

2 Types of Reactive Polymers Used in Blending

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Blending of immiscible polymers offers attractive opportunities for developing new materials with useful combinations of properties. However, simple blends often have poor mechanical properties and unstable morphologies. Compatibilization of such blends is necessary. Preformed graft or block copolymers have been traditionally added to act as compatibilizers. Another route, however, is to generate these copolymer compatibilizers “in-situ” during melt blending using functionalized polymers. In this review, a variety of reactive polymers that have been utilized in the reactive compatibilization of polymer blends is examined. They are classified into eight major categories according to the types of reactive functionality and the characteristics of blending reactions, namely, maleic anhydride, carboxylic acids, groups capable of interchange reactions, primary and secondary amines, hydroxyl groups, heterocyclic groups, groups capable of ionic bonding, and others. Their preparation methods and applications, and the chemical reactions they undergo during melt blending are presented.

2.1 Introduction

There is intense commercial interest in multiphase polymer blends or alloys because of the potential opportunities for combining the attractive features of several materials into one, or to improve deficient characteristics of a particular material including recycled plastics [1–9]. However, most blends are immiscible and have poor physical properties compared to their components. This problem is rooted in the lack of favorable interaction between blend phases. This leads to a large interfacial tension between the components in the blend melt which makes it difficult to deform the dispersed phase of a blend during mixing and to resist phase coalescence during subsequent processing. It also leads to poor interfacial adhesion in the solid state which frequently causes premature mechanical failure, depending on the nature of the applied stress and the failure mechanism.

Morphology and interfacial adhesion can be improved by the addition of suitable block or graft copolymers that act as interfacial agents. These block or graft copolymers can, in principle, be made separately and then added to polymer blends. However, due to the lack of economically viable routes for the synthesis of suitable copolymers for important systems, compatibilization by preformed copolymers has not been used as extensively as the potential utility might suggest. A more proactive alternative is to generate these copolymers *in situ* during the blend preparation through polymer-polymer grafting reactions using functionalized polymers.

In this chapter general strategies for the compatibilization of polymer blends and the functionalization of polymers are briefly reviewed, which is followed by a detailed summary of a variety of reactive polymers, the chemical reactions they undergo, and their applications.

2.2 Compatibility in Polymer Blends

2.2.1 Basic Concepts

There are two widely useful types of polymer blends: miscible and immiscible [3, 5, 10–12]. Miscible blends involve thermodynamic solubility and are characterized by the presence of one phase and a single glass transition temperature. Their properties can often be predicted from the composition weighted average of the properties of the individual components. Immiscible blends are phase separated, exhibiting the glass transition temperatures and/or melting temperatures of each blend component. Their overall performance depends on the properties of the individual components, but also depends significantly on the morphology of the blends and the interfacial properties between the blend phases. Performance is not easily predictable. In order to achieve miscibility in polymer blends, a negative free energy of mixing must exist which, in turn, requires an exothermic heat of mixing, because entropic contributions are negligible. An exothermic heat of mixing may be achieved by the introduction of specific interactions between blend components. The potentially useful specific interactions range from strong covalent and ionic bonding to nonbonding weak interactions such as hydrogen bonding, ion-dipole, dipole-dipole, and donor-acceptor interactions, etc.

Few polymer pairs form miscible blends. One of the infrequent examples is the commercially important PPE/PS blend. Most polymers, however, are immiscible. But immiscibility is not always a bad thing. Blends do not have to be miscible to be useful. HIPS and ABS have proven the importance of phase separation. The key to make successful blends of this kind is the use of compatibilization to control morphology. Compatibilization is the result of a process or technique for improving blend performance by making blend components less immiscible. Compatibilized blends are termed “compatible blends” and characterized by the presence of a finely dispersed phase, good adhesion between blend phases, strong resistance to phase coalescence, and technologically desirable properties [3]. Compatible blends constitute the majority of commercially important blends. The compatibility of these blends may vary widely from one system to another. Compatibility is a measurement of polymer blend immiscibility at chosen scales and criteria.

2.2.2 Strategies for Blend Compatibilization

There are several methods of compatibilizing immiscible blends, including compatibilization by the introduction of non-reactive graft or block copolymers, non-bonding specific interactions, low molecular weight coupling agents, and reactive polymers.

2.2.2.1 *Addition of Block and Graft Copolymers*

Suitable block and graft copolymers can be used as compatibilizers for polymer blends. A suitable block or graft copolymer contains a segment miscible with one blend component and another segment with the other blend component. The copolymer segments are not

necessarily identical with the respective blend components. Significant amounts of the copolymer are expected to locate at the interface between immiscible blend phases, reducing the interfacial tension between blend components, reducing the resistance to minor phase breakup during melt mixing thus reducing the size of the dispersed phase, and stabilizing the dispersion against coalescence. The finer morphology and the increased interfacial adhesion usually result in improved physical properties. The effects of a copolymer on the morphology of polymer blends, interfacial adhesion between blend phases, and blend properties depend on such parameters as the type and molecular weight of the copolymer segments, blend compositions, blending conditions, etc.; which have been the subject of several recent reviews [13–20].

2.2.2.2 *Utilization of Non-Bonding Specific Interactions*

Non-bonding specific interactions like hydrogen bonding, ion-dipole, dipole-dipole, donor-acceptor, and π -electron interactions are useful for enhancing the compatibility of polymer blends. There have been reviews [21–25] on the role of these interactions on blend miscibility. Typical examples that illustrate the importance of specific interactions in enhancing compatibility in polymer blends include hydrogen bonding interactions in the blends of poly(ethylene-co-vinyl acetate-co-carbomonoxyde), poly(alkylene oxide), polyacrylates, poly(vinyl acetate), or polyesters with PVC, poly(alkylene oxide) with poly(acrylic acid); ion-dipole interactions in PS ionomer/poly(alkylene oxide); dipole-dipole interactions in the blends of poly(vinyl acetate) or polyacrylates with poly(vinylidene fluoride); and donor-acceptor interactions in the blend of poly[w-(3,5-dinitrobenzoyl)-hydroxy-alkylmethacrylate] with poly[2-(N-carbazoyl)ethyl methacrylate]. Generally, however, these specific interactions are weak and high concentrations, e.g., one interacting group per repeating unit, are often required for effective compatibilization. In other words, polymers capable of these specific interactions cannot, generally, be added only in small quantities into immiscible blends to achieve compatibilization. The addition of large quantities may change the properties of the desired phase constituents and/or be uneconomical.

2.2.2.3 *Addition of Low Molecular Weight Coupling Agents*

Addition of low molecular weight reactive compounds may serve the purpose of compatibilization of polymer blends through copolymer formation. Reports on compatibilization by addition of low molecular weight coupling agents have increased greatly in the past years. Recent examples of interest in this category include the compatibilization of PPS/PET [26], PA/PPE [27], PET/PPE [28] blends by bis(2-oxazolines); PE/PP [29–31], PS/PE [32–36], PS/EPDM [37], HIPS/PP [38], PP/PA [39], PE/PA [40–41] blends by peroxides and coagents, PBT/PA66 [42–43], PA6/PPE [44–45], PET/LCP [46–47], PET/PA6 [48], PET/PPE [49], PET/EVAL [50] blends by multifunctional epoxy monomers; PPE/PA6,6 blends by organosilanes [51–52], PE/PS blends by aluminum chloride [53–54], PBT/PE blends by bismaleimide [55], and PA6/TPU blends by methylenedi-phenylenediisocyanate [56]. This class of coupling agent is discussed in more detail in Chapter 9.

2.2.2.4 Reactive Compatibilization

Graft or block copolymers acting as compatibilizers for polymer blends can be formed *in situ* through covalent or ionic bonding during the melt blending of suitably functionalized polymers [57–69]. In this kind of reactive compatibilization, generally, one phase contains reactive groups inherent in the polymer, while the other has no inherent functionality. Reactive groups can be incorporated into the second phase by adding to it a functionalized polymer miscible. In some cases, both phases may have to be functionalized. The *in situ* formed copolymer compatibilizers are located preferentially at the interface where they are most needed, reducing the size of the dispersed phase, improving the interfacial adhesion between blend phases and the physical properties of the blends. *In situ* reactive compatibilization has already been implemented in a number of commercial products and, in many instances, appears to be the method of choice for compatibilization. The concepts involved are discussed in Chapter 3.

In the following sections of this chapter, the types of reactive polymers, their preparation methods, the chemical reactions they undergo during blending, and their applications are presented.

2.3 Preparation of Reactive Polymers

A required reactive group can be incorporated into a polymer by

- a. incorporation into the backbone, side chain, and at chain ends as a natural result of polymerization;
- b. copolymerization of monomers containing the desired reactive groups; and
- c. chemical modification of a preformed polymer through a variety of chemical reactions.

Each of these approaches has its own advantages and disadvantages. Although polymerization and copolymerization can, in theory, offer an almost unlimited number of different products by variations in the architecture of the polymer and in the nature and relative amounts of comonomer units in copolymerization, they require new processes, usually polymerization. From a practical and industrial standpoint, this is less favorable. Chemical modification of preformed polymers, particularly in the melt, tends to be a more attractive technique for its apparent simplicity and cost effectiveness. It has been used extensively to modify polymers for various technological applications, including polymer blends and alloys.

The chemical modification of polymers may be carried out in solution, in the melt, or even in the solid state. However, the modification of polymers during a melt processing step has several advantages and is increasing rapidly. First of all, a solution process is eliminated, thus reducing costs associated with solvent removal, recovery, and losses. Secondly, melt processing reduces the likelihood of contamination of final products. Also, polymer processors can use in-place equipment. Furthermore, the use of an extruder as continuous reactor/processor for the modification of polymers offers additional advantages including good temperature control and pumping efficiency over a wide viscosity range and the economic savings achieved by integrating several discrete operations within a single processing device [70–74].

Table 2.1 lists a number of examples of reactive polymers obtained by different preparation methods. Condensation polymers normally have potentially reactive groups inherent in the backbone and at the chain ends. For instance, polyamides have carboxylic acid and/or amine end groups and amide groups in the backbone; polyesters have carboxylic acid and/or hydroxyl end groups and backbone ester groups. Some addition

Table 2.1 Examples of Different Preparation Methods for Reactive Polymers

Preparation methods	Examples	Remarks
<i>Polymerization</i>		
Terminal groups	COOH on polyamides, polyesters OH on polyesters, polycarbonates polysulfones and phenoxy NH ₂ on polyamides	Inherent in condensation polymers
Backbone structure	-C(=O)-O in polyesters, polycarbonates etc. C(=O)-NH- in polyamides	Inherent in condensation polymers
Side chain structure	-C(=O)-O in poly(meth)acrylates, PVAc -C=C- in EPDM, PB Cl- in PVC	Mainly for addition polymers
<i>Copolymerization</i>		
	MAN with PS, PE, SAN, AC AA with PE, PS, NBR, ABS, AC; MAA with PE GMA with PS, PE, SAN, AC, core-shell Vinyl oxazoline with PS, SAN Maleate with PET, methacrylate with PE Vinylpyridine and tertiary amine with PS	For both addition and condensation polymers
<i>Modification</i>		
Grafting	MAN on PP, PE, EPR, EPDM, PPE, ABS, SEBS AA on PP; acrylate and maleate on PE Epoxide on PP, PE, PS, EPDM, EPR, NR Oxazoline on ABS, NBR; lactam on EPR Amine on EPR, SAN, SMA; piperazine on SAN Hydroxyl on EPR, PP, PVBE Isocyanate on PE, PMMA; imidazole on PE	Mainly for addition polymers
Substitution	Bromide on PPE, XP50; chloride on PE Hydroxyl on EVAc Sulfonic acid on PS, EPDM Ethylphosphonate on EPDM	For both addition and condensation polymers
Terminal modification	Epoxide on PPE, phenoxy, PMMA Anhydride on PS, PP, PSF, PAES Carboxylic acid on PS, NBR; ester on PPS Hydroxyl on NBR, PS, PSF, PA6 Amine on NBR, PS, PIP, SAN Isocyanate on polyamides, carbodiimide on PPE	For both addition and condensation polymers
Other modification	MAN on EPDM, PB by concerted addition Anhydride on acrylics Carboxylic acid on SMA Carbonyl on PE by photo oxidation	For both addition and condensation polymers

polymers contain potentially reactive groups inherent in their side chains, e.g., carboxylic acid in poly(acrylic acid), ester groups in polyacrylates, poly(vinyl acetate), and double bonds in PB and EPDM. In many other cases, the polymers need to be functionalized with suitable reactive groups either through copolymerization or by chemical modification of preformed polymers. Functional monomers such as MAn, AA, GMA etc. have been incorporated into a variety of polymers by copolymerization. Various chemical reactions have been used in chemically modifying preformed polymers [75–81], including:

- a. free radical catalyzed grafting of MAn, AA, GMA, etc. onto a variety of polymers,
- b. substitution reactions such as sulfonation and halogenation, and
- c. terminal modification on both addition and condensation polymers.

Functionalization by grafting and copolymerization is the most frequently seen method for preparing reactive polymers for blending applications.

2.4 Types of Compatibilizing Reactions

Reactive polymers undergo the usual chemical reactions seen in low molecular weight materials. It is a common assumption in polymer chemistry that the reactivity of a functional group does not depend on the size of the molecule to which is attached. However, the functional groups in polymers are connected with a more condensed and differently organized system of “reactants”. The steric hindrance to the reaction sites by polymer backbones reduces the reaction rate [353]. When one considers the melt blending environment in which reactive compatibilization occurs the reaction rate can also be reduced by the restricted diffusional mobility of the functional groups. Also, the concentration of reactive groups used in reactive compatibilization is preferably very low and the reaction time is short (i.e., in minutes), reducing the possibility of reactive groups encountering each other in the melt so that a reaction can take place. Therefore, in order to achieve successful compatibilization of polymer blends, the polymers must have sufficiently reactive functional groups; the reaction should be fast, selective, and preferably irreversible; and mixing conditions should be such as to minimize mass transfer limitations to reaction.

Table 2.2 lists the chemical reactions that have been used in compatibilizing polymer blends [59, 61, 82]. Such reactions as amidation, imidation, esterification, aminolysis, ester-ester interchange, amide-ester exchange, ring-opening, and ionic bonding can occur rapidly at elevated processing temperatures and are frequently used in reactive compatibilization. Concerted ene addition and simple substitution between amine and halide or hydroxyl have also been utilized. Isocyanate and carbodiimide groups are also highly reactive and meet the requirements for effective compatibilizing reactions.

2.5 Types of Reactive Polymers and Their Applications

A variety of reactive polymers have been utilized for compatibilizing polymer blends. They can be classified into eight major categories, with each category having one type of

Table 2.2 Types of Compatibilizing Reactions Used in Blending

Reaction type	Reactive group	Co-reactive group	Remarks
Amidation	Carboxylic acid	Amine	Addition/substitution
Imidation	Anhydride	Amine	
Esterification	Carboxylic acid and anhydride	Hydroxyl	
Concerted addition	Maleate and MAn	Double bond	
Urea formation	Carbodiimide	Carboxylic acid	
Urethane formation	Isocyanate	Hydroxyl	
Substitution	Amine	Hydroxyl, halide	
Ester interchange	Ester	Ester	Interchange reaction
Transesterification	Ester	Hydroxyl/phenol	
Amide-ester exchange	Amide	Ester	
Aminolysis	Ester	Amine	
Amide interchange	Amide	Amide	
Acidolysis	Ester	Carboxylic acid	
Ring-opening reaction	Epoxide	Carboxylic acid, MAn, hydroxyl, amine	
Ring-opening reaction	Oxazoline	Carboxylic acid, MAn, amine, halide	
Ring-opening reaction	Lactam	Amine	
Ionic bonding	Acid	Pyridine, amine, imidazole	Ionic bonding
Ionic bonding	Ionomer	Ionomer	

functional group, namely, maleic anhydride, carboxylic acid, groups capable of interchange reactions, primary and secondary amines, hydroxyl groups, heterocyclic groups, groups capable of ionic interactions, and others.

2.5.1 Reactive Polymers Having MAn Functionality

MAn has long been used in industry to promote adhesion and dyeability [83–84]. It is not surprising that MAn is also extensively used in reactive compatibilization of polymer blends. Table 2.3 lists a number of MAn functionalized polymers, their types and possible reactions, and applications. MAn grafted PP [85–109], PE [110–121], EPR [112, 122–131], EPDM [112, 114, 115, 132–137], SEBS [138–147], ABS [148–150], PPE [151], and PSF [152, 153] have been used to compatibilize a variety of polymer blends, particularly blends involving polyamides, to improve their impact strength, tensile strength, permeability, heat resistance, crystallization, and recycling properties. A major reason for the wide use of MAn functionalized polymers is the relative ease with which MAn can be grafted onto many polymers at normal melt processing temperature without homopolymerization. SMA has been widely used to compatibilize a variety of polymer blends [93, 154–177]. MAn copolymers with SAN [178], ethylene [179–181], and AC [182–184] have

Table 2.3 Maleic Anhydride Functionalized Reactive Polymers

Polymer	Reactive group	Blends	Reaction type	Properties	Reference		
PP	Grafted MAn	PA6/PP	Imidation	Recycling	85		
			Imidation	Mechanical	86, 87		
			Imidation	Impact	88, 89		
		PA6/PE	Imidation	Morphology	90, 91		
			Imidation	Tensile	92		
		PA66/PP	Imidation	Morphology	93		
			Imidation	Heat resistance	94		
			Imidation	Mechanical	95, 96		
		PA1010/PP	Imidation	Crystallization	97		
			Imidation	Morphology	98		
		PP/aPA	Imidation	PP/aPA	Toughness	99	
					Morphology	100	
				PXA/PP	Imidation	Kinetics	101
				PET/PP	Esterification	Recycling	102
				PP/LCP		Compatibility	103–105
				PP/NBR	Amidation	Tensile	106
				PP/EPR	Esterification	Impact	107
ABS/PP	Ring opening			Mechanical	108		
PP/LDPE	Esterification			Tensile	109		
PE	Grafted MAn			PA6/PE	Imidation	Mechanical	110, 111
		Imidation	Impact		112–115		
		Imidation	Morphology		116		
		PE/LCP	Esterification	Morphology	117		
			Esterification	Crystallization	118		
		PS/PE		Morphology	119		
		PS/PE	Ring opening	Morphology	120		
		PE/EPDM	Ionic	Tensile	121		
PE/NR	Ring opening	Tensile	121				
EPR	Grafted MAn	PA6/EPR	Imidation	Morphology	122, 123		
			Imidation	Impact	112, 124–126		
			Imidation	Crystallization	127		
		PA66/EPR	Imidation	Impact	128		
			Ester interchange	Morphology	123		
		PA/EPR	Imidation	Rheology	129		
		PBT/EPR	Ester interchange	Impact	130		
SAN/EPR	Imidation	Impact	131				
EPDM	Grafted MAn	PA6/EPDM	Imidation	Impact	112, 114–115		
			Imidation	Impact	132–135		
		PA6/LCP	Amidation	Morphology	136		
		SAN/EPDM	Imidation	Compatibility	137		
SEBS	Grafted MAn	PA6/SEBS	Imidation	Impact	138–143		
		PA6/PP	Imidation	Impact	144, 145		
		PE/PA6	Imidation	Impact	146		
		PA66/PP	Imidation	Impact	147		
ABS	Grafted MAn	PA6/ABS	Imidation	Mechanical	148, 149		
		PC/ABS		Morphology	150		
PPE	Grafted MAn	PA6/PPE	Imidation	Impact	151		

(continued)

Table 2.3 Continued

Polymer	Reactive group	Blends	Reaction type	Properties	Reference
PSF	Grafted MAn	PA/PSF	Imidation	Compatibility	152, 153
SMA	Copolymerized MAn	PA6/SMA	Imidation	Thermal	154
		PA6/PPE	Imidation	Mechanical	155
				Reaction	156
		PA6/ABS	Imidation	Morphology	157–160
				Impact	161
		PA6/SAN	Imidation	Impact	161, 162
		PA6/PMMA	Imidation	Morphology	163, 164
		PA6/BA	Imidation	Impact	165
		PA6/PS	Imidation	Morphology	93
		PS/PA66	Ring opening	Impact	166
		PA11/SMA	Imidation	Kinetics	167
		PA12/PS	Imidation	Interface	168
		aPA/SAN	Imidation	Morphology	169
		PA/SMA	Imidation	Reaction	170
				Imidation	Interface
	SMA/PPE	Imidation	Impact	172	
		Imidation	Tensile	173	
	SMA/PS	Imidation	Reaction	174	
	SMA/PE	Amidation	Morphology	175	
		Imidation	Impact	176	
	EVA/SMA	Ring opening	Morphology	177	
SAN	Copolymerized MAn	PA/ABS	Imidation	Impact	178
EMAn	Copolymerized MAn	PA6/PE	Imidation	Permeability	179, 180
			Imidation	Morphology	181
AC	Copolymerized MAn	PA6/AC	Imidation	Impact	182, 183
		PBT/AC	Esterification	Impact	184
PS	Terminal MAn	PA6/PS	Imidation	Morphology	185
		PS/PIP	Imidation	Reaction	186
PP	Terminal MAn	PP/PA6	Imidation	Impact	187
PAES	Terminal MAn	PAES/PA	Imidation	Morphology	188

been used mainly in compatibilizing polyamide blends. In addition to grafted and copolymerized MAn, PS [185, 186], PP [187] and PAES [188] with terminal MAn groups have also been used in reactive compatibilization. It is worth mentioning that MAn functionalized polymers have become increasingly important in plastics recycling.

2.5.2 Reactive Polymers with Carboxylic Acid Functionality

Carboxylic acid grafted PP [88, 90, 189–193], PE [194]; copolymerized EAA [179, 195–205], EMAA [206–208], SAA [209–211], ABS [212], NBR [213–219], polyacrylate [220], AC [221]; carboxylic acid terminated CTBN [222–225], PA6 [226–232], PET [233–243], PBT [184, 244–259], PS [260]; and SMA with pendant carboxylic acid resulted from

Table 2.4 Reactive Polymers Having Carboxylic Acid Functionality

Polymer	Reactive group	Blends	Reaction type	Properties	Reference
PP	Carboxylic acid (grafted)	PA6/PP	Amidation	Reaction	189
			Amidation	Morphology	90, 190
		PA11/PP PET/PP	Amidation	Tensile/impact	88
			Amidation	Glass transition	191
			Esterification	Permeability	192
		Esterification	Morphology	193	
PE	Carboxylic acid (photooxidized)	PA6/PE	Amidation	Tensile	194
EAA	Carboxylic acid (copolymerized)	PA6/PE	Amidation	Mechanical	195
			Amidation	Permeability	179
		PA6/EAA	Amidation	Impact	196
		PPE/EAA	Ring opening	Impact/tensile	197
		EAA/PS	Ring opening	Morphology	198, 199
		PS/PE	Ring opening	Reaction	200
			Ring opening	Morphology	201–203
	ENR/EAA	Ring opening	Rheology	204	
			Mechanical	205	
EMAA	Carboxylic acid (copolymerized)	PA6/EMAA	Amidation	Tensile	206
		PET/EMAA	Esterification	Permeability	207, 208
SAA	Carboxylic acid (copolymerized)	PA11/SAA	Amidation	Crystallization	209
		SAA/ABS	Ring opening	Impact	210
		PA6/BA	Amidation	Impact	211
ABS	Carboxylic acid (copolymerized)	Epoxy/ABS	Ring opening	Tensile/impact	212
NBR	Carboxylic acid (copolymerized)	PP/NBR	Ring opening	Impact	213–217
		PS/NBR	Ring opening	Impact	218, 219
		HIPS/NBR	Ring opening	Impact	219
Polyacrylate	Carboxylic acid	PC/Polyacrylate	Acidolysis	Morphology	220
AC	Carboxylic acid (copolymerized)	PS/AC	Ionic bonding	Thermal	221
CTBN	Carboxylic acid (terminal)	Epoxy/CTBN	Ring opening	Impact	222, 223
		PA/NBR	Amidation	Interface	224
		PA6/CTBN	Amidation	Interface	225
PA6	Carboxylic acid (terminal)	PA6/PP	Ring opening	Mechanical	226
			Esterification	Morphology	227
		PA6/SMA	Imidation	Mechanical	228
		PA6/PS	Ring opening	Morphology	229
		PA6/ACM	Ring opening	Mechanical	230
		PVAI/PA6	Substitution	Compatibility	231
		PC/PA	Ring opening	Impact	232
PET	Carboxylic acid (terminal)	PET/EGMA	Ring opening	Recycling	233
			Ring opening	Impact	234
		PET/PE	Ring opening	Mechanical	235–237
		PET/PS	Ring opening	Compatibility	238

(continued)

Table 2.4 Continued

Polymer	Reactive group	Blends	Reaction type	Properties	Reference
PET	Carboxylic acid (terminal)	PET/PS	Ring opening	Mechanical	239
		PPE/PET	Ring opening	Tensile	240, 241
		PET/EPR	Ring opening	Impact	242
		PET/PC	Ring opening	Recycling	243
PBT	Carboxylic acid (terminal)	PP/PBT	Ring opening	Impact	244–248
		PBT/PS	Ring opening	Morphology	249
		PBT/HIPS	Ring opening	Compatibility	250
		PBT/ABS	Ring opening	Mechanical	251
			Ring opening	Morphology	252
			Ring opening	Morphology	253
		PBT/EPR	Ring opening	Morphology	253
		PBT/EPDM	Ring opening	Thermal	254
			Ring opening	Tensile	255
		PBT/NBR	Ring opening	Impact	256
		PPE/PBT	Ring opening	Compatibility	257
Ring opening	Mechanical		258		
Urea formation	Impact		259		
PBT/AC	Ring opening	Impact	184		
PS	Carboxylic acid (terminal)	PS/PMMA	Ring opening	Morphology	260
SMA	Carboxylic acid (pendant)	SMA/PE	Urethane formation	Morphology	261
		SMA/Core-shell	Ring opening	Morphology	262

hydrolysis [261, 262] have been used in improving the impact strength, tensile strength, permeability, compatibility, morphology, and recycling properties of PA6, PA6,6, PA11, PPE, PE, PP, PS, HIPS, PET, PBT and other polymers as listed in Table 2.4. It should be noted that the utilization of carboxylic acid end groups on PA6, PBT, and PET has increased significantly in the past few years.

2.5.3 Reactive Polymers Capable of Interchange Reactions

Table 2.5 lists examples of various reactive polymers capable of interchange reactions drawn from the literature. Random or block copolymer compatibilizers are formed in these blends by interchange reactions. PC, PET, PBT, and PA have attracted the most attention in terms of compatibilization via interchange reactions including ester interchange, amide interchange, amide ester exchange, transesterification, aminolysis, and acidolysis. PC has been reactively blended with PET [263–272], PBT [273, 274], PA [275–278], PAr [279–281], LCP [282], PPVL [283, 284], Phenoxy [285, 286], ABS [287], SAN [288], and polyacrylate [220]. PET has been reactively blended with PC [263–272], LCP [289–292], EVA [293, 294], PA [295], and PND [296]. PBT has been reactively blended with PC [273, 274], Phenoxy [286], LCP [297, 298], PE [299]. PA has been reactively blended with PC [275, 277, 278], other PA [300], ACM [301], and PET [295]. Other polymers capable of interchange reactions include PAr [279–281, 302], EVA [293, 294, 299], PND [296], AC [301, 303], ester grafted PE [304, 305], PCL [306, 307], PEN [307], PPS [308], PPVL

Table 2.5 Reactive Polymers Capable of Interchange Reactions

Polymer	Reactive group	Blends	Reaction type	Properties	Reference
PC	Backbone ester	PET/PC	Ester interchange	Microhardness	263
			Ester interchange	Transparency	264
			Ester interchange	Reaction	265, 266
			Ester interchange	Thermal	267, 268
			Ester interchange	Compatibility	269–272
		PC/PBT	Ester interchange	Compatibility	273, 274
		PA6/PC	Amide ester exchange	Morphology	275
			Aminolysis	Mechanical	276
		PA/PC	Amide ester exchange	Tensile	277, 278
		PAr/PC	Ester interchange	Compatibility	279
			Ester interchange	Tensile	280, 281
		LCP/PC	Transesterification	Morphology	282
		PPVL/PC	Ester interchange	Compatibility	283, 284
		PC/Phenoxy	Transesterification	Tensile	285
		(PBT+PC)/Phenoxy	Transesterification	Compatibility	286
PC/ABS	Aminolysis	Morphology	287		
PC/SAN	Aminolysis	Morphology	288		
PC/ polyacrylate	Acidolysis	Morphology	220		
PET	Backbone ester	PET/PC	Ester interchange	Microhardness	263
			Ester interchange	Transparency	264
			Ester interchange	Reaction	265, 266
			Ester interchange	Thermal	267, 268
			Ester interchange	Compatibility	269–272
		PET/LCP	Ester interchange	Compatibility	289–292
		PET/EVA	Ester interchange	Compatibility	293, 294
		PET/PA	Amide ester exchange	Compatibility	295
PET/PND	Transesterification	Morphology	296		
PBT	Backbone ester	PC/PBT	Ester interchange	Compatibility	273, 274
		(PBT+PC)/Phenoxy	Transesterification	Compatibility	286
		PBT/LCP	Transesterification	Mechanical	297
				Compatibility	298
		PE/PBT	Transesterification	Morphology	299
PA	Backbone amide	PA46/PA61	Amide interchange	Crystallization	300
		PA6/ACM	Amide ester exchange	Heat resistance	301
		PA/PC	Amide ester exchange	Tensile	277, 278
				Morphology	275
		PET/PA	Amide ester exchange	Compatibility	295
PAr	Backbone ester	PAr/PC	Ester interchange	Compatibility	279
			Ester interchange	Tensile	280, 281
		PAr/Phenoxy	Transesterification	Modulus	302
EVA	Pendant ester	PET/EVA	Ester interchange	Compatibility	293, 294
		PE/PBT	Transesterification	Morphology	299
PND	Backbone ester	PET/PND	Transesterification	Morphology	296
AC	Pendant ester	PA6/AC	Ester-amide exchange	Heat resistance	301
			Aminolysis	Impact	303

(continued)

Table 2.5 Continued

Polymer	Reactive group	Blends	Reaction type	Properties	Reference
PE	Grafted ester	PA6/PE	Aminolysis	Impact	304
		PE/LCP	Transesterification	Morphology	305
PCL	Backbone ester	PCL/Poly-(lactic acid)	Transesterification	Tensile	306
		PEN/PCL	Transesterification	Thermal	307
PEN	Backbone ester	PEN/PCL	Transesterification	Thermal	307
PPS	Terminal ester	PPS/LCP	Transesterification	Mechanical	308
PPVL	Backbone ester	PPVL/PC	Ester interchange	Compatibility	283, 284
LCP	Backbone ester	LCP/PC	Transesterification	Morphology	282
		PET/LCP	Transesterification	Mechanical	289–292
		PBT/LCP	Transesterification	Mechanical	297
			Transesterification	Compatibility	298
		PE/LCP	Transesterification	Morphology	305
		PPS/LCP	Transesterification	Mechanical	308
PA6	Terminal amine	PC/PA6	Aminolysis	Mechanical	276
SAN	Terminal amine	PC/ABS	Aminolysis	Morphology	287
SAN	Grafted piperazine	PC/SAN	Aminolysis	Morphology	288

[283, 284], LCP [282, 289–292, 297, 298, 305, 308], PA6 [276], and SAN [287] with terminal amine as the active group and SAN with grafted piperazine [288].

2.5.4 Reactive Polymers Containing Primary and Secondary Amines

Table 2.6 contains a list of polymers with primary and secondary amine functionalities. As might be expected, the overwhelming majority of blends in the present category employ polyamides as the matrix that may react with reactive polymers containing anhydride, carboxylic acid, oxazoline, epoxide, bromide, and ionic functionalities. Among these, PA6 is the most widely used with a large number of literature reports [74, 85–93, 95, 110–116, 122, 124, 126, 127, 132–136, 138–149, 154–161, 163–165, 178–181, 183, 185, 187, 189, 190, 194–196, 203, 206, 211, 225, 227, 303, 304, 309–323]. Other polyamides used are PA66 [94–97, 123, 128, 141, 143, 151, 166, 324], PA11 [167, 191, 209, 325], PA12 [168], PA1010 [98, 326], PA [129, 152, 153, 170, 171, 188, 224, 327–329], and aPA [99, 100, 169, 330, 331]. Other examples include amine terminated NBR rubber [106, 224, 332, 333]; PS [172–174], PIP [186], and amine grafted EPR [107, 175, 176], SAN [131, 137], and SMA [228]. More details can be found in Chapter 8.

2.5.5 Reactive Polymers Containing Hydroxyl Groups

Although amine functionalized polymers are restricted mainly to polyamides in the literature, reactive polymers containing hydroxyl groups offer more flexibility as shown in Table 2.7. Hydroxyl terminated PET and PBT have been utilized in compatibilizing a

Table 2.6 Reactive Polymers with Primary and Secondary Amine Functionalities

Polymer	Reactive group	Blends	Reaction type	Properties	Reference
PA6	Terminal amine	PA6/PE	Aminolysis	Impact	304
			Aminolysis	Crystallization	309
			Aminolysis	Morphology	310, 311
			Imidation	Impact	114–116, 146
			Imidation	Mechanical	92, 110, 111
			Imidation	Permeability	180
			Imidation	Morphology	93, 113, 181
			Amidation	Mechanical	194, 195, 312
			Amidation	Permeability	179
			Amidation	Morphology	313
		PA6/PP	Imidation	Impact	88, 89, 144
			Imidation	Impact	145, 147, 187
			Imidation	Mechanical	86, 87, 95
			Imidation	Morphology	90, 91
			Imidation	Recycling	85
			Amidation	Impact	88
			Amidation	Kinetics	189
			Amidation	Morphology	190
			Amidation/ionic	Tensile	314, 315
			Substitution	Morphology	227
		PA6/EPR	Ring opening	Impact	316
			Imidation	Impact	74, 124, 126
			Imidation	Crystallization	127
		PA6/EPDM	Imidation	Morphology	122
			Imidation	Impact	112, 114, 115
			Imidation	Imidation	132–135
		PA6/PS	Ionic bonding	Impact	317
			Amidation/ionic	Compatibility	318, 319
		PA6/SEBS	Amidation/ionic	Morphology	185
			Imidation	Impact	138–143
		PA6/ABS	Imidation	Impact	161, 178
			Imidation	Tensile	148, 149
		PA6/SMA	Imidation	Morphology	157–160, 320
			Imidation	Thermal	154
		PA6/SAN	Imidation	Impact	160, 321
			Ring opening	Impact	161
		PA6/PMMA	Imidation	Morphology	163, 164
		PA6/PPE	Imidation	Mechanical	155
			Imidation	Reaction	156
			Substitution	Tensile	322
		PA6/LCP	Amidation	Morphology	136
		PA6/AC	Imidation	Impact	183, 203
			Aminolysis	Impact	303
PA6/EAA	Amidation	Impact	196		
PA6/BA	Imidation	Impact	165		
	Amidation	Impact	211		
PA6/EMAA	Amidation	Tensile	206		
PA6/CTBN	Amidation	Interface	225		
PA6/XP50	Substitution	Morphology	323		

(continued)

Table 2.6 Continued

Polymer	Reactive group	Blends	Reaction type	Properties	Reference
PA66	Terminal amine	PA66/SEBS	Imidation	Impact	141, 143
			Imidation	Heat resistance	94
		PA66/PP	Imidation	Mechanical	95, 96
			Imidation	Crystallization	97
		PA66/PPE	Imidation	Impact	151
		PS/PA66	Ring opening	Impact	166
		ABS/PA66	Ring opening	Compatibility	324
		PA66/EPR	Imidation	Impact	128
		Imidation	Morphology	123	
PA11	Terminal amine	PA11/SAA	Amidation	Crystallization	209
		PA11/PE	Ring opening	Compatibility	325
		PA11/PP	Amidation	Glass transition	191
		SMA/PA11	Imidation	Kinetics	167
PA12	Terminal amine	PA12/PS	Imidation	Interface	168
PA1010	Terminal amine	PA1010/PP	Imidation	Morphology	98
			Ionic	Mechanical	326
PA	Terminal amine	PA/EPR	Imidation	Rheology	129
		PA/ABS	Imidation	Compatibility	327, 328
		PA/PSF	Imidation	Crystallization	329
		PA/SMA	Imidation	Compatibility	152, 153
			Imidation	Reaction	170
			Imidation	Interface	171
		PAES/PA	Imidation	Morphology	188
PA/NBR	Amidation	Interface	224		
aPA	Terminal amine	PS/aPA	Ring opening	Morphology	330
			Amidation/ionic	Structure	331
		PP/aPA	Imidation	Toughness	99
			Imidation	Morphology	100
APA/SAN	Imidation	Morphology	169		
ATBN	Terminal amine	Epoxy/ATBN	Ring opening	Impact	332
			Amidation	Tensile	106
		PP/ATBN	Substitution	Tensile	333
			Amidation	Interface	224
PS	Terminal amine	SMA/PPE	Imidation	Impact	172
			Imidation	Tensile	173
		SMA/PS	Imidation	Reaction	174
PIP	Terminal amine	PS/PIP	Imidation	Reaction	186
EPR	Grafted amine	PP/EPR	Imidation	Impact	107
		SMA/PE	Imidation	Impact	176
			Imidation	Morphology	175
SAN	Grafted amine	SAN/EPR	Imidation	Impact	131
		SAN/EPDM	Imidation	Compatibility	137
SMA	Grafted amine	PA6/SMA	Amidation	Mechanical	228

Table 2.7 Reactive Polymers Having Hydroxyl Groups

Polymer	Reactive group	Blends	Reaction type	Properties	Reference
PET	Terminal hydroxyl	PET/PP	Esterification	Recycling	102
			Esterification	Permeability	192
		PET/EPR	Esterification	Morphology	193
			Esterification	Permeability	207, 208
PBT	Terminal hydroxyl	PBT/EPR	Esterification	Impact/tensile	130
		PBT/PA6	Urethane formation	Impact/tensile	334
		PBT/AC	Ring opening	Impact	183, 184
		PBT/PE	Esterification	Permeability	179
PA6	Terminal hydroxyl	PA6/CTBN	Esterification	Interface	225
HTBN	Terminal hydroxyl	Epoxy/HTBN	Ring opening	Impact	335, 336
PS	Terminal hydroxyl	PS/PMMA	Urethane formation	Kinetics	337
PSF	Terminal hydroxyl	Epoxy/PSF	Ring opening	Impact	338
Phenoxy	Terminal hydroxyl	PAr/Phenoxy	Transesterification	Modulus	302
		PC/Phenoxy	Transesterification	Tensile	285
		(PBT+PC)/Phenoxy	Transesterification	Compatibility	286
Phenoxy	Pendant hydroxyl	Phenoxy/ABS	Ring opening	Impact/tensile	339
EVAI	Pendant hydroxyl	PP/LDPE	Esterification	Tensile	109
		EVAI/SMA	Esterification	Rheology	177
PVAI	Pendant hydroxyl	PVAI/PA6	Substitution	Compatibility	231
EPR	Grafted hydroxyl	PP/EPR	Esterification	Impact	107
PVBE	Grafted hydroxyl	PA6/PP	Esterification	Morphology	227
PP	Grafted hydroxyl	PP/ATBN	Substitution	Tensile	333

number of blends of PET [102, 123, 192, 193, 207, 208] and PBT [130, 179, 183, 184, 334]. Other reactive polymers containing terminal hydroxyl groups include PA6 [225], NBR [335, 336], PS [337], and PSF [338], Phenoxy [285, 286, 302]. Also included in Table 2.7 are reactive Phenoxy [339], EVAI [109, 177], PVAI [231] with pendant hydroxyl groups and EPR [107], PVBE [227], PP [333] with grafted hydroxyl groups.

2.5.6 Reactive Polymers Containing Heterocyclic Groups

Epoxide groups can be easily incorporated into polymers by copolymerization with functional monomers such as GMA. In the last few years, there has been a rapid increase in the number of literature reports concerning the copolymerization of GMA with other monomers as shown in Table 2.8. GMA copolymerized PS [171, 198, 199, 239–241, 249, 250, 257, 258, 324], PE [233–237, 243, 245], SAN [108, 251, 339], AC [183, 184, 230, 252], and core–shell polymers [262] have been used in blend compatibilization. The terminal epoxide groups inherent in Epoxy resins have been utilized in their reactive

Table 2.8 Reactive Polymers Having Heterocyclic Groups

Polymer	Reactive group	Blends	Reaction type	Properties	Reference
PS	Copolymerized GMA	PET/PS PPE/PET	Ring opening	Tensile/impact	239
			Ring opening	Tensile	240
		PBT/PS PBT/HIPS	Ring opening	Compatibility	241
			Ring opening	Morphology	249
		PPE/PBT	Ring opening	Compatibility	250
			Ring opening	Compatibility	257
		PS/PA66	Ring opening	Tensile/impact	258
			Ring opening	Interface	171
		ABS/PA66	Ring opening	Compatibility	324
		EAA/PS	Ring opening	Morphology	198
			Ring opening	Mechanical	199
PE	Copolymerized GMA	PET/EGMA	Ring opening	Recycling	233
			Ring opening	Impact	234
		PE/PET	Ring opening	Mechanical	235–237
		PET/PC	Ring opening	Recycling	243
		PBT/PP	Ring opening	Impact	245
SAN	Copolymerized GMA	ABS/PP	Ring opening	Mechanical	108
		PBT/ABS	Ring opening	Mechanical	251
		Phenoxy/ABS	Ring opening	Tensile/impact	339
AC	Copolymerized GMA	PBT/AC	Ring opening	Impact	183, 184
		PA6/AC	Ring opening	Mechanical	230
		PBT/ABS	Ring opening	Morphology	252
Core-shell	Copolymerized GMA	SMA/core-shell	Ring opening	Morphology	262
Epoxy	Terminal epoxide	Epoxy/ABS	Ring opening	Impact/tensile	212
		Epoxy/PSF	Ring opening	Impact	338
		Epoxy/CTBN	Ring opening	Impact	222, 223
		Epoxy/ATBN	Ring opening	Impact	332
		Epoxy/HTBN	Ring opening	Impact	335, 336
PPE	Terminal epoxide	PPE/EAA	Ring opening	Impact/tensile	197
Phenoxy	Terminal epoxide	PC/PA6	Ring opening	Impact	232
PMMA	Terminal epoxide	PS/PMMA	Ring opening	Morphology	260
EPR	Grafted epoxide	PET/EPR	Ring opening	Impact	242
		PBT/EPR	Ring opening	Morphology	253
		ENR/EAA	Ring opening	Rheology	204
			Ring opening	Mechanical	205
EPDM	Grafted epoxide	PBT/EPDM	Ring opening	Thermal	254
			Ring opening	Tensile	255
NR	Grafted epoxide	PE/NR	Ring opening	Tensile	121
PP	Grafted GMA	PP/NBR	Ring opening	Impact	213–215
		PP/PA6	Ring opening	Mechanical	226
		PP/PBT	Ring opening	Impact	246–248
PE	Grafted GMA	PA11/PE	Ring opening	Compatibility	325
PS	Grafted GMA	PS/PET	Ring opening	Compatibility	238

Table 2.8 Continued

Polymer	Reactive group	Blends	Reaction type	Properties	Reference
RPS	Copolymerized oxazoline	PS/NBR	Ring opening Ring opening	Impact	218, 219
		HIPS/NBR	Ring opening	Impact	126
		PA6/PS	Ring opening	Impact	229
		PS/PE	Ring opening	Tensile	113–115
			Ring opening	Reaction	200
			Ring opening	Morphology	120, 223
		PS/CPE	Ring opening	Compatibility	340
PS/aPA	Ring opening	Morphology	330		
SAN	Copolymerized oxazoline	PA6/SAN	Ring opening	Impact	161
ABS	Grafted oxazoline	SAA/ABS	Ring opening	Impact	210
PP	Grafted oxazoline	PP/NBR	Ring opening	Impact	215–217
		PP/PBT	Ring opening	Impact	244
NBR	Grafted oxazoline	PBT/NBR	Ring opening	Impact	256
EPR	Grafted lactam	PA6/EPR	Ring opening	Impact	316

toughening [212, 222, 223, 332, 335, 336, 338]. Terminal epoxide groups in PPE [197], Phenoxy [232], PMMA [260] and grafted epoxide groups in EPR [204, 205, 242, 253], EPDM [254, 255], NR [121], PP [213–215, 226, 246–248], PE [325], PS [238] have been used in reactive compatibilization of polymer blends. Oxazoline functionalized polymers are also included in Table 2.8. RPS with copolymerized oxazoline groups is the most frequently used reactive polymers with oxazoline functionalities [113–115, 120, 126, 200, 218, 219, 223, 229, 330, 340]. Oxazoline copolymerized SAN [161], grafted ABS [210], PP [215–217, 244], NBR [256], and EPR [316] have also been reported.

2.5.7 Reactive Polymers Capable of Ionic Interactions

A different approach to compatibilization of polymer blends is through ionic bonding instead of covalent bonding. Table 2.9 contains a number of polymers capable of ionic bonding that have been reported in the literature. Pyridine, imidazole, and tertiary amine groups attached to polymers have been shown to form ionic bonding with sulfonic acid, carboxylic acid, and ionomers, and to promote compatibility of polymer blends [221, 318, 319, 326, 341–346]. Another important type of ionic bonding is between different ionomers. Sulfonated (zinc salt) PS [347–349] and EPDM [121, 317, 343, 344, 347, 348], carboxylated (zinc salt) AC [312–315, 350], and phosphonated (ethyl ester) EPDM [349] have been reported to compatibilize polymer blends through ionic bonding and improve blend properties.

2.5.8 Miscellaneous Reactive Polymers

Included in Table 2.10 are miscellaneous polymers containing reactive groups such as bromide [322, 323], chloride [340], isocyanate [261, 334, 337], carbodiimide [259],

Table 2.9 Reactive Polymers Capable of Ionic Interactions

Polymer	Reactive group	Blends	Reaction type	Properties	Reference
PVP	Pyridine (Polymerized)	PS/PVP	Ionic Interaction	Interface	341
MMAVP	Pyridine (Copolymerized)	PS/PMMA	Ionic Interaction	Compatibility	342
SVP	Pyridine (Copolymerized)	SVP/EPDM	Ionic Interaction Ionic Interaction	Tensile Morphology	343 344
PE	Imidazole (grafted)	PE/PP	Ionic Interaction	Compatibility	345
PUR	Tertiary amine (backbone)	PS/PUR	Ionic Interaction	Compatibility	346
PS	Tertiary amine (copolymerization)	PS/AC	Ionic Interaction	Thermal	221
PP	Acrylic acid (grafted)	PE/PP	Ionic Interaction	Compatibility	345
PS	Sulfonic acid (sulfonation)	PS/PUR	Ionic Interaction	Compatibility	342, 346
		PS/PMMA	Ionic Interaction	Compatibility	342, 346
		PA6/PS	Ionic/amidation	Compatibility	318, 319
		PS/PVP	Ionic Interaction	Interface	341
		PS/aPA	Ionic/amidation	Structure	331
PP	Sulfonic acid (grafted)	PA1010/PP	Ionic Interaction	Mechanical	326
PS	Zinc sulfonate (sulfonation)	(PS + PPE)/EPDM	Ionic Interaction	Impact	347–349
EPDM	Zinc sulfonate (sulfonation)	PA6/EPDM	Ionic/amidation	Impact	317
		PE/EPDM	Ionic Interaction	Tensile	121
		SVP/EPDM	Ionic Interaction	Tensile	343
			Ionic Interaction	Morphology	344
		(PS + PPE)/EPDM	Ionic Interaction	Impact	347, 348
AC	Zinc carboxylate (copolymerization) Na carboxylate	PA6/PP	Ionic Interaction	Morphology	314, 315
		PA6/PE	Ionic Interaction	Tensile	312, 313
		PBT/HDPE	Ionic/esterification	Mechanical	350
EPDM	Ethyl phosphate (phosphonation)	(PS + PPE)/EPDM	Ionic Interaction	Impact	349

succinate [309, 311], maleate [351], anhydride [320, 321, 329], double bond [351], and metal complex [352]. Compatibilizing reactions involved are substitution, ring opening, urethane formation, urea formation, aminolysis, imidation, concerted ene addition, coordination etc.

2.6 Concluding Remarks

Compatibilization of immiscible polymer blends can be achieved by *in situ* formation of copolymer compatibilizers using functionalized polymers. Reactive polymers are classified

Table 2.10 Miscellaneous Reactive Polymers

Polymer	Reactive group	Blends	Reaction type	Properties	Reference
PPE	Substituted bromide	PA6/PPE	Substitution	Tensile	322
XP50	Substituted bromide	PA6/XP50	Substitution	Morphology	323
CPE	Substituted Chloride	PS/CPE	Ring opening	Compatibility	340
PE	Grafted isocyanate	SMA/PE	Urethane formation	Morphology	261
PMMA	Grafted isocyanate	PS/PMMA	Urethane formation	Kinetics	337
PA6	Terminal isocyanate	PBT/PA6	Urethane formation	Impact/tensile	334
PPE	Terminal carbodiimide	PPE/PBT	Urea formation	Impact	259
PE	Grafted succinate	PE/PA6	Aminolysis	Crystallization	309
			Aminolysis	Morphology	311
PET	Copolymerized maleate	PET/EPDM	Concerted addition	Impact	351
Acrylics	Pendant anhydride	PA6/SAN	Imidation	Morphology	320, 321
		PA6/ABS	Imidation	Morphology	321
PSF	Terminal anhydride	PA/PSF	Imidation	Crystallization	329
EPDM	Double bond	PET/EPDM	Concerted addition	Impact	351
PVP	Zinc complex	PVP/PB	coordination	Tensile	352
PB	Palladium complex	PVP/PB	coordination	Tensile	352

into eight major categories according to the types of reactive functionalities and the characteristics of compatibilization reactions, namely, maleic anhydride, carboxylic acids, reactive groups capable of interchange reactions, primary and secondary amines, hydroxyl groups, heterocyclic groups, reactive groups capable of ionic bonding, and others.

These reactive polymers may be obtained by polymerization through terminal, backbone, and side chain groups, by copolymerization of monomers containing the desired reactive groups, and by chemical modification of preformed polymers using free radical grafting, substitution, terminal modification, etc.

Reactive polymers undergo a variety of chemical reactions during melt blending, including addition and substitution reactions such as amidation, imidation, esterification, and concerted addition, etc.; interchange reactions such as transesterification, ester interchange, amide interchange, amide-ester exchange, aminolysis, and acidolysis, etc.; ring opening reactions involving heterocyclic groups; ionic bonding involving pyridine, tertiary amine, acids, ionomers; and others.

The applications of these reactive polymers to the compatibilization of various polymer blends are to improve the impact strength, tensile strength, permeability, heat resistance, crystallization, morphology, and other properties of polymers and recycled plastics.

In addition to reactive compatibilization, compatibilization of immiscible polymer blends may also be achieved through introduction of preformed block or graft copolymers, non-bonding specific interaction, and the addition of low molecular weight coupling agents.

List of Abbreviations

AA	Acrylic acid
ABS	Poly(acrylonitrile-co-butadiene-co-styrene)
AC	Ethylene acrylate copolymer
ACM	Acrylate rubber
ATBN	Amine terminated butadiene-acrylonitrile rubber
CTBN	Carboxyl terminated butadiene-acrylonitrile rubber
EAA	Poly(ethylene-co-acrylic acid)
EMAA	Poly(ethylene-co-methacrylic acid)
EMAn	Poly(ethylene-co-maleic anhydride)
EPDM	Poly(ethylene-co-propylene-co-diene)
EPR	Poly(ethylene-co-propylene) elastomer
EVAc	Poly(ethylene-co-vinyl acetate)
EVAI	Poly(ethylene-co-vinyl alcohol)
GMA	Glycidyl methacrylate
HIPS	High impact polystyrene
HTBN	Hydroxyl terminated acrylonitrile-butadiene rubber
LLDPE	Linear low density polyethylene
MAAn	Maleic anhydride
MMAVP	Poly(methyl methacrylate-co-vinyl pyridine)
NBR	Poly(butadiene-co-acrylonitrile) elastomer
NR	Natural rubber
PA	Polyamide
aPA	Amorphous polyamide
PAES	Poly(aromatic ether sulfone)
PAr	Polyarylate
PB	Polybutadiene
PBT	Poly(butylene terephthalate)
PC	Polycarbonate
PCL	Poly(ϵ -caprolactone)
PE	Polyethylene
PET	Poly(ethylene terephthalate)
PIP	Polyisoprene
PMMA	Poly(methyl methacrylate)
PND	Poly(ethylene 2,6-naphthalenedicarboxylate)
PP	Polypropylene
PPE	Poly(phenylene ether)
PPS	Poly(phenylene sulfide)
PS	Polystyrene
PSF	Polysulfone
PUR	Polyurethane
PVAI	Poly(vinyl alcohol)
PVBE	Poly(vinyl butyl ether)
PVC	Poly(vinyl chloride)
PXA	Poly(xylene adipamide)

RPS	Poly(styrene-co-vinyl oxazoline)
SAA	Poly(styrene-co-acrylic acid)
SAN	Poly(styrene-co-acrylonitrile)
SEBS	Styrene-ethylene/butylene-styrene triblock copolymer
SMA	Poly(styrene-co-maleic anhydride)
SVP	Poly(styrene-co-vinyl pyridine)
XP50	Brominated (isobutylene-co-para-methylstyrene) elastomer

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