elastomer (EAM)

Diene elastomers: Acrylonitrile–butadiene (NBR), Gutta percha, Natural rubber (NR), Polybutadiene (BR), Polychloroprene (CR), Polyisoprene (IR), Styrene–butadiene (SBR)

Fluoroelastomers: Hexafluoropropylene copolymer and terpolymer

Hydrocarbon (polyolefin) elastomers: Butyl rubber, Ethylene–propylene rubber (EPR), Ethylene–propylene–diene monomer rubber (EPDM), Chlorosulfonated polyethylene (CSM)

Silicone rubber: Polydimethylsiloxane (PDMS, VMQ), Fluorosilicone (FVMQ)

Other elastomers: Epichlorohydrin (ECO), Phosphazene elastomer, Polycarborane–siloxane, Polyurethanes (PUR)

Thermoplastic Elastomers (TPE)

Block copolymers: Styrene–butadiene–styrene (SBS), Styrene–ethylene/butylene–styrene (S-EB-S), Styrene–isoprene–styrene (SIB), Poly(butylene terephthalate-*b*-tetramethylene oxide) (TPE-E), Poly(amide-*g*-alkylene oxide) (TPE-A), Poly(urethane-*g*-ester/alkylene oxide) (TPU)

Dynamic vulcanizates: Thermoplastic polyolefin (TPO), Plasticized PVC/NBR blend, NR/EPR blend

Other Aspects

Coagulum, Crepe, Fluidized bed, Latex, Mastication, Microwaving, Vulcanizate

1.3 Adhesives

Hot Melts

Ethylene–vinyl acetate copolymer (EVA), Ethylene–ethyl acrylate copolymer (EEA), Polyamide, Polyester, Phenoxy

Curable Adhesives

Acrylic, Cyanoacrylate, Epoxy, Phenolic

Water-Borne

Poly(vinyl acetate), Styrene–butadiene copolymer (SBR), Poly(ethylene–vinyl acetate) copolymer (VAE)

Pressure-Sensitive Adhesive

Elastomer, Tackifier

Other Aspects

Adherend, Adhesive test, Adhesive wetting, Anodizing, Debonding, Cold plasma, Corona discharge, Critical surface energy, Critical wetting tension, Joint, Lap shear, Pot life, Tack, Work of adhesion

1.4 Composites

Fibre Reinforcement

Continuous fibres: Aramid fibre, Carbon fibre, Glass fibre, Graphite fibre

Short fibres: Asbestos, Carbon fibre, Chopped strand mat laminate (CSM), Glass fibre

Particulate Reinforcement

Fillers: Barite, Bentonite, Calcium carbonate, Carbon black, Channel black, Clay, Fumed silica, Functional filler, Glass flake, Kaolin, Mica, Quartz, Titania

Nanofillers: Carbon nanotube, Exfoliation, Montmorillonite, Nanoclay

Fire retardant and Antitracking: Aluminium trihydrate, Antimony oxide, Magnesium hydroxide, Molybdenum oxide

Other fillers: Bioactive filler, Magnetic filler, Molybdenum disulfide, Metal powder

Matrix

Thermosets: Unsaturated polyester, Epoxy resin, Phenolic, Cyanoacrylate, PMR, Polyimide

Thermoplastics: Coupled polypropylene, Polyamide, Poly(ether ketone), Poly(ether imide), Poly(phenylene sulfide)

Nanocomposites

Ceramer, Exfoliated nanocomposite, Organic modified filler, Organic–inorganic hybrid

Other Aspects

Debonding, BET isotherm, Commingled fibre, Composite manufacture, Composite

property prediction (Reinforcement theory), Composite test, Coupling agent, Critical fibre length, Gel coat, Graphene, Exfoliation, Intercalation, Ion exchange capacity (IEC), Interfacial bonding, Laminate, Low profile additive, Modulus enhancement factor, Oil absorption, Prepreg, Reinforcement factor, Size, Sizing/Finishing, Zeta potential

1.5 Foams

Aspects

Closed cell, Foam density and properties, Foam formation mechanism, Foam manufacture, Open cell, Structural foam, Syntactic foam

1.6 Coatings

Ac Curable Varnishes

Acrylic, Alkyd, Drying resin, Epoxide, Phenolic, Urethane

Water-Borne Dispersions

Microemulsions: Polyurethane, Epoxide

Polymer emulsions: Poly(vinyl acetate), Acrylic

Powders

Curable thermosetting systems: Epoxide, Poly (ester–epoxide), Polyurethane

Thermoplastic powders: Polyester, Acrylic

Other Aspects

Anodizing, Blistering, Cold plasma, Contact angle, Critical surface energy, Critical wetting tension, Dip coating, Electrolytic deposition, Electrostatic spraying, Film formation, Metallization, Gel coat, Intumescent coating, Pinhole, Plating, Pot life, Primer, Roughness factor, Sputtering, Surface energy, Work of adhesion, Zisman plot

1.7 Functional Polymers

Biopolymers

Chitin, Chitosan, Ester–amide polymer, Ethylene–carbon monoxide copolymer (ECO), Poly(lactic acid), Polylactide, Oxo-biodegradable polymer, Poly(hydroxy alkanoate), Poly (hydroxy butyrate), Polypeptide, Polysaccharide, Starch

Conductive Polymers

Polyacetylene, Polyaniline (PANI), Polypyrrole

Ionomeric Polymers

Ionomer, Ion exchange resin, Nafion, Polyelectrolyte

Other Aspects

Cross-linked thermoplastic, Dendrimer, Doping, Engineering polymer, Heat-shrinkable product, Light-sensitive polymer, Liquid-crystal polymer, Shape memory polymer, Nonlinear dielectric polymer, Piezoelectric polymer, Photoresist, Poly (amic acid), PTC polymer, Spandex fibre

2. Properties

2.1 Rheological properties

Rheology

Barus effect, Bingham body, Carreau model, Complex viscosity, Consistency index, Converging flow, Couette flow, Deborah number, Deformational behaviour, Die swell, Dilatant fluid, Drag flow, Elongational flow, Elongation rate, Elongational viscosity, Ellis equation, Extension viscosity, G' and G'', Gel time (gel point), Melt elasticity, Mooney equation, Newtonian behaviour, Non-Newtonian behaviour, Normal stress difference, First normal stress coefficient, Plug flow, Power law, Power-law index, Thixotropy, Trouton viscosity, True shear rate, True viscosity, Viscosity, Zero-shear viscosity

Rheometry

Bagley correction, Brookfield viscometer, Capillary rheometer, Cone-and-plate rhe-

ometer, Coaxial cylinder rheometer, Die-exit phenomena, Dynamic (oscillatory) flow, Gelation, Entry effect, Melt flow index (Melt flow rate), Melt fracture, Melt strength, Monsanto rheometer, Mooney viscometer, Parallel-plate rheometer, *PVT* diagram, Rabinowitsch correction, Sharkskin, Slip analysis, Slit rheometer, Torque rheometer, Weissenberg rheogoniometer

Other Aspects

Critical chain length (Z_c), Deformational behaviour, Entanglement, Flow curve, Mark–Huggins equation, Radius of gyration, Reptation, Rubbery state, Viscous state

2.2 Mechanical Properties

Elasticity and Viscoelasticity

Bulk modulus, Compliance, Complex compliance, Complex modulus, Creep, Creep compliance, Creep curves, Creep modulus, Creep period, Damping factor, Deflection under load temperature, Deformational behaviour, Dynamic mechanical spectra, Effective modulus, Elasticity, Elastic behaviour, Elastic memory, Elastic recovery, Flexural modulus, Force–deflection curve, Force–deformation curve, Force–extension curve, Heat distortion temperature (HDT), Hundred-percent (100%) modulus, Kelvin–Voigt model, Load–deflection curve, Load–deformation curve, Load–extension curve, Loss angle, Loss compliance, Loss factor, Loss modulus, Loss tangent, Master curve, Maxwell model, Modulus, M_{100} and M_{300}, Nonlinear viscoelastic behaviour, Phase angle, Recovery, Recoverable strain, Reduced time, Relaxation time, Retardation time, Relaxation modulus, Relaxed modulus, Rubber elasticity, Shear modulus, Shift factor, Standard linear solid model, Tan δ, Tangent modulus, Tensile modulus, Time-dependent modulus, Time–temperature superposition, Viscoelastic behaviour, Voigt model, Young's modulus

Failure and Fracture

a/W ratio, Brittle fracture, Brittle point, Brittle strength, Brittle–tough transition, Cold-flex temperature, Cold flow, Compression set, Crack initiation, Crack length, Crack opening displacement (COD), Crazing, Creep rupture, Critical crazing strain, Critical strain energy release rate (G_c), Critical stress intensity factor (K_c), Ductile, Ductile–brittle transition, Ductile failure, Environmental stress cracking, Fatigue life, Flex cracking, Flex life, Flexural strength, Fracture mechanics, Griffith's equation, Impact strength, Interlaminar shear strength (ILSS), J-integral, Lüder lines, Notch sensitivity, Peel strength, Permanent set, Plastic deformation, Tear strength, Tenacity, Tresca criterion, Von Mises criterion, Yield criteria, Yield failure, Yield point, Yield strength, Young's modulus

Test Methods

Ball drop, Bending test, Charpy impact test, Compression test, Creep test, Dilatometer, Dumb-bell specimen, Dynamic mechanical analysis (DMA), Dynamic mechanical thermal analysis (DMTA), Extensometer, Falling-weight impact test, Fatigue test, Fracture test, Impact test, Izod impact test, Mechanical spectroscopy, Microhardness, Notch, Peel test, Pendulum impact test, Rubber elasticity, Tensile test, Viscoelasticity

Other Aspects

Abrasion resistance, Anisotropy, Boltzmann superposition principle, Compression, Compact tension specimen, Damage tolerance, Damping, Deformation, Delamination, Distribution of relaxation times, Distribution of retardation times, Dynamic mechanical spectra, Flexural properties, Friction coefficient, Hardness, Hydrostatic stress, Life prediction, Load, Microvoid, Poisson's ratio, Rockwell hardness, Rubbery state, Shear stress, Shore hardness,

Stiffness, Strain, Strain rate, Stress, Stress concentration, Tack, Transmissibility, Tensor, Torque, Torsion pendulum, Toughness, Vicat softening point, Vickers hardness, Volumetric strain

2.3 Electrical Properties

Low Voltage

Capacitance, Clausius–Mossotti equation, Complex permittivity, Conductance, Conductivity, Corona discharge, Current density, Dielectric, Dielectric constant, Dielectric properties, Dielectric thermal analysis (DETA), Direct current, Electrostatic charge, Loss angle, Loss factor, Loss tangent, Permittivity, Polarization, Resistivity, Specific impedance, Stress concentration, Surface resistivity, Tan δ, Volume resistivity

High Voltage

Breakdown voltage, Comparative tracking index (CTI), Dielectric strength, Dry band, Electrical failure, Electric strength, Tracking

Other Aspects

Dipole, Electronic conductivity, Electrostatic charge, Ionic conductivity, Polarity, Stress grading, Nonlinear dielectric, PTC polymer

2.4 Optical Properties

Aspects

Backscatter, Birefringence, CIE chromaticity diagram, Colour, Colour matching, Direct reflection factor, Extinction index, Forward scatter, Gloss, Haze, Light microscopy, Light scattering, Light transmission factor, Optical brightener, Optical microscopy, Optical path difference, Orientation, Photoelasticity, Reflection factor, Refractive index, See-through clarity, Stress optical coefficient, Transparency

2.5 Barrier Properties

Aspects

Diffusion, Diffusion coefficient, Fickian behaviour, Permeability, Solubility, Time lag

2.6 Other Properties

Types

Acoustic: Attenuation, Loss factor

Fire resistance: Cone calorimeter, Flash point, Limiting oxygen index, Pyrolysis, Self-extinguishing, Thermal gravimetric analysis

Thermal properties: Dilatometer, Dilatation coefficient, Thermal conductivity, Thermal expansion coefficient

3. Processing

3.1 Compounding

Aspects

Banbury mixer, Decompression zone, Devolatilization, Dispersion, Dispersive mixing, Dry blend, Formulation, Master batch, Melting, Miscibility, Mixing, Mixer, Pelletizer, Plastication, Plastograph, Purging, Reciprocating screw mixer, Thermal degradation, Torque rheometer, Twin-screw extruder

3.2 Moulding and Thermoforming

Machine and Moulds

Clamping force, Clamping system, Ejection mechanism, Film gate, Gate, Hot runner mould, Locking mechanism, Mould design, Nozzle, Nylon screw, Reciprocating screw, Runner, Sprue, Stripper plate

Operations

Air-slip forming, Blow moulding, Cavity filling, Cavity packing, Compression moulding, Co-injection moulding, Drape forming, Injection blow moulding, Injection moulding, Plastication, Plug-assisted vacuum forming, Purging, Reaction moulding, Reaction processing, Resin transfer moulding, Rotational moulding, Stretch blow moulding, Thermoforming, Transfer moulding, Vacuum forming

Other Aspects

Back-pressure, Demoulding, Distortion and Warping, Flash, Gel coat, Internal stress, Moulding cycle, Moulding defect, Pre-form, *PVT* diagram, Residual stress, Sink mark, Spiral flow moulding, Void, Weld line

3.3 Extrusion and Calendering

Extruder

Barrel, Barrier flights screw, Co-rotating, Counter-rotating, Decompression zone, Devolatilization, Extruder screw, Gear pump, Nylon screw, Twin-screw extruder

Extrusion Dies

Die gap, Die lip, Fish-tail die, Land length, Sizing die, Spider leg, Mandrel

Other Aspects

Adiabatic heating, Back-flow, Blocking, Blow-up ratio, Blown film, Breaker plate, Calender, Cambering (Roll crowning), Chill-roll casting, Co-extrusion, Crow feet, Extrusion theory, Die analysis, Die drool, Drag flow, Draw ratio, Drawdown ratio, Extrudate, Fish eye, Flow analysis, Flow instability, Foam extrusion, Lamination, Leakage flow, Parison, Plastication, Plate out, Pressure flow, Purging, Screw–die interaction, Surging, Tubular film, Weld line

3.4 Welding, Prototyping and Fabrications

Hot-plate welding, Friction welding, High-frequency welding, Ultrasonic welding, Rapid prototyping, Stereolithography, Casting, Machining, Powder sintering, Tyre construction

4. Structure, Morphology and Characterization

4.1 Chemical Structure

Acid number, Aliphatic, Atactic, Attenuated total reflectance spectroscopy, Block copolymer, Carbonyl index, Chain configuration, Chain regularity, Chain stiffness, Chemical shift, Configuration, Conformation, Conjugated double bond, Coordination, Copolymer, Critical chain length, Cross-link, Degree of cross-linking, Degree of polymerization, Dendrimer, Electron spin resonance, Electron spectroscopy for chemical analysis (ESCA), Free radical, Fluorescence, Functionality, Head-to-head, Head-to-tail, Heterochain, Hydrogen bond, Hydrophilic, Hydrophobic, Hydroxyl equivalent (number), Hygroscopic, Hyperbranched polymer, Infrared spectroscopy (IR, FTIR), Interpenetrating polymer network (IPN), Isotactic, Network, Non-polar polymer, Oligomer, Orientation, Oxirane ring, Polarity, Quinone structure, Radiation, Radical, Radius of gyration, Raman spectroscopy, Random copolymer, Side group, Spectroscopy, Spectrum, Syndiotactic, Tacticity, UV spectroscopy, X-ray, X-ray photoelectron microscopy (XPS)

4.2 Crystallinity and Heterogeneity

Amorphous polymer, Atomic force microscopy (AFM), Birefringence, Chain folding, Cluster, Cold crystallization, Colloidal, Co-continuous domain, Core and shell, Crystalline polymer, Crystallization, Degree of crystallinity, Dielectric thermal analysis (DETA), Differential scanning calorimetry (DSC), Differential thermal analysis (DTA), Dynamic mechanical thermal analysis (DMA, DMTA), Exfoliation, Emulsion, First-order transition, Fractal, Fringe micelle, Intercalation, Lamella, Light microscopy, Light scattering, Melting point, Microscopy, Microcavitation, Microemulsion, Microvoid, Optical microscopy, Scanning electron microscope, Secondary crystallization, Shish-kebab crystal, Small-angle X-ray scattering (SAXS), Spherulite, Transmission electron microscopy (TEM), Unit cell, Wide-angle X-ray diffraction (WAXS), X-ray

4.3 Orientation

Anisotropy, Annealing, Biaxial, Birefringence, Draw ratio, Extension ratio, Fibre, Heat setting

Heat-shrinkable polymer, Monoaxial, Monofilament, Optical path difference, Orientation function, Wide-angle X-ray diffraction (WAXS)

4.4 Molecular weights

Dispersity index, Distribution of molecular weight, Gel permeation chromatography, Huggins' constant, Intrinsic viscosity, Molar mass, Molecular weight, Monodisperse, Measurement of molecular weight, Mark–Houwink equation, Number-average molecular weight, Osmotic pressure, Osmometry, Relative viscosity, Weight-average molecular weight, Size exclusion chromatography, Staudinger, Ubbelohde viscometer, Viscometer, Viscosity

5. Polymerization Cross-linking and Degradation

5.1 Initiators, Inhibitors and Vulcanization

Accelerator, Activator, Cobalt naphthanate and octoate, Co-agent, Cure time, Curing, Efficient vulcanization, Fatty acid, Kicker, Mechanical degradation, Mercaptan, Microwaving, Peroxide, Photoinitiator, Post-curing, Scorch time, Retarder, Thiouram, Zinc oxide

5.2 Polymerization and Cross-Linking

Mechanisms

Addition polymerization, Anionic polymerization, Cationic polymerization, Chain stopper, Condensation reaction, Condensation polymerization, Copolymerization, Depolymerization, DMP-30, Free-radical polymerization, Ionic polymerization, Metallocene catalysis, Propagation reaction, Reactivity ratio, Termination reaction, Ziegler catalyst, Ziegler–Natta catalyst

Methods

Bulk polymerization, Electron beaming, Emulsion polymerization, Heterophase or Heterogeneous polymerization, Mass polymerization, Mechanical degradation, Phase inversion, Photopolymerization, Radiation processing, Reaction processing, Seed polymerization, Solid-state polymerization, Surfactant, Suspension polymerization

5.3 Ageing and Weathering

Depolymerization, Chalking, Chain scission, Composting, Environmental ageing, Fogging, Hydrolysis, Induction time, Life cycle analysis, Life prediction, Ozone, Physical ageing, Propagation reaction, Radiation, Recycling, Secondary crystallization, Solar radiation, Thermal degradation, Ultraviolet (UV) light, UV degradation, Xenon arc lamp, Yellowness index

6. Additives and Modifiers

6.1 Additives

Stabilizers

Antidegradant, Antioxidant, Antiozonant, Chelating agent, Excited state quencher, Hindered amine light stabilizer (HALS), Hindered phenol, Hydrolysis stabilizer, Lead stabilizer, Metal deactivator, Phenolic antioxidant, Primary stabilizer, Processing stabilizer, Radical scavenger, UV stabilizer

Lubricants and Processing Aids

Antiblocking agent, Antifoaming agent, Blocking, Cationic surfactant, External lubricant, Factice, Flow promoter, Fusion promoter, Internal lubricant, Low-profile additive, Lubricant, Peptizer, Stearate, Stearic acid, Tackifier, Thickener, Thixotropic agent

Colorants
Anatase, CIE chromaticity diagram, Dye, Mineral pigment, Pigment, Rutile, Thermochromic pigment

Coupling Agents
Compatibilizing agent, Interfacial bonding, Silane, Size (Sizing), Surfactant

Functional Additives
Antifoaming agent, Antimicrobial (biocidal) agent, Antistatic agent, Antitracking additive, Blowing agent, Flocculant, Fungicide, Nucleating agent

Other Aspects
Additive concentrate, Compounding, Fogging, Law of mixtures, Master batch, Miscibility, Mixing, Solubility parameter, Stabilization, Synergism

6.2 Property Modifiers

Fire (Flame) Retardants
Aluminium trihydrate, Antimony oxide, Brominated compound, Chlorinated fire retardant, Magnesium hydroxide, Molybdenum oxide

Impact Modifiers
Acrylonitrile–butadiene–styrene terpolymer (ABS), Amine-terminated acrylonitrile–butadiene–styrene terpolymer (ATBN), Carboxylic acid-terminated acrylonitrile–butadiene–styrene terpolymer (CTBN), Methacrylate–butadiene–styrene terpolymer (MBS), Liquid rubber, Polymer alloy, Polymer blend, Telechelic oligomer

Functional Fillers
Barite, Bioactive filler, Carbon black, Carbon nanotube, Magnetic filler, Metal powder

Plasticizers
Epoxidized soya-bean oil, Extender, Low-temperature plasticizer, Non-migratory plasticizer, Organosol, Primary plasticizer, Reactive diluent, Secondary plasticizer

Reinforcing Fibres
Glass fibre, Carbon fibre (Acrylic fibre), Aramid fibre

Other Aspects
Antiplasticization, Cold-flex temperature, Compatibility, Glass transition temperature, Internal plasticization, Lower critical solution temperature (LCST), Miscibility, Mixing, Plasticization, Plastisol, Solubility parameter, Upper critical solution temperature (UCST)

7. Supporting Fundamental Principles and Terminology

Absorbance, Activation energy, Activation volume, Alpha transition, Alternating current, Aprotic polar solvent, Arrhenius equation, Beer–Lambert law, Beta transition, Boundary condition, Case II diffusion, Cluster, Cohesive energy density, Cold plasma, Colligative properties, Colloidal, Conformation, Configuration, Conservation law, Continuum mechanics, Coordination, Current density, Deconvolution, Direct current, Elasticity, Electromagnetic radiation, Empirical, Endothermic, Engineering design, Enthalpy, Entropy, Exothermic, Extinction coefficient, Fickian behaviour, First-order transition, Fluorescence, Fractal, Fractography, Free radical, Fundamental property, Gibbs free energy, Hooke's law, Hydrogen bond, Hydrolysis, Hydrophilic, Hydrophobic, Hydrostatic pressure, Hydrostatic stress, Hydrothermal stress, Hygroscopic, Induction time, Insulation, Interaction, Interfacial polarization, Intermolecular, Internal energy, Intramolecular, Isothermal, Isotropic, Law of mixtures, Linear behaviour, Linear elastic, Lower bound, Lubrication approximation, Melting point, Modulus, Momentum, Momentum equation, Morphology, Non-destructive test,