Compatibilisation and reactive blending

J.G. BONNER and P.S. HOPE

3.1 Introduction

The achievement of compatibilisation, whether by addition of a third component (a so-called ‘compatibiliser’) or by inducing in situ chemical reaction between blend components (reactive blending), has played an important role in the development of polymer blends. Indeed most commercial blends are considered to be compatible. The first question must therefore be ‘what do we mean by compatibility?’ The answer is not necessarily straightforward, as many workers in the past have used different definitions.

Compatibility is frequently defined as miscibility on a molecular scale (e.g. [1]). This undoubtedly has the merit of clarity, but has the disadvantage of confining the definition of compatibility to encompass only those blends showing true thermodynamic miscibility, and thereby excluding a very large number of blends, both academically studied and commercialised, which many workers would consider compatible. Another way of defining compatible blends is as polymer mixtures which do not exhibit gross symptoms of phase separation. This widens the scope considerably, and it is certainly true that most compatibilised blends contain very finely dispersed phases, but the definition still excludes some blends which have been modified to facilitate the generation of a preferred, but not necessarily fine, morphology and hence preferred physical properties. One example of such a system would be the compatibilised polyethylene/polyamide blends developed by Du Pont to give blow-moulded containers with enhanced barrier properties to solvents (see [2] for example).

A third definition, preferred by the present authors, is simply to consider blends as compatible when they possess a (preferably commercially) desirable set of properties. This leaves unanswered the question of how this is achieved, and therefore allows the materials developer free rein to exploit any avenue which will lead to a technologically useful product.

The purpose of this chapter is to review compatibilisation technology (sections 3.2 and 3.3), after which the most extensively studied systems will be discussed in detail (sections 3.4 and 3.5). For this purpose a distinction is drawn between blends compatibilised by addition of a third component (compatibiliser), and those produced by reactive blending. Within these headings the blends are described under major groupings; to some extent this
COMPATIBILISATION AND REACTIVE BLENDING

has been done arbitrarily, as some blends may clearly fit more than one grouping. Finally, future trends are identified (section 3.6)

The focus of the chapter is on thermoplastic blends produced by melt compounding. For this reason we have chosen to exclude discussion of rubber blends (including thermoplastic elastomers), interpenetrating networks and thermosetting blends.

3.2 Compatibilisation mechanisms

In most cases, melt mixing two polymers results in blends which are weak and brittle; while the low deformation modulus may follow an approximately linear mixing rule, the ultimate properties certainly will not. This is because the incorporation of a dispersed phase in a matrix leads to the presence of stress concentrations and weak interfaces, arising from poor mechanical coupling between phases. It is most common for compatibilisation to be achieved by addition of a third component, or by in situ chemical reaction, leading to modification of the polymer interfaces in two-phase blends, and thereby to tailoring of the phase structure, and hence properties.

The factors contributing to end-use properties during manufacture of a blend by melt compounding, and subsequent conversion processing to produce a finished article, are illustrated in Figure 3.1. The mechanical properties of a blend or alloy will be determined not only by the properties of its components, but also by the phase morphology and the interphase adhesion, both of which are important from the viewpoint of stress transfer within the blend in its end-use application. The phase morphology will normally be determined by the processing history to which the blend has been subjected, in which such factors as the process (mixer type, rate of mixing and temperature history), the rheology of the blend components and the interfacial tension between phases in the melt are important. The phase morphology is unlikely to be in thermodynamic equilibrium, but generally will have been stabilised against de-mixing by some method or other; this usually means via quenching to below the glass transition temperature of one or both phases, or via the occurrence of crystallinity in one or both phases, or occasionally by cross-linking.

In any case, it is readily understood that compatibilisation can in principle interact in complex ways to influence final blend properties. One effect of compatibilisers is to reduce the interfacial tension in the melt, causing an emulsifying effect and leading to an extremely fine dispersion of one phase in another. Another major effect is to increase the adhesion at phase boundaries, giving improved stress transfer. A third effect is to stabilise the dispersed phase against growth during annealing, again by modifying the phase-boundary interface. In practice it is likely that all these effects will occur to some extent with addition of a particular compatibiliser, and that the possibility of other effects (such as modification of rheology) may also occur.