WILLIAM J. TROPF

GUEST EDITOR'S INTRODUCTION

Characteristics of materials dictate the design and performance of devices, components, and systems. Size, cost, reliability, and performance often rest on the proper selection and use of appropriate materials. Material selection may be directly based on the properties of a specific material or indirectly based on the properties of a component or device. For example, an electronic component may be selected for its reliability; that reliability is based on the properties of the constituent materials and their use in making the device.

Similarly, material characteristics can be fundamental properties such as elastic moduli, melting temperature, or dielectric constant, or attributes of an aggregate structure or device. Such composite attributes can be measured in terms of simple pass/fail, weight, reliability, flexure or deformation, or property (or performance) changes with time or environmental conditions.

Properties of materials and manufacturing methods are closely linked. Several key material properties depend on processing conditions and assembly techniques. Material purity and homogeneity depend on the preparation environment. Properties such as strength vary greatly with thermal history, material uniformity (including surface finish), and the concentration of atomic-scale defects. Small changes in composition can have drastic effects on many material characteristics such as electrical (and optical) properties, thermal conductivity, and strength.

The underlying science of materials ("solid state" or "condensed matter" physics) enables us to understand fundamental properties, to model from first principles, and to interpolate and extrapolate measured data. In general, the application of science (the engineering) requires careful property measurements. When properties are adequately established, powerful engineering tools are available to examine the performance of the materials in candidate designs. Once produced, these designs can again be evaluated and aggregate properties measured.

Materials work at APL includes all phases of material development, property measurement, material selection and use in system design (including manufacturing technology), and the testing of the products of those designs. Since material properties frequently govern performance, materials work at the Laboratory is widely distributed among the various departments and technical groups. Particularly noteworthy are several materials groups in the Milton S. Eisenhower Research Center[1] and those involved in the development of electronic components and packaging techniques in the Technical Services Department.[2–4] The Aeronautics Department specializes in propulsion, fluid dynamics, and structural materials.[5–7] Electromagnetic properties of materials, devices, and systems[8] are heavily studied in the Fleet Systems Department, and the Space Department[9] concentrates on high-reliability electronics and specialized materials and devices.[10,11] Hydrodynamics and ocean (seawater) properties[12] are of particular concern in the Submarine Technology Department, and recent work in our Biomedical Programs includes the characterization of tissue[13] and the study of eye properties.[14,15]

This is the first of two theme issues on materials research and applications at APL. Our theme begins with a paper by Sova et al. on the very-high-temperature emission of oxide ceramics. These high-strength materials can be used for visible or infrared windows in high-speed aircraft or missiles. Window emission characteristics are important to the performance of sensors looking through hot windows. Laser heating of the test sample produces very high temperatures (>2000 K). By not heating the sample in a conventional furnace, contamination of the sample emission via scattered furnace radiation is avoided. Measured emissivity is found to agree well with multiphonon theory previously developed at APL. Further reading on optical properties can be found in previous *Digest* issues.[16–18]

The next several articles focus on electromagnetic window materials for high-speed flight. High flight speeds create high temperatures and large thermal gradients, with accompanying thermal stress and increased likelihood of failure. The Laboratory has been a leader in the analysis and testing of both structural and electromagnetic properties of microwave and optical materials for radomes and infrared windows.

Lin and Weckesser describe thermal shock tests conducted on infrared domes made of a variety of materials. A one-of-a-kind facility was built at APL specifically to measure heat transfer, thermal shock survivability, and optical performance of infrared sensors in flight conditions. This facility allows infrared windows to be exposed to very high heat fluxes in flow conditions characteristic of Mach 5 flight. Some windows were instrumented (see cover) to compare test results with predictions; good agreement between analysis and experiment was achieved.

The suitability of advanced materials must be analytically assessed before full-scale electromagnetic windows are available for testing. Kouroupis discusses analytical techniques and performance characteristics used to assess existing and developmental radome materials for high-speed flight. With such an assessment, we can establish the need for further material development, evaluate material limitations on system performance, and forecast missile performance.

The suitability of silicon nitride for radomes is explored in the article by Frazer. Silicon nitride is a high-temperature material of potentially high strength and good microwave characteristics. Its strength depends on the fabrication technique and surface condition. The article presents silicon nitride strength measurements made as a function of temperature for samples from different manufacturers. Strength is determined for both finished material and samples damaged by high-speed particle impact. These tests show that silicon nitride has considerable promise for advanced radomes.

The next two articles investigate the effects of material properties on the reliability and performance of electronic devices. Benson et al. study the characteristics of organic epoxies, which have advantages in the manufacture of hybrid microelectronics. Unfortunately, these epoxies release volatile materials that degrade long-term reliability. Variables affecting the stability (outgassing) of one epoxy formulation are examined to enhance our understanding of its chemical processes as a function of temperature and time. Knowledge of these factors will lead to improved epoxies and better manufacturing techniques.

In a similar vein, Maurer et al. examine the reliability of commercial gallium arsenide devices. A scanning electron microscope equipped with an X-ray detector provides a powerful tool for understanding local device structure or areas of unusual performance. Material properties, such as diffusion and chemical oxidation/reduction reactions, and manufacturing flaws are found to be the principal causes of device degradation or failure. Although most devices studied were suitable for long-term space applications, burn-in or derating was required for some components to ensure adequate performance.

Neradka et al. continue our theme with an investigation of failure under bullet impact in composite structures used for rocket motors. The goal of this work is to prevent detonation of solid propellant, a primary military safety problem. An interdisciplinary application of material properties, structural design, computer codes, and powerful computers is used to model complex laminated composites to evaluate their structural performance and failure modes. Results show that it is possible to properly tailor rocket motor case designs to avoid explosions caused by bullet impact.

In the concluding theme article, Resch examines the development of models for ablating materials useful for thermal insulation in rocket motor cases. The mass loss and complex endothermic chemical reactions of typical ablating materials make temperature prediction difficult. Appropriate use of the time-dependent material properties, calculated from the chemical kinetics, can accurately predict the temperature of the protected structure. Tests validated the prediction methods for two significantly different ablating materials.

The Applied Physics Laboratory offers its customers a special blend of science and engineering expertise by promoting continuing education, sabbaticals, and research opportunities for its staff. In particular, APL does not separate the research and engineering functions as most institutions do. This combination of basic and applied science allows the Laboratory staff to solve unique problems and develop new engineering tools through fundamental understanding.

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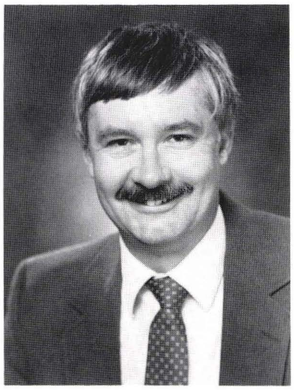
THE AUTHOR



WILLIAM J. TROPF was born in Chicago in 1947. He received a B.S. degree from the College of William and Mary (1968) and a Ph.D. degree from the University of Virginia (1973), both in physics. He is now the supervisor of the Electro-Optical Systems Group at APL's Fleet Systems Department. Dr. Tropf has been engaged in the development and testing of advanced missile guidance systems since joining APL in 1977. His activities have encompassed both radar and infrared sensors, including atmospheric, target, and background modeling; signal processing for clutter suppression; and material properties.