

BN 1394

Evaluating Polymer Cure Using Raman Spectroscopy

Discussion

Raman spectroscopy is a powerful nondestructive tool for analyzing the degree of cure of polymers such as polyimides, epoxies and acrylates. A high degree of curing is important to obtain desired physical properties or minimize the amount of low molecular weight material (e.g., monomer or oligomer) that could dissolve or volatilize out of the polymer during use. The example shown in Figure 1 illustrates the polyimide curing process, called imidization, in which polyamic acid is heated to produce a conversion to polyimide. The polyimide is fully cured when no amide groups (-CONH) of polyamic acid are left over. The Raman band due to the CONH amide group (mainly C-N stretching) is located at 1350 cm^{-1} and the polyimide C-N stretch is blue-shifted at $\sim 1400 \text{ cm}^{-1}$ (Figure 2). The relative intensity of these bands can be used for measuring the degree of imidization. The top spectrum in Figure 2 is typical of a fully cured polyimide, as only imide C-N stretch is present at 1400 cm^{-1} . The bottom spectrum represents a partially cured polyimide (Figure 2). Based on the peak areas of the 1350 & 1385 cm^{-1} bands, the polyimide represented by the bottom spectrum is approximately 86% cured. The relative blue-shift of the imide C-N stretch band could be also used for imidization evaluation after a calibration process. Other Raman bands (carbonyl stretch at $\sim 1780 \text{ cm}^{-1}$ etc.) can be used for polymerization evaluations, such as the chain length of polyimides.

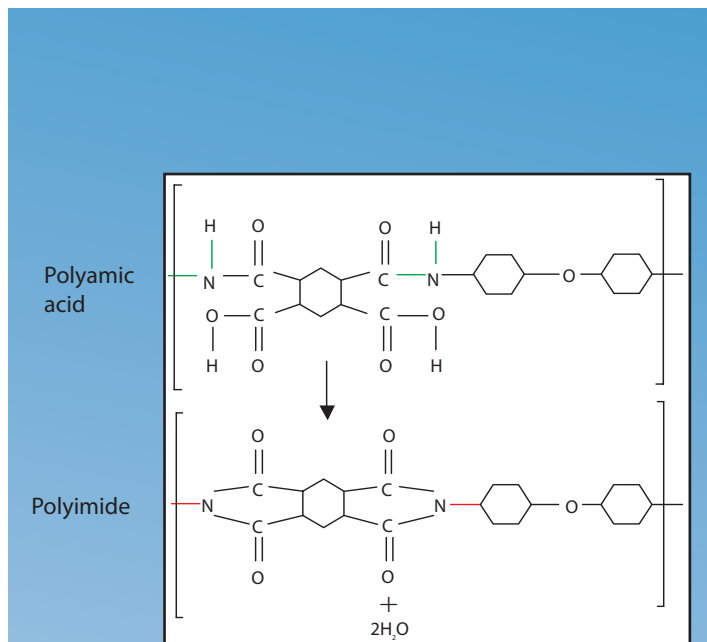


Figure 1

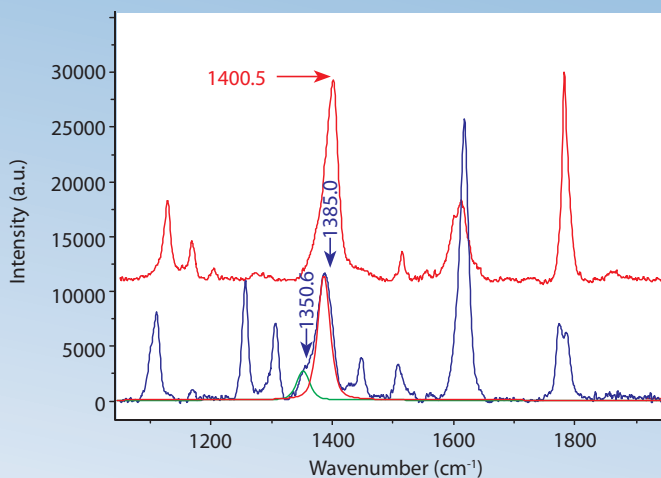
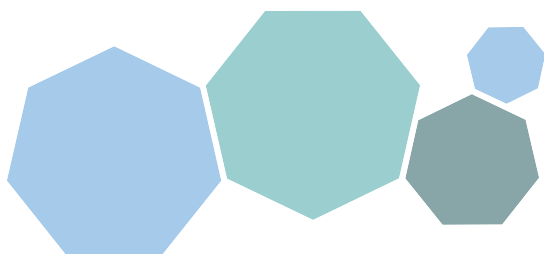


Figure 2



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