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History of the Rutgers University-

U. S. Army Electronics Command

Ceramic Research Program 1946-1974

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The origin of this program dates back to World War II where the extreme geographical range of the combat areas subjected military electronic systems to new enviornments of temperature, humidity, fungus and sea water corrosion. The development of high powers at radio and microwave frequencies subjected ceramic materials to new levels of electrical, mechanical and thermal stresses.

In the deserts of North Africa the climatic conditions are very hot and dry, however at night the temperatures can drop below freezing. This resulted in many thermal shock failures of ceramic parts. In Alaska the climatic conditions are very cold and in many cases high humidity. These conditions also resulted in thermal shock failures. In the Pacific Islands hot and humid conditions prevail. Failure here was due to fungus problems. In fact waxes, which were used as moisture repellent coatings on selected components in communications equipment, were food for the fungus. This resulted in a large percentage of the equipment becoming inoperative even before it could be put to use.

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[1] E. J. Smoke, Professor of Ceramics, Rutgers University. Over the life of the project he was Research Specialist and Project Leader.

[2] S. DiVita, Ceramic Engineer, U. S. Army Electronics Command, Fort Monmouth, N. J. He was project engineer, initiated the program and rendered technical guidance.

A. W. Rogers, an electrical engineer, was an officer in the U. S. Army Signal Corps (later U. S. Electronics Command). Mr. S. DiVita headed up a small ceramic laboratory at Fort Monmouth. These problems and failures came under their responsibilities. Further, they found that there were no specifications as to high frequency insulation. They formed a committee of manufacturers and the military, and after much hard work came up with the Joint Army-Navy Specifications JAN-I-10 (later MIL-I-10) which identified grades or categories of high frequency insulation including the technical properties dielectric constant, loss factor, puncture voltage, transverse strength, porosity and thermal shock resistance. This helped materially in supplying the best material for a specific application, but there was still failures, due in most cases to the ceramic not having the necessary basic properties, or not understanding the mechanisms producing the failures. This pointed out very vividly the need for research in this field. Dr. John Koenig, who was to become the Director of the School of Ceramics at Rutgers University after the war, and A. W. Rogers knew each other while on duty in Washington, D. C. Koenig's background was ceramics, and his responsibilities in the Navy included seeing that high frequency insulation was being produced and on schedule for communications equipment; thus he was familiar with the problems.

In the latter part of 1945, Rogers, DiVita and Koenig ~~met~~, analyzed the problems involved and setup a research program. On January 1, 1946 Koenig assumed his position as Director of the School of Ceramics at Rutgers. Soon after Rutgers, Department of Ceramics, was awarded a research contract which started on March 1, 1946. This effort was destined to continue for 27 years, eight months and two days to November 3, 1973. The program started with five phases:

1. High Thermal Conductivity - of prime interest because of failure of power tubes. William Scholes, deceased, earned a Ph.D. degree.
2. Dense Cordierite - its low thermal expansion was of interest but it had to be made impervious for R.F. coil forms for critically turned circuts. Harriet Wisely earned a Ph.D. degree and is employed by General Electric Company.
3. High Resistivity Coatings - needed to maintain high electrical resistivity under high humidity conditions mainly for miniture sockets and rotary switches. Roy Brown worked on this phase as a Research Specialist. He is associated with Carborundum Company.
4. High Impact Resistance - always a problem in ceramics. A. V. Illyn earned a Ph.D. degree for his efforts and is presently associated with Babcock and Wilcox Company.
5. Thermal Shock Resistance - another very important problem. Edward J. Smoke worked on this phase and has been associated with Rutgers ever since.

N. H. Snyder, referred to above, was the project leader and Dr. John Koenig was director of the project.

Twelve contracts covered the entire period of this effort; one was for two years, the rest for one year. With proposals, extensions, quarterly reports for all but the last seven years, then semi-annual, plus the actual effort, the group of researchers were kept very busy. In total, over $1.4 million was devoted by the U. S. Army Electronics Command to this effort, and it has been estimated that this generated an additional $600,000 in electronic ceramic research by other sponsors including the Navy, Air Force and the Army Quartermaster Corps.

Eighteen different project areas were studied. They are as follows:

1. High Thermal Conductivity Ceramics
2. High Thermal Shock Resistant Ceramics
3. Moisture Repellent Inorganic Coatings in Ceramics
4. Development of Ceramic Material Free of Electrolytes
5. Development of Dense Cordierite
6. Ultra Low Loss Ceramics
7. High Impact Resistant Ceramics
8. Precision Molded and Machined Radio Ceramics
9. Void Free Structure in Ceramic Insulation
10. Devitrification Studies
11. Devitrification Studies of Ferroelectric Ceramics

12. Low Loss Microwave Dielectrics
13. Structural Studies of Polycrystalline Ceramics
14. High Temperature Extrusion of Barium Titanate
15. Low Loss Boron Nitride Ceramic Dielectrics
16. Lanthanum Aluminosilicate Dielectrics
17. Advanced Ceramic Forming Techniques
18. Linear, Low Loss, Voltage Variable Dielectrics

A number of phases were worked on for from 4-7 years, others from 1-2 years, depending on the magnitude of the problem and the interest of the sponsor. The problems fall into three rather distinct categories namely, the study of some specific property such as thermal conductivity, impact resistance, etc.; high dielectric constant ceramics, such as high purity $BaTiO_3$; and advanced ceramic processing techniques such as hot extrusion, formation of fibers and flakes of devitrifiable barium titanate compositions, glass - ceramic systems, etc. This resulted in 18 Ph.D. and 14 M.S. degrees being earned by 28 individuals. It generated an additional 20 Ph.D. degrees in the electronic ceramic area under other sponsors. Over 30% of the 327 advanced degree graduates from the Rutgers Department of Ceramics during this period entered the field of electronic ceramics. The ECOM sponsored work resulted in the presentation of 102 papers before American Ceramic Society meetings, 19 papers published, 5 patents awarded, and two College Bulletins published.

Approximately 50 people were involved over the whole period including research associates, research assistants, technicians and staff members.

Dr. John Koenig started meetings devoted to electronic ceramics which became the Rutgers Dielectric Symposia. Twenty-six meetings were held at Rutgers between 1948 and 1957. These were well attended ranging from 150-300 attendees at one of the last meetings the president of the American Ceramic Society, the late Karl Schwartzwalder, indicated that this effort should be taken over by the Society. A committee was formed which included John Koenig, Karl Schwartzwalder, Dr. Merle Rigterink of Bell Telephone Laboratories, Dr. Edward Henry of General Electric Company, Dr. Seymour Blum of Raytheon Mfg. Company and Professor Edward J. Smoke of Rutgers University to initiate the formation of a new division. The first meeting of the Electronics Division was held at the 60th Annual Meeting of the Society in 1958. John Koenig was chairman and keynote speaker.

On December 6, 1966 the U. S. Army Electronics Command celebrated the 20th anniversary of this research program. It consisted of a luncheon and several addresses. Included were industrial and research people from producers and consumers of electronic ceramics, and members of the military and academic communities, all from New Jersey. A. W. Rogers, then chief engineer of ECOM, presented "Perspectives on the Rutgers-ECOM Ceramic Program." Major General William B. Latta, then Commanding General of ECOM presented a plaque commemorating the occasion. It was accepted by Dr. Mason Gross, then President of Rutgers University. The plaque hangs in the lobby of the College of Engineering.

As noted earlier 102 papers on the results of this research program were presented before meetings of the American Ceramic Society, yet only 19 were published. This was due to pressures on the regulars of the research team, and those earning their advanced degrees not writing papers. The above mentioned 20th Anniversary celebration motivated a 550 page report identified as ECOM-0232-5, Inorganic Dielectric Research (contract #DAAB07-67-C-0232) Twenty-Three Year Summary Report by Edward J. Smoke, dated December 1969, covering all the work to that date. It also was published as College of Engineering Research Bulletin #50, Rutgers University.

Much fine research in some of these same areas was conducted by other universities and industrial laboratories during this period, and industry had adopted many of the findings. Because of this, the changing priorities of the U. S. Army Electronic Command, and the realization of the original objectives, the project was terminated as of November 3, 1973. The advancement of the fundamentals of ceramics, and the solution of some of the basic problems as noted above were among the objectives. This resulted in more reliable electronic devices with long life, operating under adverse conditions.

The following are just a few of the outstanding developments or accomplishments of the research program: the first to measure the high thermal conductivity of beryllia; an ASTM standard for measuring thermal conductivity of impervious ceramics; development of zero and negative thermal expansion, high frequency electrical insulation; thermal conditioning of dense ceramics for strengthening; the prereacted approach for improved structure and properties of ceramics, via presintering for more refractory compositions, and fritting for low melting compositions; nonwetting glazes; zero firing shrinkage, high frequency insulation type ceramics; vitrified high frequency insulation compositions that can be quenched from 2200^{o}F to water at room temperature; hot extruded barium titanate; devitrified ferroelectric fibers and flashes, etc. The results of this ECOM - Rutgers Department of Ceramics research program lead to newly developed electronic ceramics which are vital materials with unique electrical, mechanical and thermal properties that make them essential elements in modern satalite communications, military systems and computers.