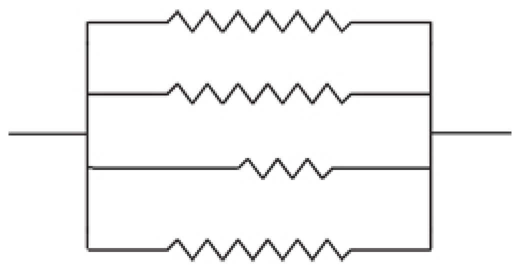
Conductive Composites Made Less Expensively

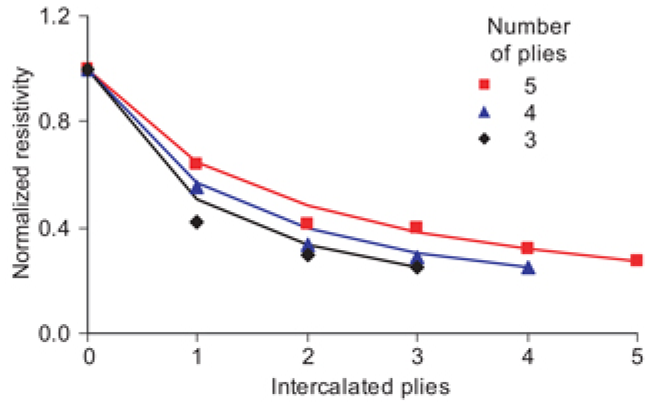
The use of electrically conductive composite structures for electrostatic dissipation, electromagnetic interference shielding, and ground return planes could save between 30 and 90 percent of the mass of the structure, in comparison to aluminum (ref. 1). One strategy that has been shown to make conducting composites effectively uses intercalated graphite fiber as the reinforcement. Intercalation--the insertion of guest atoms or molecules between the graphene planes--can lower the electrical resistivity of graphite fibers by as much as a factor of 10, without sacrificing mechanical or thermal properties.

But what can you do if your requirements call for a material with a higher conductivity than that of graphite epoxy composite, and intercalated graphite composite exceeds your budget? A cost-effective alternative might be a laminar composite in which just some of the graphite fiber plies are intercalated. Scientists at the NASA Glenn Research Center have found that constructing laminar composites with just one ply of intercalated graphite fibers combined with three plies of pristine graphite fibers results in a composite resistivity that is one-half that of the fully pristine composite.



A simple four-resistor parallel circuit is electrically equivalent to a four-ply composite. In this figure, the short resistor represents a layer of lower resistance (i.e., intercalated) fibers.

Through constructing many different laminar composites using woven graphite fiber fabrics with a different resistivity in each layer, it was found that the resistivity of laminar composites follows a parallel-circuit model (see the preceding sketch). Since bromine intercalation lowers the fiber resistivity by a factor of 5, one ply of bromine-intercalated Thornel (Cytec Engineered Materials, Tempe, AZ) P-100 graphite fiber (50-μΩ-cm) combined with three plies of pristine P-100 graphite fiber (250-μΩ-cm) results in a composite resistance half that of a composite made solely from the pristine fibers. This very simple model does not take into account such factors as the variation in the volume fraction of the fiber, which can be very important. But even at that, the data were found to be a very close fit for three-, four-, and five-ply composites (see the graph). The results were the same whether the intercalated fibers were in surface layers or buried layers.



Points represent the experimentally measured (resistivity/resistivity of pristine fiber composite) of three-, four-, and five-ply graphite fiber-epoxy composites as a function of the number of plies intercalated with bromine, with the remaining plies pristine. The lines show the results from the parallel resistor model.

The implication of this work is that the most cost-effective solutions to filling the needs of specific applications may involve composites in which a single layer carries most of the electrical load, while all the layers share the mechanical load.

Reference

1. Gaier, J.R.: Intercalated Graphite Fiber Composites as EMI Shields in Aerospace Structures. IEEE Trans. Electromag. Compat., vol. 34, issue 3, 1992, pp. 351-356.

Glenn contact: Dr. James R. Gaier, 216-433-6686, James.R.Gaier@nasa.gov
Author: Dr. James R. Gaier
Headquarters program office: OAT
Programs/Projects: High-conductivity, low-weight applications such as electromagnetic shielding enclosures and ground planes