EES NOTES

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In This Issue:

THROMBOGENIC CHARACTERISTICS OF CERAMICS

The field of biomedical engineering requires a wide variety of materials which must be compatible with blood, tissue, and bone. The most critical area of application is concerned with materials which must be placed within the body and function over extended periods of time. Surgical implants of polymeric materials have exhibited physical and chemical instability. Metal implants are usually stable physically, but often react chemically after long periods of exposure to body fluids. On the other hand, ceramics offer the promise of both chemical and physical stability since they usually exist in the highest oxidation states.

When considering a material which will be in contact with blood, tissue, and bone, it is first necessary to determine its compatibility with blood. That is, it should neither damage blood components nor incur clotting. Damage to blood components is indicated by the release of chemicals composing the blood. The presence of the released chemicals can be determined with the use of standardized hospital blood analyses such as the Styphen Time Test, which indicates the amount of thromboplastin, a factor involved in the clotting mechanism, released from cellular elements; the Hemoglobin Assay, which quantitates erythrocytes (blood cells); or the Adenosine Triphosphate Assay, which indicates cellular damage predominantly to platelets.

Clotting may be incurred by the introduction of a foreign surface to the blood. The development of a blood clot on implant materials is undesirable since the clot would present a restriction to the flow of blood. In order to have some guideline for comparing materials for implant use, the clotting time of blood in contact with glass can be used. Glass is considered to be a poor material for use in contact with blood. Whole blood usually clots in 18-23 minutes when exposed to the glass of a test tube. Therefore, a material which produces clotting in less than 18 minutes would be considered unsatisfactory for use as an implant. On the other hand, a material which requires more than 23 minutes to produce a clot under these conditions would be considered for further investigation. The clotting or coagulation rate also may be measured by the use of a Partial Thromboplastin Time Test, which gives the degree of activation of the coagulation mechanism brought about by the contact of blood with the test material. The PTT is a more precise means of measuring the clotting rate since it involves the use of the blood plasma without the influence of cellular elements which have been previously removed by centrifuging. Although these tests are useful for the preliminary evaluation of materials, more sophisticated tests with animals are required before bioengineering applications can be made.

Past efforts to develop materials which are compatible with blood (nonthrombogenic) have been limited because of a lack of complete characterization of the materials which are exposed to blood. This incomplete characterization has contributed to the problem of achieving reproducibility of data obtained by independent investigators.

Presently, a study is being carried on in the High Temperature Materials Division which is directed specifically toward determining the compatibility of ceramic materials with blood for biomedical engineering applications as determined by suitable blood clotting tests. Another purpose of this experimental study is to provide a correlation with previous in vitro investigations by attempting to gain reproducible results using standardized medical laboratory techniques and well-characterized materials. This study also will consider the effect of certain treatments on the thrombogenic behavior of ceramic materials. Such a study will provide experience in this field of surface phenomena and establish a reference for more sophisticated in vivo compatibility studies in the future.

Kathryn V. Logan
High Temperature Materials Division

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MANAGEMENT AND TECHNICAL ASSISTANCE SERVICES

The Industrial Services Branch was established in the Industrial Development Division to serve the needs of existing business and industry in Georgia. Within this branch, a wide range of management and technical services is provided on problems affecting the growth or expansion of industry in the state.

The impetus for formation of the Industrial Services Branch came from a research study sponsored by the Small Business Administration of the problems and needs of small manufacturers. The conclusions reached in this study emphasized the needs of business and industry for assistance not only in identifying and resolving operating problems, but also in locating and utilizing sources of information. Most of the firms surveyed during this project commented on the critical need for direct personal assistance on operating problems. The Industrial Services Branch provides practical, short-term management and technical services designed to meet these needs.

The IDD program has gained national recognition for its work with existing industry. In commenting on the then new State Technical Services Act, the National Observer stated on September 20, 1965:

> One of the best current programs -- and an early model for drafting the Federal legislation -- is in Georgia. There Georgia Tech's Industrial Development Division helps local businesses, even to the point of helping them with plant layouts -- a point not included in the Federal plan.

The staff of the Industrial Services Branch has had a wide range of practical experience in consulting, administrative, and operational work with a variety of industries. Supporting the Branch staff are other professional members of the Industrial Development Division staff: market analysts, plant location specialists, industrial economists, statisticians, research librarians, and six disciplines of engineers. In addition, the facilities and personnel of other divisions of the Engineering Experiment Station are called on for consultative work on special projects.

As a matter of policy, no industrial service project is undertaken which is considered to be competitive with the services of private consulting firms. The purpose of the program is to complement, not duplicate, private sources of service. Industrial service projects are limited to a maximum of five man-days of effort, except in those cases where a number of firms are being served under a single project. This limitation serves to restrict projects to problems which ordinarily would not demand the services of private consultants.

A standard policy approach guides all technical assistance projects:

1. Efforts are initially directed toward assisting the firm in solving its problem by itself. This procedure essentially consists of helping company representatives to identify the true nature of a problem and define a series of steps by which they can correct the problem.
2. If it is impractical for a firm to resolve a problem situation with its own personnel, actual assistance is provided in attacking those aspects of the problem which IDD can competently approach on a short-term basis.
3. When the technical aspects of the problem are beyond the scope of IDD, other divisions of EES are called upon for assistance. When the self-imposed time limitation is not adequate to complete the necessary assistance, the company is referred to consultants who specialize in that field.

IDD's Industrial Services Branch has serviced over 1,260 requests for assistance since it was established in November 1961. The scope of assistance given during the ensuing years is best illustrated by a partial listing of the work performed for these business and industrial organizations:

> Organizational analysis . . . manufacturing systems analysis . . . determination of manpower requirements for new or expanding companies . . . market analyses . . . plant layouts . . . materials handling . . . inventory controls . . . search for sources of capital . . . cost controls, cost centers, and cost accounting . . . distribution systems . . . analyses of financial statements

. . . evaluation of equipment . . . preparation of supporting documentation for federal loan applications . . . assistance to firms interested in bidding on federal government contracts . . . aid in solving labor turnover problems . . . feasibility studies for new and expanding companies . . . labor surveys and registrations . . . location of suppliers of special equipment and services.

William I. Denman Jr.
Industrial Development Division

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QUARTZ CRYSTAL RESONATORS

The use of the electromagnetic frequency spectrum for radio communication, navigation, and telemetering is being extended year by year to higher frequencies. Although the spectrum available for communication covers a range of 10^7 Hz (cps), it is still crowded because a band width of at least 3×10^3 Hz is required for voice communication.

An amplitude-modulated radio transmission consists of a carrier plus an upper and lower side band separated from the carrier by the frequency of the modulation. Sophisticated transmission systems, such as single-side band and single-side band with suppressed carrier, have been devised to make more efficient use of the spectrum. When a single-side band transmission (SSB) is used, one of the side bands is removed by a filter before the signal is transmitted. When the carrier also is suppressed, only one information-bearing side band is used; the signal must be reconstructed at the receiver by supplying the missing carrier before demodulation is possible.

Both of these systems were designed to compress the information to be transmitted into the minimum required band width, thus making more channels available. This spectrum crowding makes frequency control important; without it interference between adjacent channels would make communication unreliable. Precise frequency control is achieved by the use of quartz resonators to control the operating frequency and to hold it within tolerance thereafter.

Quartz is one of the piezoelectric crystals; this effect was first discovered by the Curie brothers in 1880. The first practical use of the quartz resonator, in 1918, was by Dr. W. G. Cady, who later patented a piezoelectric device for frequency control. During World War I and especially during World War II, the success of military communication depended on the use of quartz resonators.

Quartz is crystalline silicon dioxide (SiO_2) which often occurs as hard, transparent, six-sided prisms. The quartz crystal is oriented by X-ray, diamond-sawed into slices, and ground into wafers of the desired size and shape. The AT-cut crystal is an important type which covers the frequency range from 1 MHz to 50 MHz in the fundamental mode of thickness-shear vibration and up to about 250 MHz for overtone modes.

AT-cut quartz resonator plates (X axis in the surface with the normal to the surface rotated about 35° from the Y axis) have a zero temperature coefficient of frequency at two temperatures; one is usually below 25°C, the other above. The exact temperature at which this coefficient vanishes is determined by the angle of rotation.

Quartz resonator research has been continuously active at Georgia Tech for almost twenty years. Currently used AT-cut resonators are wafers about one-half inch in diameter; they range from about 0.067 to 0.001 inch thick, the thicker the plate the lower the operating frequency. For our work metal electrodes about 200 nanometers thick are evaporated on each face to provide the required electrical excitation. The resonator is mounted on a commercial base and the electrical leads ultrasonically bonded to the metal film. The mounted crystal is then vacuum encapsulated.

One of our interests is the change of the resonant frequency with time, termed aging. The aging behavior is determined by measurements over a period of months of the frequency and impedance. The crystal is measured as a passive element in an impedance bridge while the crystals are stored at the designed operating temperature, currently 85 ± 0.02°C.

We have shown that the environment in the holder affects the aging and that evacuated holders are usually preferred. However, very recent studies of crystals designed for rapid thermal response indicate that a pressure of 10 to 50 torr (mmHg) of an inert gas such as helium may be acceptable. We have substituted ultrasonic bonded electrical connections in place of solder or conducting cement, which may contaminate the encapsulated resonator. The metal electrode deposition has undergone extensive research; at present we are using oil-free vacuum systems for the production of films of high-density gold, copper, and aluminum.

The need for research and development on resonator performance is a continuing one because the requirements are becoming increasingly stringent. In fact crystals needed today for commercial uses approach the frequency-standard crystals of a few years ago.

W. H. Hicklin
Physical Sciences Division

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IMPROVEMENTS IN HIGH-FREQUENCY RADIOLOCATION

Passive radiolocation of remote electromagnetic sources is one of the oldest disciplines in the broad field of radio and electronics. This technique employs direction-finding (DF) receivers at two or more different sites. Each DF receiver determines the direction of arrival (azimuth) of the radiation from the transmitter to be located. When the azimuths of the source as measured at the different sites are plotted on a chart, the intersection of the bearing lines gives the location of the transmitter.

The first successful radiolocation of a remote source was obtained by G. Marconi in 1904 when he located a spark-gap generator on the H.M.S. Furious 16 miles off the English coast. Since that time, passive radiolocation has advanced in both sophistication and application. Today, it plays a major role in spectrum surveillance and control, intelligence collection, navigation, radio astronomy, search and rescue, ionospheric propagation research, and even in such specialized areas as wildlife surveys.

However, long service does not imply perfection, and the radiolocation discipline is no exception. A major continuing problem has been the accuracy of high-frequency radiolocation systems with electrically small antenna systems. In general, most high-frequency (2-30 MHz) transmissions are propagated via the ionosphere, which introduces a rotation of the polarization and multi-path effects resulting from reflection by areas at different distances. Small-aperture HF radiolocation systems with antennas small relative to the wavelength are especially vulnerable to these signal perturbations.

For nearly five years, investigators in the Electronics Division have been innovating, developing, and evaluating techniques for improving overall performance and reducing bearing errors on ionospherically propagated signals. Major emphasis has been placed on HF radiolocation systems with simple loop antennas and with short-baseline interferometers; however, many of the techniques developed are generally applicable to larger aperture systems. Substantial improvements have been made by the use of signal processing techniques such as fade-crest detection and clutter reduction applied to the signals from the intermediate frequency amplifier. Signal processing has enhanced the accuracy of bearing readings and sharply reduced erroneous information prior to the display.

Improvements also have been made on the antenna systems, and use of synchronous detection has improved sensitivity by about 14 decibels. Ferrite-loading of transmission lines has reduced undesired abnormal polarization response and susceptibility to environmental coupling. A tilted, rotating loop technique has been developed to obtain both bearing error reduction and an estimate of the elevation angle of arrival of the signal.

All of the above techniques are incorporated into an HF radiolocation system developed by Georgia Tech that is currently being operationally evaluated at the Rosser Road Test Site located three miles north of Stone Mountain.

Overall, significant advances in HF radiolocation have been made, although much work remains to be done. The potential of a novel processing technique will be investigated in the near future, and other techniques such as high-speed electronic scan and digital bearing readout are under consideration. Electronic scan and digital readout would promote the development of an improved, lightweight radiolocation system, which is the ultimate goal.

H. H. Jenkins
Electronics Division

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PHOTOPHORESIS

The phenomenon of motion exhibited by small particles suspended in gas at reduced pressure when exposed to an intense beam of light is called photophoresis. When closely observed, particles may be seen both to rotate and to undergo translational motion as long as exposed to light. The movement may be in a straight line, a circle, a helix, or an irregular curve. The particles may move either away from or toward the light source. Particles that move away are called light positive, and those that move toward the light are called light negative. These two different phenomena are observed simultaneously in most cases, and sometimes a light positive particle may change to a light negative one or vice versa. Normally, straight-line motion prevails in a parallel beam, while circular, helical, or irregular motions are characteristic in divergent and convergent beams. In a convergent beam of sunlight, particles within the beam would not cross the beam boundary under the influence of gravity, but instead they would bounce or tumble along it toward the focus. This behavior indicates the special nature of the light-dark interface.

There are several types of photophoresis. They may be divided simply into two groups: one is called pure photophoresis and the other, field photophoresis. Pure photophoresis is produced by light alone. The pressure of the gas medium, the intensity and wavelength of the light beam, and the nature of the particles are the main factors influencing this type. Field photophoresis involves either an electric field (electrophotophoresis), a magnetic field (magnetophotophoresis), or both (electromagnetophotophoresis). Field photophoretic forces, when they occur, are proportional to the strength of the field for low strengths, but they will reach saturation at higher fields. In other words, once saturation is attained, the force no longer depends on the field strength.

Photophoresis has been known for over fifty years, but there is as yet no adequate theory. Particle motion caused by light in gas at reduced pressures probably is due primarily to uneven heating of the particle surface. The resulting forces, termed radiometric, appear to be the major cause of photophoresis. Differential heating alone, however, cannot account for all the phenomena observed. Some of the observations indicate additional forces acting on the particle in a light beam.

Both positive and negative photophoretic forces for many materials have been measured in the Micromeritics Laboratory. Predictions of particle behavior in the upper atmosphere were made by relating measured photophoretic forces to gas pressure, light intensity, and particle properties at several altitudes. Photophoresis is shown to be capable of causing some very small particles to rise and some to fall faster under gravity than they normally would. It is speculated that this may have significant consequences with regard to meteorological processes and fallout behavior.

Edward Y. H. Keng
Chemical Sciences and Materials Division

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ANTENNA SIDELOBE REDUCTION

Most directional antennas have radiation patterns with a main-lobe response in the desired direction and minor lobes (sidelobes) in undesired directions. The usual radiation pattern, which shows these characteristic lobes, is a graphical representation of the relative radiation level measured as a function of angle in a plane through an axis of the antenna. Reduction of the sidelobe level of high-gain antennas used for microwave communications and radar has been the goal of antenna designers for many years. Electronic systems are especially susceptible to interfering signals received on antenna sidelobes; therefore, a lowering of sidelobe levels can reduce interference significantly.

Antenna sidelobe reduction is the objective of a research program now under way in the Electronics Division. Techniques for improving the antenna pattern by adjusting the amplitude distribution of the electric field across the antenna aperture, known as tapering, are well known. However, little use has been made of the changes in sidelobe level achievable by varying the phase distribution of the field across the aperture. Our aim is to shape both the phase and amplitude distributions of aperture antennas to yield radiation patterns with low sidelobes.

A computer program using the fast Fourier transform to calculate far-field antenna patterns from aperture distributions has been developed which includes routines for plotting the antenna pattern and the input phase and amplitude aperture distributions. The results to date have shown that control of the phase distribution can be used to lower antenna sidelobe levels significantly.

A major objective of this research is to generate practical information for antenna engineers. To this end, we plan to modify several existing horn antennas as part of the effort. The modified phase and amplitude distribution will be measured using a large precision X-Y-Z positioner and receiving system located in the Electronics building. Measured antenna distributions and radiation patterns will be compared with theoretical predictions. When techniques have been proved for horn antennas, they will be extended for use with larger high-gain antennas.

C. P. Burns
Electronics Division

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THE TENTH SYMPOSIUM ON ELECTROMAGNETIC WINDOWS

The High Temperature Materials Division (HTMD) hosted the Tenth Symposium on Electromagnetic Windows in the Georgia Tech Student Center on July 29, 30, and 31, 1970. This symposium had special significance since it marked the 15th year that regularly scheduled symposia on electromagnetic windows have been held either annually or biennially. The theme of this symposium was "State of Radome Technology - 1970." Total attendance at the meeting was 127. There were 20 foreign attendees, representing England, France, Germany, Israel, Norway, and Sweden, with France and Germany having the majority.

The technical program of this meeting was noteworthy with respect to the large number of papers that dealt with high-temperature dielectric window materials and systems. A highlight of the symposium was a presentation by W. F. Croswell of NASA on the electromagnetic window problems and requirements for the space shuttle. Another outstanding event was a panel discussion on "Future Outlook." Panel members represented the United States Army, Air Force, Navy, NASA, Great Britain, and France. Herman Kraenzler of the French Navy gave a comprehensive review of the state of radome technology in France.

Participation by Georgia Tech was excellent. For example, J. D. Walton, Jr., Chief, HTMD, served as Chairman of the Symposium, Chairman of the Papers Review Committee, and as a session moderator. N. E. Poulos, Associate Chief, HTMD, was the Symposium Coordinator and a session moderator. Demetrius T. Paris, Head, School of Electrical Engineering, presented a paper entitled "Computer-Aided Radome Analysis." C. W. Gorton, School of Chemical Engineering and HTMD, presented "Evaluation of Ceramic Coatings for Rain Erosion Protection," which was coauthored with J. D. Walton, Jr. E. A. Welsh, HTMD, read a paper on "High Purity Slip-Cast Fused Silica"; J. N. Harris, HTMD, was the coauthor. A paper entitled "Dielectric Constant and

Loss Tangent Measurement of High Temperature Electromagnetic Window Materials," with H. L. Bassett, Electronics Division, as coauthor, was presented by S. H. Bomar, Jr., HTMD.

The Department of Continuing Education provided its usual outstanding services for the meeting. It is of historical interest that this meeting is the first of its kind to be held in the recently opened Georgia Tech Student Center. The facilities available at the Center make it ideal for such meetings. Ohio State hosted the first seven and Georgia Tech has hosted the last three of these regularly scheduled symposia.

N. E. Poulos
High Temperature Materials Division

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TWO TECH MEN NAMED TO PRESIDENTIAL ADVISORY POSTS

During August, President Nixon announced the appointment of Dr. E. E. David, Jr., as Science Adviser to the President and Director of the Office of Science and Technology. Dr. David was an honor graduate of the Georgia Tech Electrical Engineering class of 1945. He has participated in many policy-level activities concerning Georgia Tech, and at the time of the announcement he was serving as Chairman of the Advisory Board for the School of Electrical Engineering. Some of the old-timers at EES will recall working with "Eddie" in microwave research at EES during summers while he was pursuing his doctoral program at MIT.

Also last month, Dr. Thomas W. Jackson, former chief of the Mechanical Sciences Division at EES, was named technical director for the National Industrial Pollution Control Council, whose purpose is to advise President Nixon on methods of cleaning up the environment. He will direct the staff work required by 30 subcouncils of the newly created organization. For the past two years, Dr. Jackson has been Director of the Skidaway Institute of Oceanography at Savannah.

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PROFESSIONAL ACTIVITIES

Papers and Presentations

A paper entitled "Prediction Method to Statistically Determine Potential Antenna Interference," by F. L. Cain, ED, J. W. Cofer, ED, and H. A. Ecker, ED, was presented at the 1970 IEEE International Symposium on Electromagnetic Compatibility, Anaheim, California, July 14-16.

A. P. Sheppard, ED, spoke to the Atlanta Chapter of the American Health Physics Society on July 20 on "Microwave Radiation Hazards."

G. W. Simmons, PSD, gave an invited paper at the 44th National Colloid Symposium held at Lehigh University, Bethlehem, Pennsylvania, June 21-25.

At the DECUS meeting in Atlantic City on May 4-5, Douglas E. Wrege, PSD, presented a paper on "A Focal Controller for Neutron Diffractometry."

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Publications

J. M. Bradford, PSD, K. B. Wear, PSD, and M. E. Sikorski, PSD, "Ultra-High Vacuum Twist Compression Apparatus," Rev. Sci. Inst., September 1970.

K. K. Brandes and R. J. Gerdes, PSD, "Formation and Electrolytic Dissociation of the Potassium Compounds of Monohydronaphthalene and Monohydroanthrocine," Zeitschreft fur Naturforschung 25, 175-178 (1970).

R. K. Hart, PSD, T. K. Kassner, and J. K. Maurin, "The Contamination of Surfaces During High-Energy Electron Irradiation," Philosophical Magazine 21, 453-467 (March 1970).

R. K. Hart, PSD, and J. K. Maurin, "The Nucleation and Growth of Oxide Islands on Aluminum," Surface Science 20, 285-303 (1970).

Charles I. Poole, IDD, "Mechanical Fasteners," Mobile Home/Recreational Vehicle Dealer, July 5, 1970, pp. 86-87, and "Adhesives," MH/RV Dealer, August 5, 1970, pp. 184-188.

W. van der Lugt, D. M. Knotterus, and R. A. Young, PSD, "NMR Determination of Fluorine Position in Mineral Hydroxy Apatite," Caries Research 4, 89-95 (1970).

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SUBMISSION OF ARTICLES

Contributors in the divisions should submit their articles to the appropriate division coordinator listed below. Others may send their contributions via campus mail to Martha Ann Deadmore at the Industrial Development Division.

Division Coordinators

Chemical Sciences and Materials Division	Walter H. Burrows
Electronics Division	H. A. Corriher, Jr.
High Temperature Materials Division	Nick E. Poulos
Industrial Development Division	Martha Ann Deadmore
Nuclear and Biological Sciences Division	Geoffrey G. Eichholz
Physical Sciences Division	Robert L. Bullock