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Using DSC to Measure the Degree of Crystallinity in Polyethylene Waste Bags

Differential Scanning Calorimetry (DSC) is a powerful technique for measuring the thermal properties of materials, and is a popular tool for determining the percentage of crystallinity for polymers. A material's crystallinity is vital in predicting bulk physical properties including brittleness, toughness, modulus, optical properties, and more. In the case of plastic waste bags, it is especially important to understand the degree of crystallinity to ascertain how well the product will hold up to the increasing demands of waste management. Disposal bags need to be strong enough to resist tears and punctures that could cause leaks, but also require enough flexibility to stretch around lids and conform to their contents.

The Nano Analytical Testing Laboratory at Ebatco is equipped with a Netzsch STA 449 F3 Jupiter thermal analyzer. With variable furnaces, high sensitivity sensors, and simultaneous TGA capabilities, this instrument is designed to deliver accurate results in determining thermal properties including the degree of crystallinity.

Table 1 Test Conditions for Determining the Degree of Crystallinity of Polyethylene Waste Bags

Starting Temperature	Room temperature
Heating Rate	10 °C/min
Final Temperature	200 °C
Purge Gas	30 ml/min N ₂

To determine the degree of crystallinity, a baseline test was run to remove any influence from changes in the reference pan during heating before a small sample from a commercial polyethylene waste bag was placed within an aluminum crucible. The sample was heated from room temperature up to 200 °C at a constant rate of 10 °C/min, as described in Table 1.

After running the analysis, endotherms of heat flow versus temperature were observed. The enthalpy of melting ΔH_m was calculated by integrating the area beneath the peak corresponding to its phase transition. The degree of crystallinity can be calculated by comparing the ratio of the observed heat of melting to the heat of melting of a 100% crystalline reference sample, ΔH^o_m . If a recrystallization peak is present during the heating scan, it also may be necessary to subtract the associated enthalpy ΔH_c from the observed heat of melting to isolate the crystalline components present in the original sample. The resulting equation for determining the degree of crystallinity is presented here:



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$$DoC = \frac{\Delta H_m - \Delta H_c}{\Delta H^o_m} * 100\%$$

As can be seen in Figure 1, the enthalpy of melting for the waste bag was observed to be 164.4 J/g. No appreciable peaks corresponding to recrystallization were observed in the test sample. The theoretical enthalpy of melting for 100% crystalline polyethylene is known from the literature to be 293.4 J/g. By substituting the values into the above equation, a degree of crystallinity of approximately 56.03% was calculated for the commercial waste bag tested in this experiment.



Figure 1. Results from the thermal analysis of a polyethylene waste bag by DSC for determination of the degree of crystallinity.