Effect of Layer Thickness on Polymer Morphology and Physical Properties of Fluoropolymer Films Prepared by Multilayer Coextrusion

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Fluoropolymers have excellent weather, heat and chemical resistance but are expensive. The high material costs necessitate imparting additional functionality, such as high mechanical strength, to the final product. As improving the mechanical properties of the fluoropolymers themselves remains a challenge, our strategy to add functionality is to fabricate multilayers from different materials with the desired properties. However, combining fluoropolymers with nonfluorinated polymers can result in the loss of the unique advantages of fluoropolymers such as weather resistance. Therefore, it is preferable to combine different fluoropolymers. Typically, high mechanical strength along a direction (MD) can be achieved by orienting the chains along MD, say using elongational deformation. However, the sample becomes weak and brittle in the perpendicular direction (TD). Therefore, our goal is to impart significant mechanical strength along MD without significantly affecting the toughness along TD.

In this work, we have fabricated multilayers of ethylene tetrafluoroethylene (ETFE), which has an adequate balance of physical properties, and fluorinated ethylene propylene (FEP), an excellent water barrier. Keeping the total film thickness constant and varying the number of layers (3, 9, 33, 129 and 513), we varied the layer thicknesses, t_l. Planar stretching (along the flow direction, MD) was used to impart strength along MD and resulted in further reduction of t_l. For these multilayers, the mechanical properties and the polymer morphology were investigated.

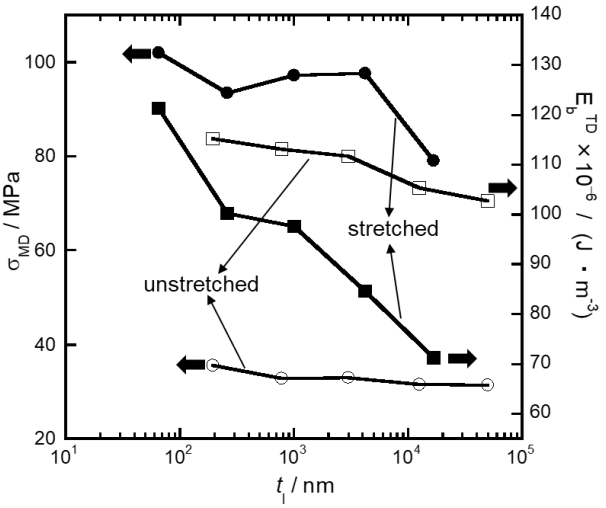

Fig.1 Variation of the energy and strength to break with the layer thickness.

Fig. 1 indicates that the mechanical strength along MD, σ_{MD}, exhibited a weak dependence on t_l for both the unstretched and the stretched films. Upon stretching, σ_{MD} increased by more than a factor of two. For the multilayers with t_l in the micron scale, this was accompanied by a significant drop in the energy at break along TD, E_b^{TD}. Upon reducing t_l, E_b^{TD} progressively increased and exceeded the E_b^{TD} for the unstretched multilayers when the t_l approached a few tens of nanometers. Small angle X-ray scattering (SAXS) results shown in Fig. 2, suggest that the increase in E_b^{TD} accompanied by a change in the structure at the nanoscale. Future work will involve further exploring the structure at different size scales and investigating the origin of E_b^{TD} increase.

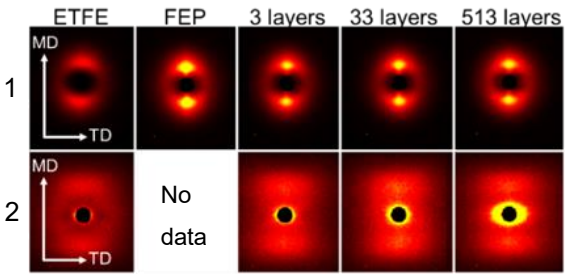

Fig.2 2D SAXS patterns of ETFE, FEP and ETFE/FEP multilayers 1) unstretched 2) stretched (MD× TD=3×1).