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Product Information

Carbon Nanofibers

Technical Bulletin AL-270

Processing and Dispersing

Product Description
Carbon nanofibers (CNFs) are discontinuous, highly graphitic, highly compatible with most polymer processing techniques, and can be dispersed in an isotropic or anisotropic mode. They have excellent mechanical properties, high electrical conductivity, and high thermal conductivity, which can be imparted to a wide range of matrices including thermoplastics, thermosets, elastomers, ceramics, and metals. Carbon nanofibers also have a unique surface state, which facilitates functionalization and other surface modification techniques to tailor/engineer the nanofiber to the host polymer or application.

Procedures
A. Dispersion into aqueous sytems
Carbon nanofibers are hydrophobic and will consequently not disperse well in water. Surfactants such as poly(ethyleneimine) PEI and polyisobutylene succinimide (PIBSI) have proven to be helpful in dispersing and maintaining the CNFs in a stable suspension. Organic solvents miscible in water, such as isopropyl alcohol, can also be used to disperse nanofibers in water if the mixture is processed within 24 hours.

B. Dispersion into organic solvents with ultrasonication
Ultrasonication is typically the preferred method to disperse CNFs into low viscosity organic solvents. Dispersion is accomplished by the formation and collapse of bubbles, also known as cavitation. This sequence of events generates local ultra-high shear rates, as high as 10^9 s^{-1} and pressure gradients that cause dispersion and breakage of the nanofibers.[1] An ultrasonication time of 20 minutes at moderate intensity is recommended to maximize dispersion and minimize length reduction.
Note: Extended ultrasonication times can significantly alter the morphology and aspect ratio of the nanofibers, reducing the conductivity of the final composite.

C. Dispersion into thermoplastics
If available, a co-rotating twin screw extruder (co-TSE) should be used. Co-TSEs are proven to be more effective in distributing and dispersing CNFs in thermoplastics when compared to counter-rotating or single screw extruders.[2] For maximum electrical conductivity, the CNFs should be fed downstream, after the polymer is molten to avoid fiber breakage. Lower melt viscosities and residence time will aid the formation of a network, which can be done by increasing the processing temperature. Higher melt viscosities and screw speeds, which are dependent on the polymer type and processing equipment, will improve dispersion and mechanical properties.

D. Dispersion into thermosets
Centrifugal planetary mixers are recommended for dispersing nanofibers in thermoset resins and other low viscosity fluids. By simultaneously revolving and rotating the container, a centrifugal planetary mixer pushes the material to the outer circumference of the mixing container, creating a strong whirlpool flow in the materials themselves.
Note: Although most CNF suspensions are quite stable, the suspensions should not be stored for long periods of time to avoid potential settling. The rate of settling is dependent on the viscosity of the resin carrier.

References
1. Leer, C., Carbon Nanofibers Thermoplastic Nanocomposites: Processing – Morphology – Properties Relationships. Ph.D. Thesis, University of Minho (Minho, Portugal: 2010).
2. Huang, Y.Y. et al., Strength of Nanotubes, Filaments, and Nanowires From Sonication-Induced Scission. Adv. Mater., **21**, 3945-3948 (2009).

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