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Color stability of polycarbonate for optical applications

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ABSTRACT

Poly(bisphenol A carbonate) or polycarbonate has excellent mechanical properties which, combined with its inherent transparency, makes it the material of choice for lighting applications such as lenses, light guides and bulbs but also for construction of roofing, greenhouses and verandas. With the advent of LED technology, the functional lifetime of lighting products has increased impressively and will further expand in the years to come. Also in construction applications, durability is key. Plastics will age though under the influence of heat, light and time, causing reduced light transmission and color changes. In this paper, we will indicate several key factors that determine the optical material performance and show how detrimental two specific monomer impurities are on the color performance of the resulting plastic over time.

1. Introduction

Poly(bisphenol A carbonate) or polycarbonate (PC) is used for a wide range of applications that make use of its interesting combination of mechanical and optical properties. Its high impact resistance makes it an important component in numerous consumer goods such as smartphones, tablets, computers, laptops, while due to its transparency it finds use in optical media, automotive lenses, roofing elements, greenhouses and safety glass. The developments in LED technology have led to significantly prolonged lifetimes for the lighting products in which this technology is applied. This has led to increased requirements on the durability of PC, in particular on its optical properties. In other applications such as automotive lighting, product developers feel the need to design increasingly complex shapes which cannot be made out of glass and for which the heat requirements are too stringent for polymethyl methacrylate (PMMA). Also in these applications PC is the material of choice, but the high transparency of PMMA and glass should be approached as closely as possible. PC has the tendency to develop a yellow tint due to light absorption stretching into the blue regions ($\lambda < 495$ nm) of the spectrum (Fig. 1, solid line), a tint which gets worse over time, especially at elevated temperatures. This tint can be compensated for through the addition of colorants which absorb light in the yellow region ($550 < \lambda < 650$ nm) to give a neutral tint (Fig. 1, dashed line). Absorbing both blue and yellow light however, lowers the overall transmission of the material. This is visualized in Fig. 2 by moving within the left ellipse from top to bottom. It is preferred to generate a colorless material by preventing or removing the blue light absorption which increases the overall transmission (Fig. 1, dotted line). This is visualized in Fig. 2 by moving from the left ellipse to the right one. Reducing the blue light absorption is of particular importance for products that utilize LED lights. Although there are many different LED light sources, a significant part of those that deliver white light do so by combining a

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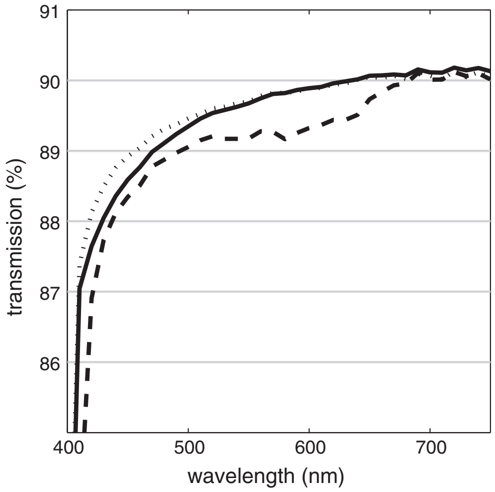

Fig. 1. Transmission spectra of polycarbonates. Solid line Lexan™ HP1140R-111 tinted polycarbonate resin (—); dashed line is Lexan™ HP1140R untinted polycarbonate resin (---); dotted line is Lexan™ LUX2110T untinted polycarbonate resin (···), all measured on 2.5 mm thick color plaques.

blue light emitting diode with phosphorous technology to shift part of this light to higher wavelengths of different colors. Nonetheless, the emission spectrum (Fig. 3) still contains a strong emission peak in the blue region. If the polycarbonate material that is exposed to such light absorbs part of the blue light, it will be converted into heat which will accelerate the aging process and increase further blue light absorption. This paper describes work on the optical properties of PC, upgrading transparency and improving the durability of this transparency by lowering the blue light absorption. In order to achieve this, the entire chain of chemical processes that leads to PC granulate has been carefully optimized.

2. Experimental

In order to test the effect of process parameters on resin color, all resins were tested in a simple, fixed formulation with only 0.05% tris(di-t-butylphenyl)phosphite as thermal stabilizer. Such a formulation may not give optimal color results in all applications, but allows differences in resin color to be observed. The formulated resins were dry blended and afterward extruded into granulate using a Coperion ZSK 25 mm, vacuum vented, co-rotating, intermeshing, twin screw extruder. The temperature profile for the barrels was: 40–200–275–285–285–285–285 °C, the screw speed was set at 300 RPM, the throughput was 20 kg/h, resulting in a torque ~55%. The strand was cooled in a water bath and pelletized. The resulting granulate was dried before molding at 120 °C for 2 h to remove volatiles. It was molded on an Engel molding machine with

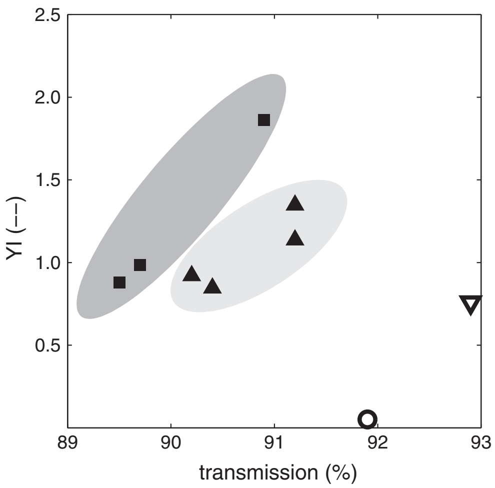

Fig. 2. Yellowness and transmission of PC compared to PMMA (▼) and standard uncoated glass (○). With colorants it is possible to move within one of the ellipsoid areas, lowering yellowness at the expense of transmission. By making process improvements, one can move from the darker area to the lighter one, lowering yellowness while gaining transmission.