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Technical Evaluation of Russian Aircraft Stealth Coating and Structural Materials

Frank D. Gac*, Ainslie T. Young, Jr., and Albert Migliori,

Abstract

This is the final report of a one-year, Laboratory-Directed Research and Development (LDRD) project at the Los Alamos National Laboratory (LANL). Treating aircraft, missiles, and ships with materials that absorb electromagnetic energy continues to be an important technique for reducing a vehicle's radar cross section (RCS) and improving its combat effectiveness and survivability. Work at the Russian Scientific Center for Applied Problems in Electrodynamics (SCAPE) has produced and experimentally validated an accurate predictor of the interaction of electromagnetic radiation with discontinuous composite materials consisting of magnetic and/or dielectric particles dispersed in a non-conductive matrix (i.e. percolation systems). The primary purpose of this project was to analyze rf-absorbing coatings and validate manufacturing processes associated with the Russian percolation system designs. An additional objective was to apply the percolation methodology toward a variety of civilian applications by transferring the technology to US industry.

1. Background and Research Objectives

Treating aircraft, missiles, and ships with materials that absorb electromagnetic energy continues to be an important technique for reducing a vehicle's radar cross section (RCS) and improving its combat effectiveness and survivability. A Soviet center for the development of these "ElectroMagnetic (EM) absorbing materials" technologies was at the Institute for High Temperatures of the Russian Academy of Sciences in Moscow. The Institute, now known as the Russian Scientific Center for Applied Problems in Electrodynamics (SCAPE), had the direct responsibility for the development of RCS materials since 1987. Under the current government, these formally classified technologies may become available on the world market

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on a first come, first served basis. SCAPE is presently outfitting demonstration aircraft for several countries around the world. SCAPE is very concerned about proliferation of their technology and has expressed a strong preference to share this technology on an exclusive basis with United States industry, with an emphasis on dual-use applications.

The SCAPE technology is based on at least 30 years of Soviet theoretical work on the interaction of electromagnetic radiation with materials, commonly known as Percolation Theory. This work has produced an accurate predictor of the interaction of electromagnetic radiation with discontinuous composite materials consisting of magnetic and/or dielectric particles dispersed in a non-conductive matrix (i.e., percolation systems). The former Soviet scientists have successfully validated this theory with extensive experiments. The director of SCAPE, Prof. Andrey N. Lagarkov, is considered to be one of the world's leading authorities in the theory and application of electrophysical properties of percolation systems and has published many definitive articles on the subject.

Prof. Lagarkov presented a summary of this work to Los Alamos scientists early in the summer of 1993, at a special meeting held in Santa Fe. Subsequent to that meeting, he provided, through the Northrup-Grumman Aircraft Co., nine pre-1989 SCAPE retrofit low observable coating samples for non-destructive evaluation. The evaluation was performed by Northrup-Grumman, the Georgia Tech Research Institute Signatures Technology Laboratory, the Office of Naval Research, and Los Alamos. The first three organizations focused on electromagnetic characterization, whereas Los Alamos provided selective, "non-destructive" microstructural and chemical analyses.

The samples showed promise, but it was concluded that more detailed analyses were needed on post-1988 materials to verify the validity and utility of Prof. Lagarkov's claims. Consequently, Los Alamos established a verbal agreement for cooperative interactions with SCAPE, which evolved into the present project, whose primary purpose was to explore developments in Russian work associated with their percolation system designs for radar absorbing applications. An additional objective of this collaboration was to apply the Russian percolation methodology toward a variety of civilian applications by transferring the technology to US industry.

2. Importance to LANL's Science and Technology Base and National R&D Needs

This project exercises three particularly strong capabilities of the Los Alamos science and technology base: materials science, radio-frequency/microwave measurements, and modeling. The understanding of the performance parameters of the Russian technology will enhance this

country's counter-stealth programs, minimizing effective proliferation of the technology. SCAPE's EM absorbing materials technological approach is different from that currently in use in the US. The US approach relies upon complex radar absorbing structure/shape design. In contrast, the SCAPE technology is a retrofit technology. Current military equipment, buildings, bridges, and other structures can effectively be made to have a lower radar cross section by simply coating these structures utilizing SCAPE technology.

3. Scientific Approach and Results

Because of the collapse occurring in the Russian economy, it was concluded that SCAPE could not collaborate with Los Alamos on a gratis basis. Financial support for SCAPE would be essential. As a result, a critical part of this LDRD project was to rapidly secure external funding and establish a 2-3 year research contract with SCAPE, requesting specific deliverables. An additional aspect of the programmatic approach was to involve experts from other U.S. institutions, to assist Los Alamos in the evaluation and validation of the SCAPE technology.

The scientific approach was very straightforward. The program would be broken down into three components: 1) physical and chemical analysis of sample materials, 2) measurement of low observable performance characteristics, and 3) evaluation of the percolation model to determine the model's effectiveness in predicting the performance characteristics of the samples. With this data in hand, the Los Alamos/US Team would then be able to assess the utility of the SCAPE technology. If the technology lived up to Prof. Lagarkov's claims and continued to show promise, the next step would be to establish a \$1M/year technology commercialization program, centered at Los Alamos.

We were successful in securing \$400K of new support for the first year of a three-year effort, from a program jointly sponsored by the Department of Energy (DOE) - Defense Programs Office and the Department of State (DOS). The objective of the DOE/DOS program is to prevent the proliferation of Former Soviet Union (FSU) weapons of mass destruction by gainfully employing FSU weapons scientists in the development of dual-use technology that could be commercialized in non-defense sectors. With this new support, a \$250K/year for three years research subcontract was established with SCAPE. The goals of the subcontract are as follows:

- 1) Identify and develop demonstration and commercialization plans that will focus on the study and application of Russian dielectric and magnetodielectric materials with desirable frequency dispersion. Test samples shall be exchanged for testing and evaluation.

- 2) Develop multi-layer ferromagnetic films, chiral, and artificial magnetic materials. Test samples shall be exchanged for testing and evaluation.
- 3) Discuss potential development efforts for three-dimensional numerical theory of diffraction and new types of lossy dielectrics for wave guides and microstructure test methods for carbon-fiber-loaded polymers. SCAPE's expertise in the theory of dielectric and magnetodielectric interactions with composite materials shall be used to develop predictive models for these systems.

In addition, \$35K/year research subcontracts were established with the Georgia Tech Research Institute (GTRI) Signatures Technology Laboratory and with Prof. Nicolaos G. Alexopoulos of the University of California - Los Angeles (UCLA), Department of Electrical Engineering, effective in May and July 1995, respectively. Los Alamos, GTRI and UCLA constitute the US Team responsible for the evaluation and validation of the SCAPE technology. GTRI had previous experience in measuring the electromagnetic performance of pre-1989 SCAPE samples. Prof. Alexopoulos is an internationally recognized expert in radar absorption technology and enjoys the distinctions of: 1) overseeing the translation of Prof. Lagarkov's book on percolation theory and 2) being an outspoken but judicious critic of SCAPE technology.

SCAPE has been very responsive in providing the necessary progress reports. These reports have been copied and disseminated among the members of the US Team for critical review. Concern arose amongst the US Team regarding the following topics: 1) the practical utility of continuing research on using chiral inclusions for radar absorption, 2) the fact that SCAPE appeared to be spending little effort on percolation theory, the supposed hallmark of the SCAPE technology, and 3) the accuracy of the methods used by SCAPE to measure the electromagnetic performance of their samples.

To address these concerns, arrangements were made for a scientific contingent of the US Team to visit SCAPE on September 25-27, 1995. These individuals were: Drs. Frank Gac and Albert Miglori of Los Alamos, Dr. Paul Kemper and Mr. Paul Friederich of GTRI, and Prof. Nicolaos Alexopoulos of UCLA. The visit to SCAPE proved to be very worthwhile. Many of the US Team's technical questions were answered. A very important outcome of the visit was clarification of the type, size, and projected performance of samples to be provided by SCAPE to Los Alamos in early November 1995. We will be receiving a series of samples that are representative of: Giant Magneto-Impedance (GMI), near-percolation-threshold conductive fiber inclusions, chiral/racemic inclusions, and artificial magnetic materials.

Summary

This single-year LDRD project has clearly served its purpose in that it provided the necessary seed funding to begin evaluation of the SCAPE technology and secure a major external program for continuing the evaluation. It is still too early to conclusively state whether or not the SCAPE technology lives up to its claims. However, the results of our initial evaluation of SCAPE's progress show promise. We will be in a much better position to formulate our judgment after we have received and characterized the first series of SCAPE samples in the first quarter of FY 1996.