In situ peel test investigations of polyethylene/polybutene-1 peel systems using environmental scanning electron microscopy

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Peel systems of polyethylene/polybutene-1 (PE/PB-1) - peel films are often used in packaging, for example in food and household packaging as well as for packages of OI instruments in the medical sector [1]. In practice, a seal area between the two peel films is produced by application of heat and pressure to get a peel system, which can be re-opened with a low and defined peel force. The easy opening of such a peel system is based on the breakdown of the interface between the immiscible polymer components PE (matrix) and PB-1 (the dispersed peel component) within the seal area. For a characterization of the peel process an investigation of strucure phenomena within the seal area during the peel process is necessary with the aim to establish morphology-property correlations. To realize these dynamic experiments, the use of the environmental scanning electron microscopy is necessary, because it enables the possibility of dynamic investigations of non conducting specimens [2].

The investigated peel films consist of linear low-density PE as matrix and isotactic PB-1 (iPB-1) as peel component. The peel films have been sealed at 413 K for a period of 2 s and were then cooled in air to ambient temperature. The *in situ* investigations were performed in an ESEM Quanta 600 FEG from FEI (Eindhoven, The Netherlands), working in the low vacuum mode. An MT5000 tensile stage from Deben (Suffolk, UK) was equipped with modified clamps for the variation of the geometric parameters. The *in situ* peel tests were accompanied by the characterization of the specimens by SEM and TEM.

To characterize the peel behavior the peel force was mainly used. However, the occurring deformation energy of the seal area is not considered in the application parameter peel force. Thus, it is intend to extend the evaluation of the peel behavior by an energy-determined parameter, the adhesive energy release rate G_{aIc}, using fracture mechanics concepts [3]. The adhesive energy release rate considers the deformation of the seal area to obtain a general evaluation of the peel process.

In the present study the influence of the iPB-1 content and the influence of the peel angle on the peel properties of the peel films are investigated. The T-peel test according to ASTM D 1876 and the fixed arm peel test according to ESIS TC 4 standard suggestion were mainly used [4,5].

As a result of the *in situ* T-peel test an exponential dependence of the peel force on the iPB-1 content was found. In the correlated ESEM images the deformation zones of the seal areas of the PE films with different iPB-1 content are shown and their dimension are in good agreement with the mechanical data.

The influence of the peel angle is investigated using the *in situ* fixed arm peel test with ESEM. The peel force shows a minimum at 120–130° peel angle. The data of G_{aIc} reveal

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two characteristic ranges which are connected by a so-called transitional range θ_T. G_{aIc} is independent of the peel angle in the range 70–120° and, consequently, it can be considered as a geometry-independent material parameter. In the second range from 140° up to 180° peel angle G_{aIc} increases significantly, even though the influence of the peel angle was considered. However, the peel conditions changed in the second peel angle range. Parallel recorded ESEM images reveal two different types of crack propagation: (1) ***interlaminar***, i.e., the crack grows along the interface of the two sealed peel films and (2) ***translaminar***, i.e., the crack grows over the cross-section of the peel film (figure 1).

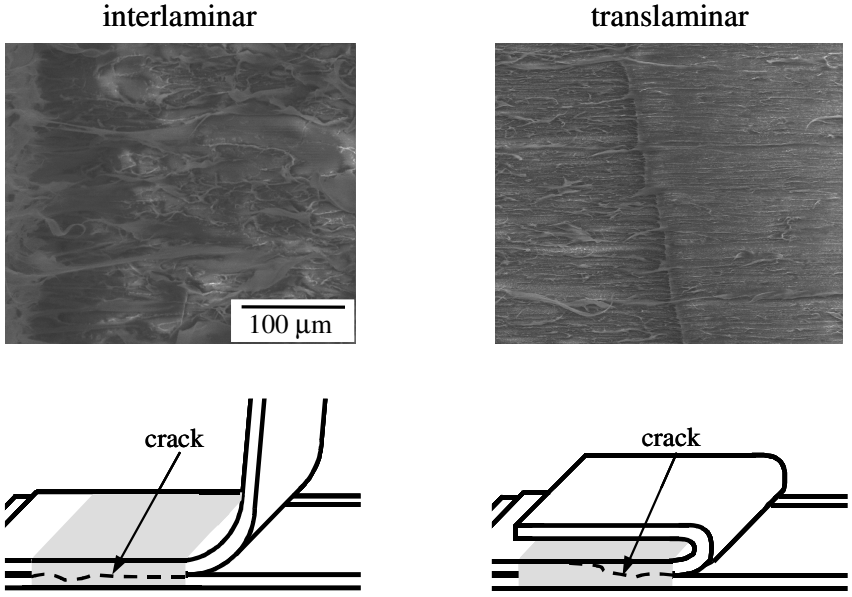

Figure 1. ESEM image of the interlaminar crack propagation (top, left) and the corresponding schematic (bottom, left), as well as the ESEM image of the translaminar crack propagation (top, right) and its corresponding schematic (bottom, right). The dashed lines represent the course of the crack.

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