

Multilayer Coextrusion Reveals Interfacial Dynamics in Polymer Blending

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by

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ABSTRACT

Blending two or more polymers together has been used as an alternative to tailor the end-use properties of polymeric materials. Most of the polymers of practical interest in blends are immiscible, thus multiple phases coexist in such blends. Their properties are dictated by the micro-morphology of each phase which develops during mixing and are determined by interfacial and rheological properties of the components. Interfacial properties and rheology interact with each other, making it difficult to clearly separate their individual effects. Coextruded multilayers provide a model system to decouple interfacial dynamics from component rheology.

In this PhD thesis work, a multilayer coextrusion line is constructed in our laboratory. This coextrusion setup is interfaced with a series of layer multiplication dies which are capable of making multilayer sheets with number of layers ranging from 2 to 2048. One unique aspect of this process is the large amount of interfacial area generated in a fast and well controlled manner, and the rheological properties of the components do not interact with the interfacial area generation up to the point of layer breakup.

Using these coextruded multilayers, a novel technique is developed to measure the interdiffusion coefficient of a high density polyethylene and a linear low density polyethylene. In this technique the interdiffusion is followed by monitoring the increase of apparent viscosity of the multilayers of these two polyethylenes. Finite element method is used to solve the interdiffusion in the multilayers, and the concentration dependent interdiffusion coefficient is calculated by fitting the measured apparent viscosity of the multilayers.

This technique is also applied to measuring the interfacial reaction kinetics in a miscible pair of polyethylene-graft-maleic anhydride/polyethylene-co-glycidyl methacrylate (PE-MA/PE-GMA) and an immiscible pair of polystyrene-co- maleic

anhydride/ polyethylene-co-glycidyl methacrylate (PSMA/PE-GMA) reactive polymers. The kinetics obtained from the rheological measurement on these multilayers is in agreement with that from FTIR spectroscopy measurement on the same system.

Comprehensive rheological measurements are done on coextruded multilayers of polypropylene/polystyrene (PP/PS) with 8, 32 and 64 layers. These measurements show strong evidence of slip at the melt interfaces of PP/PS when shear stress is above a critical value. The slip velocity is calculated and appears to be dependent on shear stress. A modified Ellis model is used to describe the relation of slip velocity to shear stress.

In addition to the rheological measurements, slip is also directly visualized at the interface of PP/PS bilayers. In this experiment, a technique is developed to imbed carbon black particles (about $1\mu m$) across the interface of a PP/PS bilayer sample. After shear, particles on each side of the interface move away from each other due to slip. The estimated slip velocity agrees with our rheological measurements. These studies provide the first reliable experimental evidence for slip.