Relaxation processes in polymer nanocomposites

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This work investigates the viscoelastic melt rheology of a range of polycarbonate - multi-walled carbon nanotube (PC-MWCNT) nanocomposites with varying matrix molar mass. The aim is to identify the roles played by nanotubes and matrix polymer on different aspects of the viscoelastic response: time–temperature superposition (TTS) and relaxation processes. There is considerable industrial interest in these materials because of their potential in melt-processable conductive packaging.

Small amplitude oscillatory shear rheometry was performed on four grades of PC (M_w = 33.6 – 50.5 kg mol^{-1}) filled with 3 wt% Nanocyl NC7000 MWCNTs, melt-compounded in a twin screw extruder, and on the virgin polymers. Mastercurves were constructed from isothermal frequency sweeps using both vertical and horizontal shift factors obtained with an in-house TTS tool. The nanocomposites exhibited a second plateau at ~10^5 Pa, and tan δ < 1 throughout the extended frequency range. The two-phase model of Song and Zheng (Polymer 51 (14) 3262–3268) was fitted to the mastercurves, and suggests no pronounced strain amplification of the polymer due to the presence of CNTs. Hence, the stiffness of the CNT network corresponds to the second plateau.

Nanocomposite relaxation timescales, obtained from the peak in tan δ, were found to scale with the weight-average molar mass of the polymer matrix, in the same way as reptation times scale for unfilled polymers. This supports the view that the dominant relaxation mechanism in these nanocomposites is the relaxation of the polymer network.