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Correlating the adhesion of an acrylic coating to the physico-mechanical behavior of a polypropylene substrate

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ABSTRACT

In this study, the adhesion strength of an acrylic coating onto a polypropylene (PP) based substrate was studied. The adhesion strength of the PP containing various wt% of oxidized wax was found to be dependent on the surface free energy of the substrate. To this end, the geometric mean and the acid–base approaches were used to estimate the surface free energy, both of which shown to exist a direct relation between surface hydrophilicity and the content of the oxidized wax. The viscoelastic behavior of the adherend also contributed to the coating adhesion. The viscoelastic response of the blends was investigated using dynamic mechanical thermal analysis (DMTA) and universal testing machine (UTM) for the bulk properties of the substrate and a depth sensing indentation technique for its near-surface, respectively. Bulk and near-surface moduli were decreased as a result of incorporation of wax additive into PP matrix. These were attributed to the homogeneous distribution of low molecular weight wax chains in the polymeric matrix and hence their impact on substrate integrity. The DMTA analysis showed a single phase matrix for all blends. Using a linear trend line, the adhesion test results revealed a good correlation to surface free energy calculations compared with the substrate modulus. The weaker effect of substrate modulus on surface adhesion was ascribed to the substrate plasticity and/or development of internal stresses in the coating layer. However, the glass transition temperature of the coating suggested that the internal stresses in coating layer were responsible to relax prior to conducting adhesion measurement.

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1. Introduction

The poor adhesion of coatings to polyolefins is a real concern in industry. Different approaches have been adopted to overcome this difficulty. Due to the ease of application, the use of effective additives such as chlorinated polyolefin (CPO) or polar waxes into either polymer substrate or coating formulation has been attracted much attention [1–3]. The main properties of a substrate such as elastic modulus and elongation-at-break have been reported to be influenced by the presence of such additives. In the case of polyolefin/modified wax blends, the incompatibility of the additive with the polymer matrix is responsible for the impairment of mechanical properties [4].

In polyolefin-based substrates the presence of modified waxes was suggested to influence the wetting properties of the surface [5]. There are different mathematical approaches to estimate the surface free energy of solid polymers. In geometric mean

theory, also known as Owens–Wendt–Rabel and Kaelble approach (OWRK approach) [2,6], the polar and dispersive components of surface free energy contribute to the total surface free energy. However, the acid–base theory involves the electron donor/acceptor interactions and London–van der Waals forces to calculate the components of surface free energy more closely with surface chemical nature. The theory of acid–base, as proposed by van Oss–Good–Chaunhury (VOGC approach) [7–9], has received significant supports from many researchers recently. In both approaches, different combinations of appropriate probe liquids play an important role in calculating the components of surface free energy [10].

In the study of coating adhesion, the potential effect of substrate viscoelastic behavior has also been addressed. An analysis by Ryntz et al. [11] showed that the mold filling parameters affecting the surface crystallinity are decisive in achieving a good coating adhesion to thermoplastic polyolefins. The effect of substrate on the coating adhesion can also be considered due to the existence of the internal stresses and also because of the plastic deformation within the coating layer [12,13]. The internal stresses which appear during the

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