The Physics and Chemistry of CERAMICS

A symposium report by **Leonard F. Herzog**

MODERN technology makes exacting and varied demands of materials, and the ancient art of ceramics has not remained immune from the impact of these demands. Traditionally, the development of ceramics has been primarily an empirical process; the complexity of these systems, and of the processing techniques used to fabricate them, has largely precluded the possibility of that rigorous control of experimental conditions necessary to the attainment of unambiguous results. Recently, however, studies of systems compositionally and structurally less complex than the traditional ceramics (for example, single crystals) have revealed additional properties of this class of materials which can be usefully exploited. Many of these studies have been carried out by physicists, and this work has grown into a discipline within what is now known as solid-state physics.

Today, in some organizations, the solid-state physicists and metallurgists have been given the assignment of applying their techniques to the design of polycrystalline ceramic substances of specified properties—for instance, high-temperature-stable materials for space-age applications. To the surprise of few ceramists, the present techniques of solid-state physics turn out not to be adequate by themselves for this task. Polycrystalline materials, even those of the highest purity, differ from single crystals of the same composition in their mechanical and electromagnetic properties, and "real" ceramics, lacking the definite and simple "ideal" compositions and/or structures of theory, or even of laboratory-batch materials, tend to exhibit additional variability in properties, and hence in performance.

Against that background, a conference on the physics and chemistry of ceramics was organized and sponsored by the Office of Naval Research at the Pennsylvania State University, May 28–30. The conference had two stated purposes: (1) to review the principles of solid-state physics and solid-state chemistry that are applicable to ceramics research and education today, and (2) to examine mechanisms by which ceramics research can be made more effective in meeting the future needs of ceramics.

Thus the president of the National Academy of Sciences, Frederick Seitz, in his leadoff address at the conference (read in his absence by R. J. Maurer), could state that an important question is "whether solid-state physics can and should have a major influence on the future development of ceramics . . ." and conclude that "Progress in the future will depend in a critical way on interdisciplinary research." In the view of Seitz, "the main lore of the physics of solids has not yet become a part of the traditional structure of ceramics to the extent it has of metallurgy. One suspects the field would be enriched very much if it were . . ." The ceramist should "accept the solid-state physicist on the latter's terms as a partner in both instruction and research."

In the view of the next speaker, W. R. Buessem, professor of ceramic technology at Penn State, the important question was timing: "Should one take steps now, especially in connection with ceramics education, to accelerate the process of unification, or should we let inertia determine a more 'natural' course?" In answer, he listed five important classes of problems in ceramics which are amenable to study by the techniques of solid-state physics. Prof. Buessem also called attention to the fact that ceramics already possesses a large reservoir of traditional knowledge that has been adequate for classical ceramic purposes, and that this need not be ignored by a "new" ceramics. He suggested that solid-state physicists might make their most important contribution by "turning some of their efforts to the problems of the polycrystalline solid state . . ., defining the significant geometrical factors and developing workable methods to space-average single-crystal properties. The ceramists can support this work by developing methods to manufacture pure and ultra-pure materials, to facilitate the identification of the crystallites in the ceramic body with those which the physicist is using in his studies."

The conference was then given over to a program of fourteen papers dealing with various specific aspects of the structure, properties, and behavior of ceramic materials. The diversity of the "new" approaches to the science of ceramics is well illustrated by the fact that the list of speakers included mineralogists, mechanical engineers, chemists, geochemists, and metallurgists, as well as ceramists and physicists.

After mulling over the interactions of these varied yet related studies for two days, the conference participants attended a panel discussion on the future of ceramics education. The panel, which was made up of

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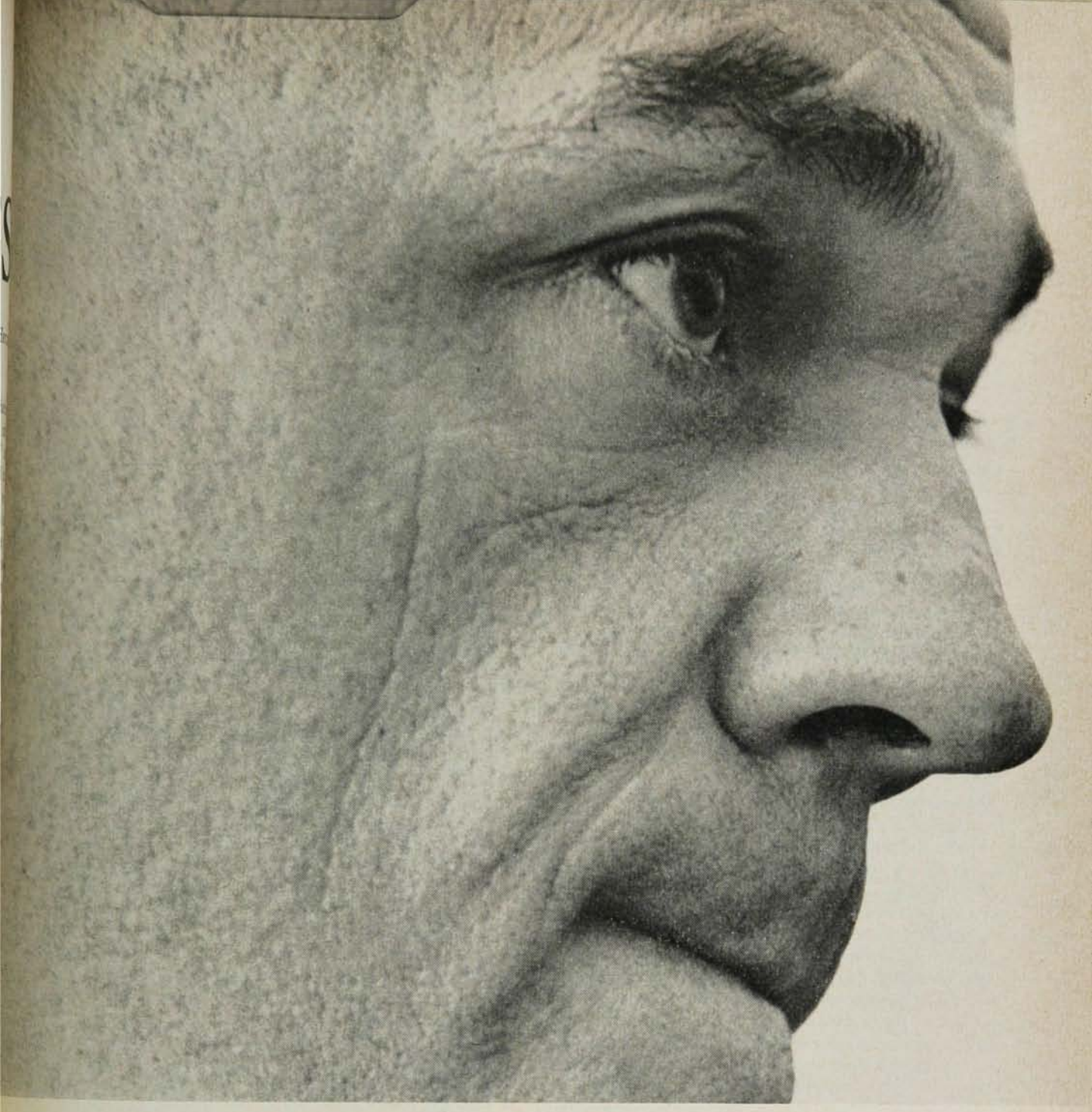

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eight professors of ceramics and one physicist, with G. W. Brindley of PSU in the chair, addressed itself to the problem "what is to be the balance between old and new" in ceramics curricula? The conservatives present (no one at the conference seemed comfortable with the label, "classical" ceramist) made the usual, convincing case for caution lest the baby (in this case the accumulated empirical lore and art of the centuries of ceramics history) be thrown out with the bath water, but to this observer at least, the direction of things to come is epitomized by the history of the panel chairman himself: a physicist by training, then a mineralogist, then a ceramist, now a professor of "solid-state technology". The participants in this discussion were R. L. Coble (MIT), R. L. Cook (Illinois), I. B. Cutler (Utah), V. D. Frechette (Alfred), J. E. Mueller (Washington), J. A. Pask (California at Berkeley), R. Russell, Jr. (Ohio State), and R. L. Sproull (Cornell).

The conference was organized by Cyrus P. Klingsberg, a ceramist in the Metallurgy Branch of ONR, who spoke on the subject of the federal government's interests in research in ceramics. Klingsberg pointed out that, of about $10 billion currently budgeted by the government for research, only about $16 million was being spent on ceramics research, in spite of the pressing need for new ceramic materials. This total includes the amount spent by the Advanced Research Projects Agency on interdisciplinary laboratories at eleven universities. He pointed out that "enormous" sums were being expended in metals research (e.g., in the search for high-temperature alloys), and that by comparison "relatively trivial" sums have been made available for studies of such importance as the explanation of the brittle nature of ceramics. In part, he put the blame for this state of affairs on university ceramics departments, which, compared to metallurgy departments, show "less physics and chemistry", "a greater orientation to problems of industry", "less breadth and imagination", "in-breeding", "too large an effort toward optimizing the properties" of already well-tested materials, and "insufficient emphasis on truly basic problems". He felt that federal funding agencies could best implement the government's research goals in the ceramics field by supporting "to the fullest the most sophisticated proposals that originate from ceramics departments", by increasing "the effort directed to a study of the properties of compounds produced from very high purity elements", and by developing "a bank of pedigreed (ceramic) single crystals possessing a high level of crystalline perfection". Klingsberg pointed out that the last of these aims had just been strengthened by ARPA grants totaling over $1 million, with the major award having been made to Professors R. Roy, M. E. Bell, and others in the new Materials Research Laboratory of the College of Mineral Industries at Penn State.

While attendance at the conference (60) was by invitation, the entire proceedings, including discussion, are being published this fall by Gordon and Breach, 150 Fifth Ave., New York, N. Y.