Electromagnetic Interference Shielding via Carbon Nanotubes

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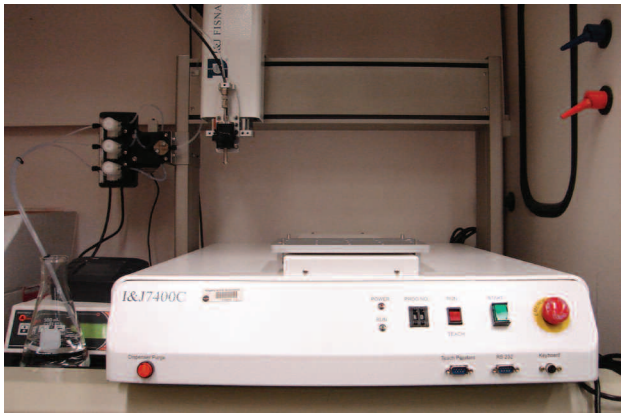
This article is dedicated to the memory of our friend and colleague David Beverly

The Applied Nanotechnology Team at NASA's Johnson Space Center (JSC) is an interdisciplinary team working to answer technological challenges faced by exploration and human spaceflight. The team works in concert with the whole of the NASA community as well as academic, industrial, and other government collaborators to identify and solve these challenges. Laptop computer screens in space vehicles present one such challenge. Laptop computer screens are among the major violators of NASA's electromagnetic interference (EMI) requirements. Development of a good EMI-shielding material, which is also transparent, is required for compliance. This is a technology development that has been requested by the Space Station Program Office and Engineering Avionics Division, and will also be a benefit to the Constellation Program.

The Applied Nanotechnology Team is working to deliver this technology through nanomaterial-based, transparent, conductive coatings. Coatings with transmittance of at least 90% and a shielding effectiveness (SE) of 15 dB over a wide range of frequencies will allow laptops to meet current requirements. Although an SE of 15 dB will serve the current need, shielding as high as 40 dB is being pursued for future applications. Shielding effectiveness is achieved through absorption and reflection, and improves with increased surface conductivity. The nano-size, large-aspect ratio and conductive carbon structure of carbon nanotubes enables thin coatings of these to be simultaneously transparent and highly conductive. Conductivity depends on the weight percent of carbon nanotubes added, as well as nanotube quality and dispersion.

Well-dispersed nanotubes suspended in various solvents are spray-coated onto substrates. Single-wall carbon nanotubes (SWCNTs) have been used, to date. The SWCNTs are produced primarily via the high-pressure carbon monoxide process, as well as via laser ablation and chemical vapor deposition. Polymeric substrates are investigated, as polymeric materials are typically lightweight and are also often flexible and transparent. Proper selection of solvent/substrate combinations is necessary for sufficient substrate wetting and appropriate solvent evaporation rate to result in a continuous nanotube coating. To date, sonicated nanotube suspensions have been sprayed onto various substrates using a handheld air brush and have resulted in films of marginal uniformity, as determined via optical and scanning electron microscopies. The recent acquisition of an integrated spray system will allow for more accurate, controlled, and reproducible application of coatings of well-dispersed nanotube suspensions to substrates. The integrated system is comprised of an ultrasonic spray head, a ceramic tri-pump, and an X-Y positioning dispensing robot. Spraying ultrasonically is imperative for coating with nanotube dispersions, as nanotubes must be sonicated continuously to produce a well-dispersed solution, else aggregates of nanotubes can form and the resultant coatings are nonuniform. The ceramic tri-pump provides a smooth, continuous flow,

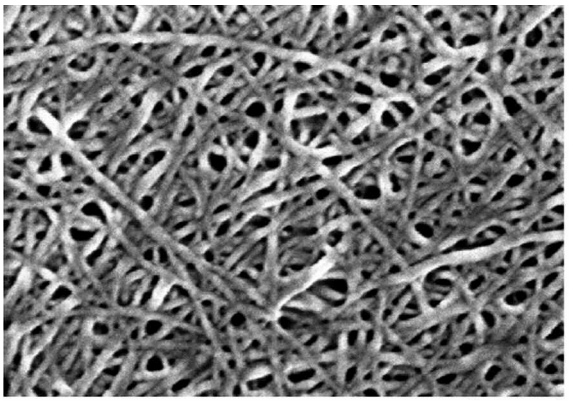


The integrated spray system is comprised of an ultrasonic spray head, a ceramic tri-pump, and an X-Y positioning dispensing robot for accurate, controlled, and reproducible application of coatings of well-dispersed nanotube suspensions to substrates.

which prevents starting and stopping of the fluid stream, and, together with the X-Y positioning dispensing robot, will help achieve uniform nanotube coatings. Collaborators have additional promising processing techniques.

Surface resistivity and electromagnetic shielding effectiveness of the samples are measured for film performance. Samples are also characterized via optical and scanning electron microscopies, as well as Raman spectroscopy, to examine structure-property relationships. Surface resistivity is determined both in standard atmosphere and in dry conditions. Electromagnetic shielding effectiveness is tested according to ASTM D 4935-89, the American Society for Testing and Materials (ASTM) standard for measuring the electromagnetic shielding effectiveness of planar materials. This standard is valid over an approximate frequency range of 30 MHz to 1.5 GHz. Shielding effectiveness testing is done by the Avionics Systems Division at JSC for immediate validation by the ultimate customer. To date, preliminary shielding effectiveness tests of thin nanotube coatings on polymer substrates produced at JSC, as well as those produced by various academic and industrial collaborators, have shown that moderately effective shielding can be obtained with extremely simple introductions of carbon nanotube coatings. Collaborators with samples in testing include Nanosonic, Inc., Rice University, The University of Texas (UT) at Dallas, and University of Florida.

Currently, a material sample with a diameter of 13.3 cm is required for shielding effectiveness testing. Efforts in the laboratories of a UT-Pan American University collaborator will allow for smaller sample sizes as well as an increase in frequency range. The capability to test smaller samples will be key to screening samples before investing resources in scale-up to larger sample production. Scale-up to a size suitable to cover a laptop computer screen, and subsequent testing for radiated emissions is the ultimate goal in the near term. The material could then be applied to laptop computers already flying on the International Space Station, and later applicable to future missions such as the Crew Exploration Vehicle and Lunar Outpost, where laptop computers will be used near other electronic equipment.



The morphology, as elucidated via scanning electron microscopy, of a nanotube coating that exhibited favorable shielding effectiveness.