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APPLICATION NOTE

Raman Spectroscopy as a Tool for Studying Polymer Phase Transitions

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Introduction

Semicrystalline polymers, such as polyethylene, are the largest group of commercially produced plastics. Heating and cooling between phase transitions is used in industry for shaping these polymers into their final product. A phase transition occurs when a substance changes from one state e.g. from a solid to a liquid.

Polymers can be classified as either amorphous or crystalline. Crystalline polymers are highly ordered which provides strength and rigidity, in amorphous polymers the molecules are randomly ordered and this allows for flexibility and elasticity. Two transitions that polymers can go through, studied in this application note, are the melting transition and the glass transition. The melting transition refers to changing from solid to liquid, and is only seen in crystalline polymers. The glass transition occurs in amorphous polymers and is gradual and reversible. An amorphous sample would change from a hard "glassy" state to a rubbery or viscous state. Polymers are generally a mix of the two, termed semicrystalline, and thus can have both a glass and melting transition.

Raman spectroscopy can be used to determine the glass transition temperature, melting transition temperature, and occurrence of crystallinity. Peak intensities provide identifying changes in the complex molecular organization and therefore the temperature of transition such as the glass transition. In this application note we investigated the phase transitions occurring in polyethylene and nylon-6 using the TR56000 Raman Microscope and a temperature stage.

Materials & Methods

Polyethylene and nylon-6 powders were purchased from Sigma Aldrich and loaded into a quartz cuvette. The powders were analyzed using an TR56000 Raman Microscope equipped with a 785nm laser and a Linkam TR65000 temperature stage. This temperature stage allows measurements from -193°C to 100°C.

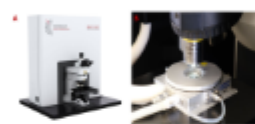


Figure 1: TR56000 Raman Microscope & temperature stage

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Results & Discussion

Polyethylene

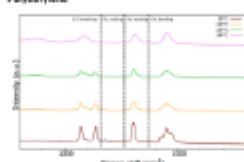


Figure 2: Raman spectra of polyethylene at various temperatures

Figure 2 shows the Raman spectra for polyethylene at four different temperatures. The crystalline phase, shown here at 30°C, has characteristic narrow Raman bands. This is due to the strict organization of the polymer in this state with trans-unit conformation. As the polymer heated it moves into the amorphous state and the polymer becomes more disorganized with gauche-rich conformations, meaning the Raman bands become broader. It can clearly be seen from these Raman spectra that by 245°C the polyethylene sample has gone through the melting transition and is in the amorphous phase.

Nylon-6

Raman Spectroscopy as a Tool for Studying Polymer Phase Transitions

Semicrystalline polymers, such as polyethylene, are the largest group of commercially produced plastics. Heating and cooling between phase transitions is used in industry for shaping these polymers into their final product. A phase transition occurs when a substance changes into a different state e.g. from a solid to a liquid. In this application note a Raman microscope, with a heated stage, is used to observe phase transitions in two polymers; polyethylene, and nylon-6.

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