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Review

A review on colorless and optically transparent polyimide films: Chemistry, process and engineering applications

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ABSTRACT

Recent research and development of colorless and optically transparent polyimide (CPI) films have been reviewed. CPI films possess both of the merits of conventional aromatic PI films and common polymer optical film; thus have been widely investigated as components for microelectronic and optoelectronic fabrications. The current review coveres the latest research and development for CPI films, including synthesis chemistry, manufacturing process, and engineering applications. Especially, this review focuses on the applications of CPI films as flexible substrates for optoelectrical devices, such as flexible active matrix organic light emitting display devices (AMOLEDs), flexible printing circuit boards (FPCBs), and flexible solar cells.

Contents

Introduction

Wholly aromatic polyimide (PI) films have been widely applied in engineering fields for many decades due to their excellent combined properties, including high thermal and chemical resistance, high mechanical properties, and good dielectric features [1–5]. However, in microelectronic and optoelectronic engineering, conventional PI films generally suffered from the deep colors and poor optical transmittance originated from the formation of charge transfer complexes (CTC) in their highly-conjugated molecular structures [6–8]. In recent years, with the

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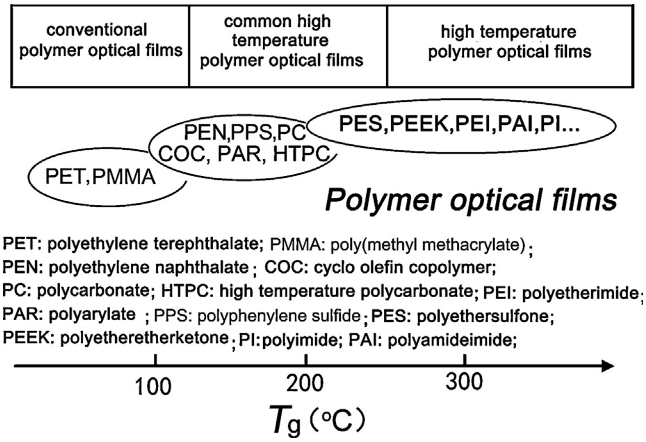

Fig. 1. Classification of polymer optical films.

rapid development of optoelectronic engineering, optical films with high thermal resistance are highly desired due to the ever-increasing demands for high reliability, high integration, and high signal transmission speed in optoelectronic devices [9,10]. For instance, in the fabrication of flexible active matrix organic light emitting display devices (AMOLEDs), the processing temperature on the flexible polymer film substrates might be higher than 300 °C [11–13]. Most of the common polymer optical films, such as polyethylene terephthalate (PET) or polyethylene naphthalate (PEN) will lose their optical and mechanical properties at such a high processing temperature. Thus, colorless and optically transparent high-temperature-resistant polymer optical films have attracted a great deal of attentions from both of the academic and engineering applications. This driving force has greatly promoted the development of polymer optical films with outstanding thermal stability.

Generally, polymer optical films could be roughly classified into three types according to their servicing temperatures or glass transition temperatures (T_g), including conventional optical films ($T_g < 100$ °C), common high temperature optical films ($100 \leq T_g < 200$ °C) and high temperature optical films ($T_g \geq 200$ °C), as shown in Fig. 1. The typical chemical structures for the polymer optical films and their T_g values are illustrated in Fig. 2. Conventional polymer optical films (PET, T_g: ~78 °C, PEN, T_g: ~123 °C, etc.) possess excellent optical transparency. However, they are facing great challenges in advanced optoelectronic engineering due to their limited service temperatures. Conversely, various high temperature polymers (polyamideimide, polyetherimide, polyimide, etc.) with good optical transparency achieve good compromise among their pale color, good thermal stability, and excellent mechanical and dielectric properties; thus have been becoming one of the hot topics in advanced polymer optical films R&D.

Considerable progress has been achieved in both of the academic development and commercialization for novel high temperature resistant polymer optical films in the past decades,. Among the novel films, colorless and transparent polyimide (CPI) films and their analogues, including polyamideimide (PAI), polyetherimide (PEI) occupy the leading edge position in advanced polymer optical films in terms of their comprehensive properties and potential market volume. In this review, the state of art and future development of CPIs in optoelectronic engineering has been reviewed. The molecular design, synthesis chemistry, film manufacturing engineering for CPI films was introduced. The applications of CPI films in several important optoelectronic fields, including flexible display, flexible printing circuit boards (FPCBs), and flexible solar cells were also presented.

Molecular design, synthesis chemistry, and film manufacturing

CPI molecular design

For the molecular design of CPIs, one of the most challenging topics might be the balance among their high-temperature stability, optical transparency, and other properties, such as mechanical properties, and dielectric characteristics. This is mainly because that in most cases, these goals contradict with each other. For instance, methodologies increasing the thermal resistance of CPI films, including introduction of rigid and highly-conjugated substituents usually inevitably deteriorate their optical transparencies at the same time, and vice versa.

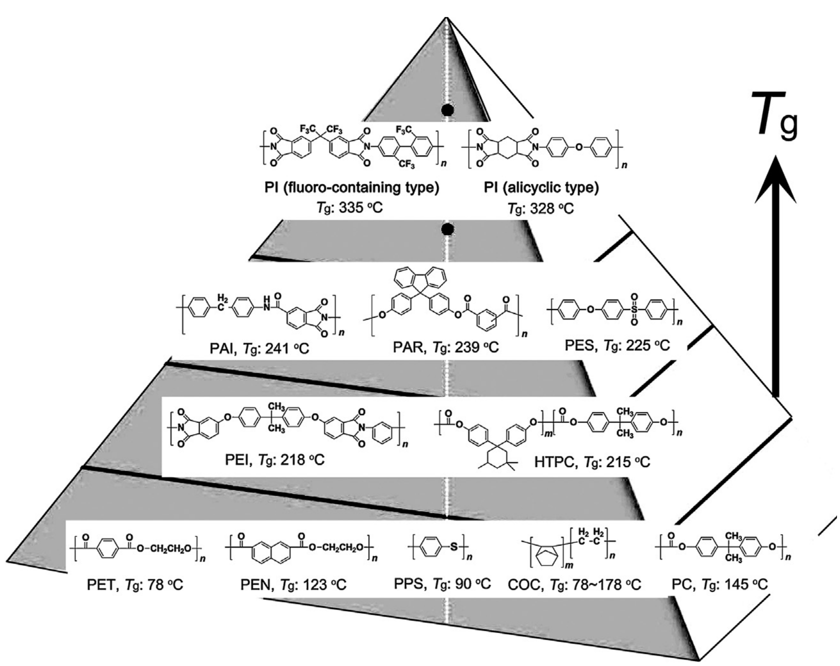

Fig. 2. Typical chemical structures and glass transition temperatures for polymer optical films.

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