Chapter 9

Permeation

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Abstract

Polymer nanocomposites have attracted interest as barrier materials in packaging and protective applications, enabling higher performance in terms of low gas permeability. The addition of nanoplatelets effectively enhances tortuosity, leading to lower gas permeabilities. This chapter reviews gas permeation behavior in polymeric materials, conventional processing methods of polymer nanocomposites, and corresponding gas permeation theory. Barrier nanoplatelets such as silicate clay and graphene, innovative processing technology such as layer-by-layer deposition, and multifunctional characteristics of polymer nanocomposites are discussed. The factors influencing barrier properties and the corresponding improvement approaches are emphasized. Some applications for gas storage tanks, electronics, food packaging, and anti-corrosion coating are also presented.

9.1 Introduction to gas permeation

Barrier materials are widely used for packaging and protection, such as gas storage tanks, food and pharmaceutical packaging, and electronic devices [1]. The general requirement for barrier materials is to have extremely low permeability, also called transmission rate for gas or water vapor permeation. Yoo et al. [2] summarized the oxygen and water vapor transmission rates of conventional polymeric barrier materials and also described the high requirements for various gas barrier applications, as shown in Figure 9.1. It is well known that polymeric materials possess the advan-

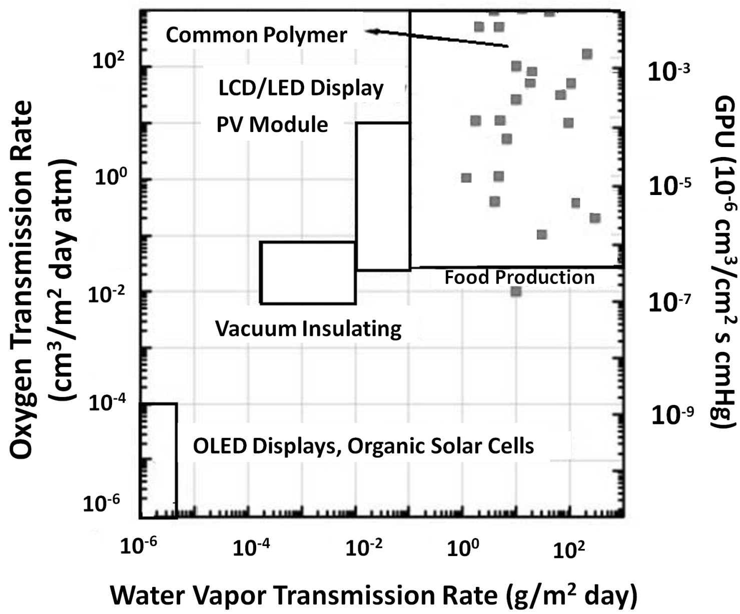

Figure 9.1: Oxygen and water vapor transmission rates of conventional polymeric barrier materials, and the requirements for various gas barrier applications. Adapted from [2], copyright (2013), with permission from Wiley Periodicals, Inc.

tages of flexibility, lightweight, transparency, etc, but have the drawbacks of relatively high permeability. By incorporating inorganic particles a polymer composite is obtained that successfully combines the advantages of the polymeric matrix and the inorganic particles, such as being impermeable to gas and water vapor. In fact, polymer nanocomposites reinforced by evenly dispersed nanoscale inorganic fillers exhibit exceptional properties, such as remarkable gas barrier, excellent solvent resistance, as well as high modulus and strength. The development of nanomaterials and their processing technologies have greatly stimulated the interest for polymer nanocomposites as barrier materials.

Gas permeation is determined by the gas solubility and its diffusion across the barrier material. The solubility coefficient refers to the amount of permeant that is absorbed by the polymer at equilibration state under certain gas or vapor pressure. The diffusion coefficient implies the rate at which gas or vapor is transported through the polymer material [3]. Gas diffusion is closely related to the dispersion, aspect ratio, and orientation of nanoscale fillers, environmental factors, and so on [4]. The chemical characteristics of both nanoplatelet and polymeric matrix, interactions between them, and fabrication process of polymer nanocomposites play important roles on gas barrier performance. The optimization of these factors is a priority for further enhancement of gas barrier properties.

This chapter reviews recent progress on nanofillers and processing technologies for gas barrier polymer nanocomposites. The influence factors on barrier properties, the improvement approaches, multifunctional characteristics, and some applications