Dielectric spectroscopy and thermally stimulated depolarization currents on carbon nanotube – polycarbonate composites

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Dielectric Relaxation Spectroscopy (DRS) in the frequency range between 10^{-4} to 10^{7} Hz [1] together with Thermally Stimulated Depolarization Currents in the temperature range -180 – 200 ^{o}C are presented for composites of polycarbonate (PC) filled with different amounts of multiwalled carbon nanotubes (MWNT) varying in the range between 0.5 and 5 wt%. The composites were obtained by diluting a PC based masterbatch containing 15 wt% MWNT by melt mixing using a Micro Compounder.

From DC conductivity measurements it was found that for samples processed at a mixing screw speed of 150 rpm for 5 minutes the percolation occurs at a threshold concentration (p_c) between 1.0 and 1.5 wt% MWNT. For concentrations of MWNT near the percolation threshold the processing conditions (screw speed and mixing time) were varied. The differences in the dispersion of the MWNT in the PC matrix could be detected in the complex permittivity and AC conductivity spectra and have been explained by changes in p_c. The AC conductivity and permittivity spectra are discussed in terms of charge carrier diffusion on percolation clusters and resistor-capacitor composites.

For the samples below the percolation threshold, DRS measurements in a wide temperature range provide information about the molecular mobility in the polymer matrix, concerning both local relaxations and larger-scale motions related to the glass transition. Therefore, the effect of the MWNT and of their state of dispersion on the glass transition of the polymer as well as on local relaxations can be followed. The results are compared to those obtained from other polymer/carbon nanocomposite systems. In many polymer nanocomposites an interfacial layer of polymer with altered structure and chain mobility in the vicinity of the filler particles has been found. DRS measurements can also give evidence for the existence of this layer in the MWNT composites. Finally, the temperature dependence of the dc conductivity can also contribute to the understanding of the conduction mechanism in the composites.

The materials were also studied by thermally stimulated depolarization currents (TSDC) in a wide temperature range. TSDC is sensitive both to dipolar relaxations in the polymer matrix and to charge transfer inside and between, clusters of MWNT. Because of its low equivalent frequency and the availability of special techniques such as fractional polarization and partial heating, the TSDC technique is well suited to the study of multiple overlapping polarization mechanisms, as is the case with these materials. An attempt is made to correlate the results with those from DRS measurements.

[1] P. Pötschke, S. M. Dudkin, I. Alig, Polymer 44 (2003) 5023–5030