A versatile latex-based route furnishing polymer/carbon nanofiller composites

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***C.E. Koning*,[a]** N. Grossiord,[a] M.C. Hermant,[a] J. Loos,[a] K. Lu,[a] , J. Yu,[a] J. Meuldijk,[a] P. v.d. Schoot,[a] H. Miltner,[b] B. Van Mele,[b] O. Regev[c]
[a]Eindhoven University of Technology, P.O. Box 513, 5600 MB Eindhoven, The Netherlands.
[b] Free University of Brussels, PSSC, Pleinlaan 2, B-1050 Brussels, Belgium
[c] Ben-Gurion University of the Negev, 84105 Beer-Sheva, Israel
e-mail : c.e.koning@tue.nl

A versatile, latex-based concept for dispersing Single and Multi Wall Carbon Nanotubes (S/MWNTs) in a highly viscous polymer matrix is described [1]. The first, crucial step of the concept is the ultrasound-driven exfoliation of the as produced SWNT and MWNT bundles in water, containing surfactant for the stabilization of the obtained dispersion. By applying UV/Vis spectroscopy, the minimum required energy input for obtaining the maximum attainable degree of exfoliation of the nanotubes could be determined [2]. The exfoliation process was also directly visualized with cryo-TEM images, which were in agreement with the collected UV/Vis data.
The surface coverage of exfoliated carbon nanotubes with sodium dodecylsulfate (SDS) surfactant molecules was determined by thermogravimetric analysis, UV-Vis spectroscopy, surface tension measurements and a variant of Maron's titration [3]. All four methods, applied to aqueous mixtures of carbon nanotubes and the surfactant SDS, consistently yielded a surface coverage of approximately 2-3 SDS molecules per square nanometer, which is comparable to the known maximum packing density of SDS at the air-water interface and in agreement with the theoretical value calculated with the Gibbs equation for surface excess.
The second step of the concept is mixing the stable aqueous CNT dispersions with polymer latex, preferably stabilized by the same surfactant as the CNT dispersion. The third step implies freeze-drying, followed by melt processing of the obtained powder into a polymer film.
The extremely high aspect ratio of the CNTs, along with the very efficient way of dispersing them, generates a percolating network of the SWNTs in a highly viscous polystyrene (PS) matrix, which becomes semi-conductive for SWNT amounts as low as 0.2-0.3 wt %. For commercially available MWNTs, having a lower aspect ratio, the percolation threshold is around 1-2 wt%.
Depending on the molar mass distribution of the PS matrix in PS/SWNT nanocomposites, the well-dispersed CNTs significantly raise the Tg of the PS. A low molar mass PS fraction, probably acting as a wetting agent for the SWNTs and replacing SDS at the CNT surface during melt processing, seems to be required for an improved PS/SWNT interaction [4].
The versatility of the 'latex concept' is demonstrated for semi-crystalline polypropylene/CNT nanocomposites, prepared from aqueous PP emulsions. For this system, a very low percolation threshold was found, and the extremely well-dispersed CNTs proved to be excellent nucleation agents for PP, raising the crystallization temperature by ca. 15 ºC.
Three attempts to enhance the conductivity properties of our polymer/CNT nanocomposites will be briefly described, *viz.*(1) the use of high quality, vertically grown MWNTs, (2) the replacement of SDS surfactant by conductive surfactants, lowering the contact resistivity, and (3) the manufacturing of conductive PS foams with reduced percolation thresholds.
Finally, the latex-concept was also successfully applied for the manufacturing of polymer/graphene nanocomposites.

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[3] N. Grossiord et al., *Langmuir*, **2007**, *23*, 3646
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