Adjusting Permittivity by Blending Varying Ratios of SWNTs

High, intermediate, and low permittivity values can be tailored for specific applications.

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A new composite material of single-walled carbon nanotubes (SWNTs) displays radio frequency (0 to 1 GHz) permittivity properties that can be adjusted based upon the nanotube composition. When varying ratios of raw to functionalized SWNTs are blended into the silicone elastomer matrix at a total loading of 0.5 percent by weight, a target real permittivity value can be obtained between 70 and 3. This has particular use for designing materials for microwave lenses, microstrips, filters, resonators, high-strength/low-weight electromagnetic interference (EMI) shielding, antennas, waveguides, and low-loss magneto-dielectric products for applications like radome construction.

High permittivities contain higher ratios of raw SWNTs, while lower permittivity values contain higher ratios of functionalized SWNTs. The functionalized SWNTs contain t-butyl aryl groups that allow for good dispersion in the composite due to favorable interactions between the functional groups and the matrix. The functionalized SWNTs are prepared using diazonium chemistry with raw, HiPco-produced SWNTs and t-butyl aniline. Various ratios of raw functionalized SWNTs totaling 0.5 percent by weight (to the elastomer matrix) composition of nanotubes (weight does not include the added functional groups) are first dispersed in chloroform via bath sonication. The dispersion is then solvent-blended in chloroform with Part A of the NuSil silicone elastomer R-2625. After the solvent is removed through flowing air, the mixture is dried further in a vacuum oven at 60 °C. Part B of the NuSil silicone elastomer R-2615 (10 percent by weight to Part A) is added to the sample and mixed until an even distribution is achieved. The sample is allowed to evacuate in a vacuum desiccator for approximately one hour to remove any air bubbles that are trapped within it. The sample is then thermally cured at ≈200 °C for approximately two hours. At this point, the sample is ready to be tested for dielectric permittivity measurements.

One limitation in this material occurs when there is a variance in the SWNTs that is produced via the HiPco process. If the tubes vary from batch to batch, it is possible that the electric properties of resulting composites may be affected. This, in turn, could also affect the uniformity of the resulting SWNTs that are functionalized. The best consistency in data trends is observed when the composites are made from the same batch of raw and functionalized SWNTs.

It is expected that, in order for the materials described above to be used in the field of microwave radar devices, other additives and components most likely will be incorporated, depending on the intended application. Some examples may include a magnetic component for magneto-dielectric materials, as well as changing the type of polymer host matrix. In addition, metallic particles could be added (1 to 100 weight percent) to bring up the permeability to ranges that equal the permittivity.

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