APPLICATION NOTE
CARBON NANOTUBES

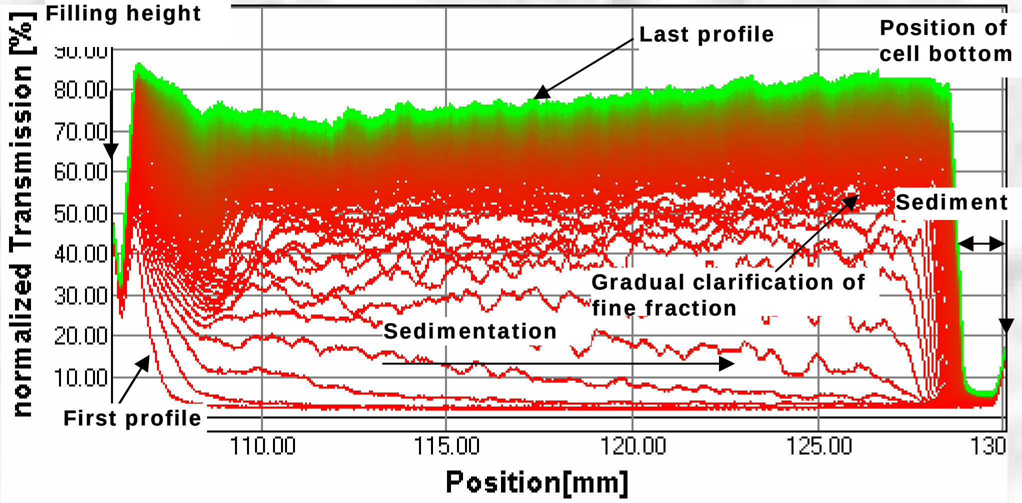
Stability Analysis of Multiwalled Carbon Nanotube Dispersions
Different products and different dispersion media

1. Introduction

Due to the unique physical and electric properties of carbon nanotubes (CNT), carbon fibers have highest thermal conductivity and highest strength of any known material, they are used in a wide range of applications. CNT can be used as semiconductors, too.
Current production volume of multiwalled CNT (MWNT) decreased their price down to a level enabling a use as filler in commercial thermoplastic products. Further applications include the use of CNT to control the properties of magnetorheological fluids, including their sedimentation velocity.
Multisample analytical centrifugation, based on STEP®-technology, is suitable for the qualitative and quantitative characterization of the sedimentation behaviour of different CNT dispersions, as shown in examples below.
Two different products (MWNT A & B) with a concentration of 0.1% m/m, dispersed in ionic liquid (1-butyl-3-methylimidazoliumtetrafluoroborate) were compared.

2. Fingerprinting of the dispersions – Different products

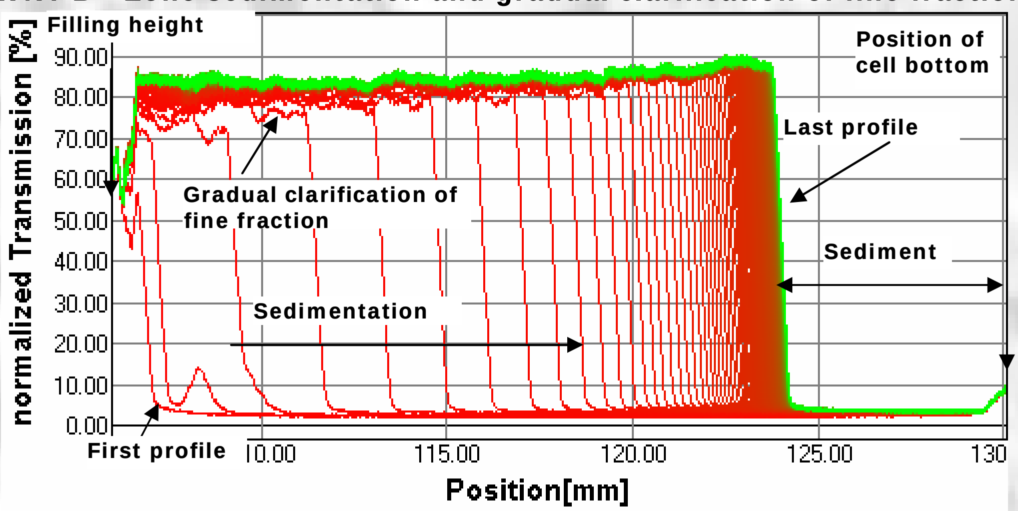
MWNT A - Polydisperse sedimentation



MWNT A, Evolution of transmission profiles with time at 2300 xg, 20 °C.

The transmission profiles represent the concentration profiles of particles, low transmission = low concentration and high transmission = high concentration.
The separation process of MWNT A is characterized by a polydisperse sedimentation, particles and flocs move independent of each other with different speed. Only close to the sediment a sharp front is formed, due to the compaction of the sediment. The shape of the transmission profiles (spikes) indicates the existence of large flocs.

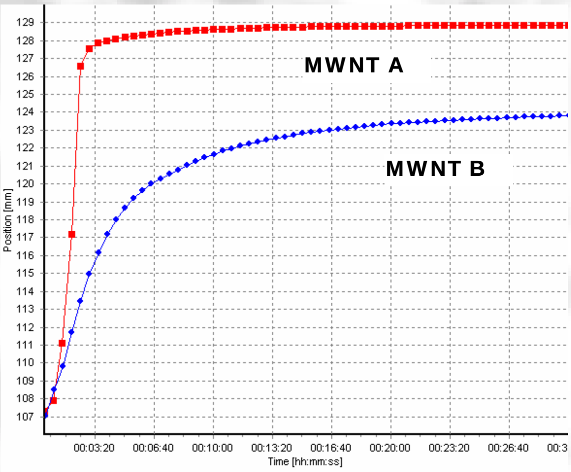
MWNT B - Zone sedimentation and gradual clarification of fine fraction



MWNT B, Evolution of transmission profiles with time at 2300 xg, 20 °C.

The evolution of the transmission profiles for MWNT B is characterized by a sharp sedimentation front (the particles sediment as a collective). The distance between two consecutive profiles is decreasing, the resistance against compaction is continuously increasing. This is typical for dispersions with particle aggregates and attractive particle-particle interactions, building a network structure. A gradual clarification of fines is observed, which are not part of the network structure.

3. Sedimentation velocity and Packing density for different products



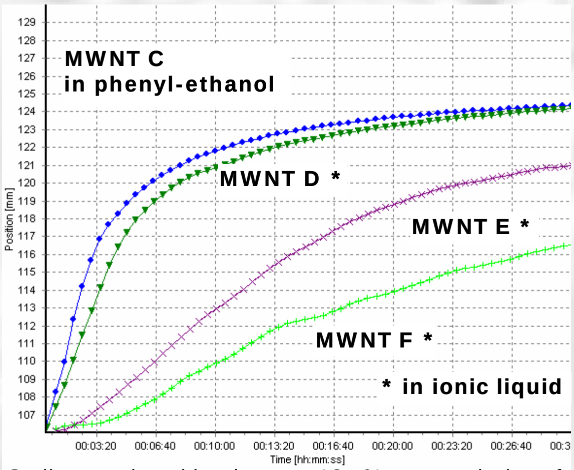
Sedimentation kinetics at 10 % transmission for range 106 – 130 mm, at 2300 xg, 20 °C

The detailed analysis of the demixing kinetics is obtained applying the front tracking mode, following the movement of the phase border supernatant-particle containing phase, at a transmission value of 10 %.
While for MWNT B here the zone sedimentation is followed, for MWNT A the movement of the largest particles is monitored, i.e. the corresponding sedimentation velocity is higher (slope within the initial range of the curves).
Near the equilibrium sediment height an abrupt deceleration of velocity is detected for MWNT A, as typical for colloid-chemical stable dispersions.
MWNT B sediments slower and the packing density is significantly smaller (the sediment height is bigger).

The samples can be distinguished referring to the sedimentation velocity within few minutes.

4. Sedimentation velocity in different dispersion media

Different MWNT products C-F (0.1% m/m, C dispersed in phenyl-ethanol, D, E, F in ionic liquid *1-butyl-3-methylimidazolium-*tetrafluoroborate) were compared with respect to the sedimentation velocity. Their transmission profiles are similar to MWNT B.
The reasons for the different sedimentation velocities are found in size and density of flocs as well as in the sedimentation hindering by the network.
Comparing the different dispersion media, their viscosity and density influence the sedimentation process, too.
The resulting order of stability is F (most stable)> E > D > C (least stable).



Sedimentation kinetics at 13 % transmission for range 106 – 130 mm, at 2300 xg, 20 °C

5. References

- Particle size distribution of Carbon Nanotubes according to ISO 13318-1 and ISO 13318-2, Application note L.U.M. GmbH
- STEP-Technology see www.lum-gmbh.com/pages/technology.htm
- Dispersion, agglomeration, and network formation of multiwalled carbon nanotubes in polycarbonate melts, S. Pegel et al., Polymer (2008), doi:10.1016/j.polymer.2007.12.024