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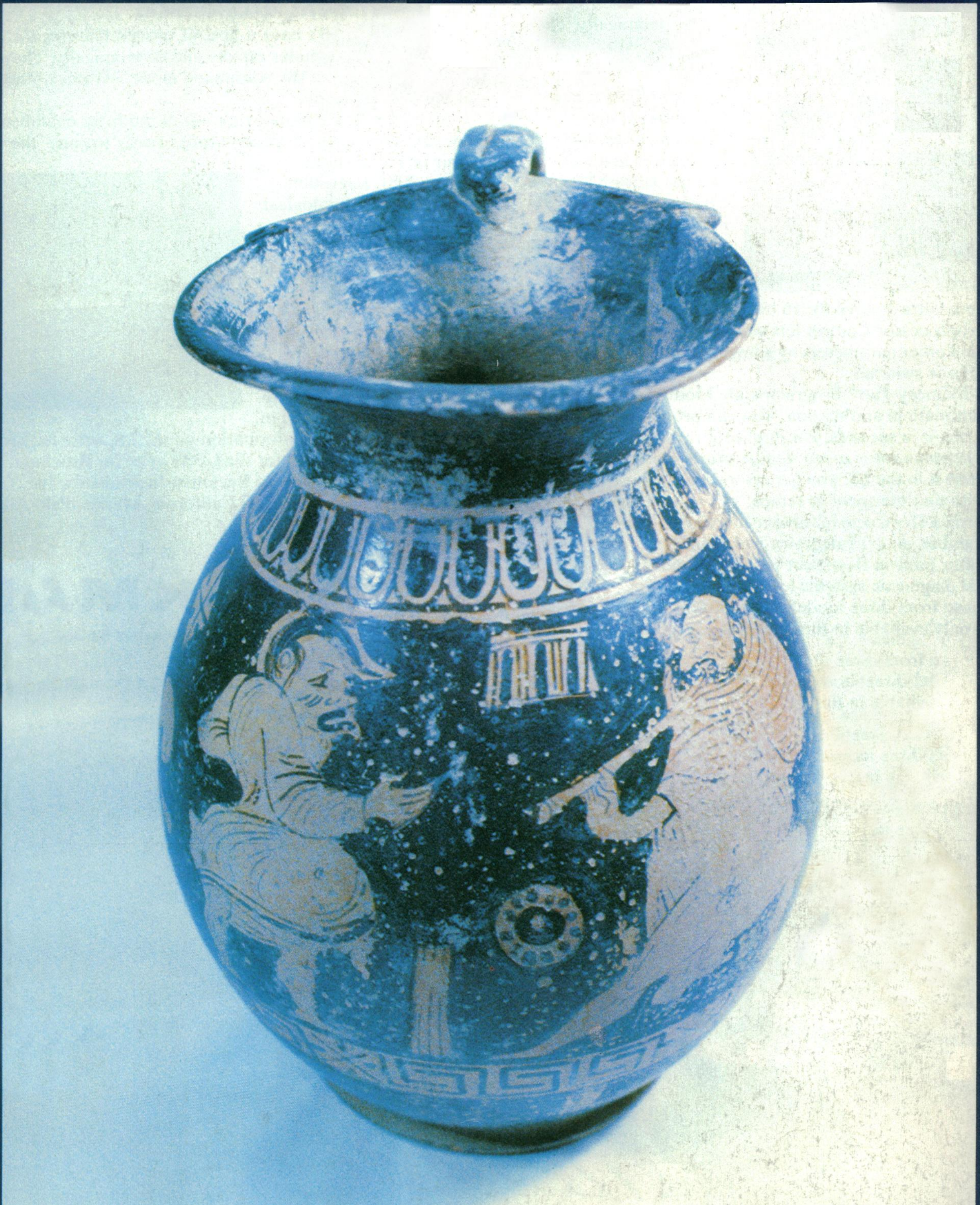
SCIENCE

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE



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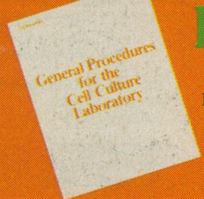

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AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

The American Association for the Advancement of Science was founded in 1848 and incorporated in 1874. Its objects are to further the work of scientists, to facilitate cooperation among them, to foster scientific freedom and responsibility, to improve the effectiveness of science in the promotion of human welfare, and to increase public understanding and appreciation of the importance and promise of the methods of science in human progress.

COVER

Greek pottery oinochoe (wine jug), late 6th century B.C. The person on the left appears to be a reveler; the one on the right plays a flute. Has mankind been attracted to alcohol because of its GABA-potentiating properties? See page 708. [Photograph by L. Lurie, permission of Petit Musée, Montreal, Canada]

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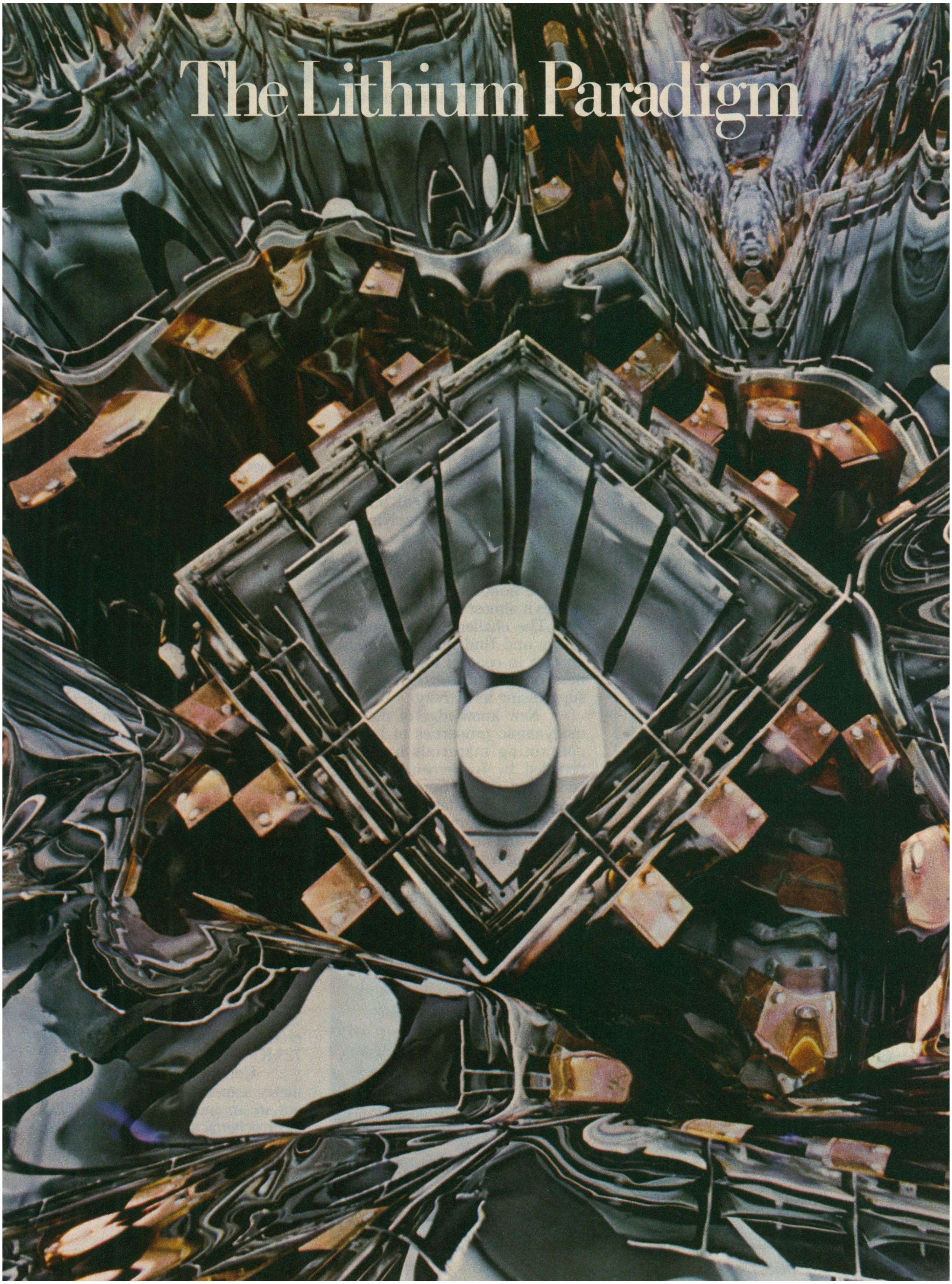
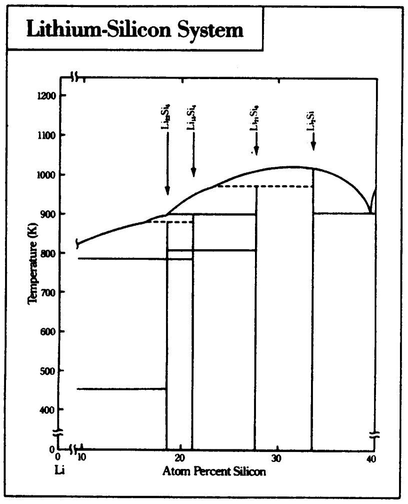
The Lithium Paradigm



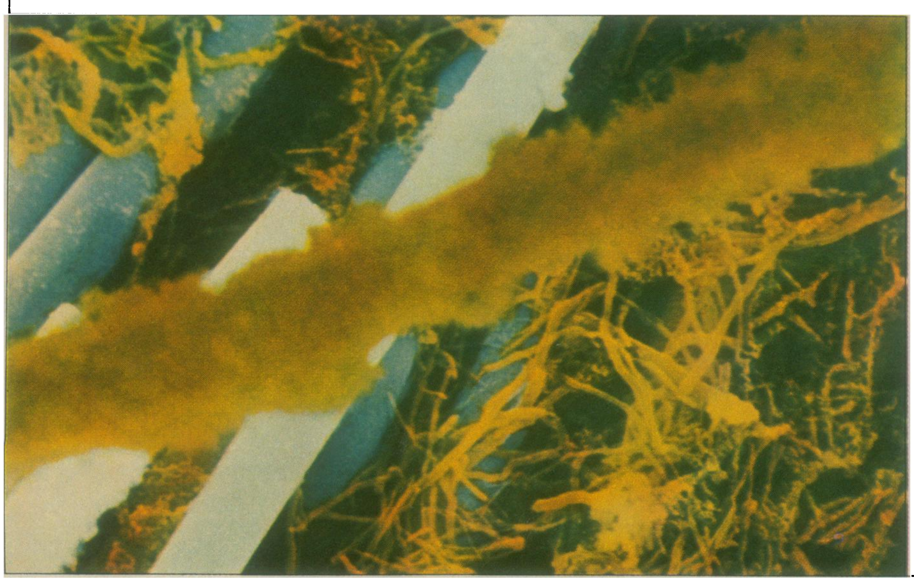
The Lithium Paradigm

The practicality of a mass-produced electric car depends upon the development of a long-life, low-cost, rechargeable battery. Recent discoveries at the General Motors Research Laboratories have encouraged scientists seeking to harness the abundant but elusive energy available in lithium—a highly desirable battery component.



Partial phase diagram of the lithium-silicon system. Lithium activity changes by two orders of magnitude in the concentration range shown.

Color-enhanced scanning electron micrograph showing the results of lithium attack on boron nitride.



HIGH ELECTROPOSITIVITY and low equivalent weight make lithium an ideal battery reactant, capable of supplying the specific energy needed to operate an electric vehicle. The source of the abundant energy available in lithium, however, is exactly what makes it almost impossible to manage. The challenge is to prepare alloys and find materials stable enough to contain the aggressiveness of lithium without greatly suppressing its activity.

New knowledge of the thermodynamic properties of lithium-containing materials has been revealed by fundamental studies conducted at the General Motors Research Laboratories. Investigations, carried out by Dr. Ram Sharma and his colleagues, aim at developing a basic comprehensive understanding of selected "exotic" systems. Their work is directly related to the search for an advanced molten salt battery cell.

Specific energies greater than 180 W·h/kg, about five times that of the lead-acid battery, have been demonstrated by electrochemical cells utilizing LiCl-KCl electrolyte and electrodes of metal sulfide and lithium alloy. But operating temperatures of 723 K and the aggressive nature of the chemical reactants pose serious new challenges to cell construction materials. Of particular concern is the lithium attack upon separators and seal components. Most inorganic insulators, including the refractory oxides and nitrides, are destroyed or rendered conductive by this attack. Boron nitride, one of the more resistant materials, has been the subject of Dr. Sharma's recent, successful efforts to establish conditions under which attack may be avoided.

Dr. Sharma began by exploring the thermodynamics of the lithium-silicon system. Silicon reduces the activity of lithium without substantially increasing its weight, and produces a manageable solid at 723 K.

Constant-current potentiometry experiments were carried out in an inert atmosphere. The electrochemical cell consisted of a Li-Si alloy positive electrode, a eutectic mixture of LiCl-KCl electrolyte, and two Li-Al alloy electrodes—one negative and one reference electrode.

A series of anodic and cathodic cycles at very low current densities indicated three well-defined voltage plateaus below 80 atom percent lithium composition. This behavior was confirmed by experiments in which pure silicon was used in place of Li-Si alloy as the starting material.

The results were used to modify the Li-Si phase diagram, which indicated only two such plateaus. The revised phase diagram shows four compounds: Li_2Si, $Li_{21}Si_8$, $Li_{15}Si_4$ and $Li_{22}Si_5$. The exact composition of $Li_{21}Si_8$ had not previously been known.

Dr. Sharma confirmed the existence of the new compound by x-ray diffraction analysis. He determined its melting point to be 976 ± 8 K by differential thermal analysis. He produced a scanning electron micrograph that clearly indicates a single phase for the compound. He was also able to determine the maximum nonstoichiometric ranges of the lithium-silicon compounds from charge passed during the transitions between voltage plateaus.

KNOWLEDGE OF THE lithium activity present in the system's various compounds allowed Dr. Sharma to evaluate the stability of boron nitride with Li-Si alloys of differing composition.

A controlled potential was imposed on a boron nitride cloth sample in an electrochemical cell. By monitoring the current in the cell at different potentials, Dr. Sharma established the point at which lithium activity produces reaction.

Boron nitride was found to react with $Li_{15}Si_4$ only when in the presence of $Li_{22}Si_5$. The new compound, $Li_{21}Si_8$, did not exhibit sufficient lithium activity to attack boron nitride.

Reaction occurred according to the following equation:

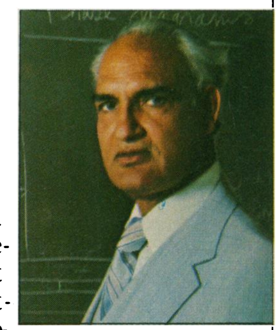
$$BN + (3+x)\,Li = Li_xB + Li_3N$$

The lithium nitride that formed during reaction dissolved in the molten salt electrolyte, but the lithium boride remained on the surface and became electronically conductive, causing high self-discharge in the cell.

"The establishment of the region of stability of boron nitride makes it possible to recommend appropriate charging limits," according to Dr. Sharma.

"Restricting the amount of charge in keeping with the recommended limits will control lithium activity, preventing the formation of highly-conductive compounds and adding durability to an electrochemical system which already displays high specific energy. Ultimately, that brings the prospect of high-performance electric vehicles closer to reality."

THE MAN BEHIND THE WORK

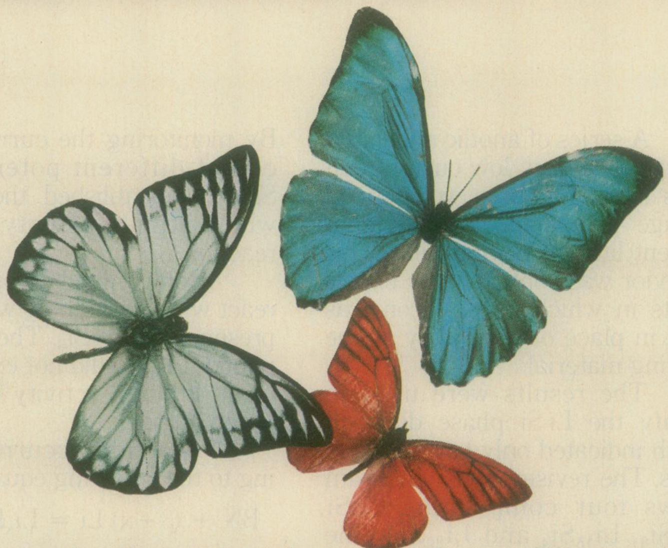


Dr. Ram Sharma is a Senior Research Scientist in the Department of Electrochemistry at the General Motors Research Laboratories.

Dr. Sharma was educated in India and England. He graduated from Banaras Hindu University with an M. Sc. in physical chemistry. He received a Ph. D. in physical chemistry and chemical metallurgy from London University's Imperial College of Science and Technology.

Before joining General Motors in 1970, Dr. Sharma conducted research at the Argonne National Laboratory, the Institute of Direct Energy Conversion at the University of Pennsylvania, the Nuffield Research Group in England and the National Metallurgical Laboratory in India.

DREAMERS, HERETICS, GADFLIES, MAVERICKS, AND GENIUSES.



The story goes that Henry Ford once hired an efficiency expert to evaluate his company.

After a few weeks, the expert made his report. It was highly favorable except for one thing.

"It's that man down the hall," said the expert. "Every time I go by his office he's just sitting there with his feet on his desk. He's wasting your money."

"That man," replied Mr. Ford, "once had an idea that saved us millions of dollars. At the time, I believe his feet were planted right where they are now."

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8 August 1980, Volume 209, Number 4457

SCIENCE

Needed: Conviction to Match Our Science

The quality of technology actually used in U.S. industrial production is best mirrored by looking at productivity figures. There the U.S. economy demonstrates a miserable performance overall, with a productivity growth rate that lags that of most of our foreign industrial competitors. Yet much of this poor performance is not a reflection on the technology of which our engineers are capable, and certainly not on our science. Instead, it reflects the failure of our society to give priority to savings and to capital formation, plus a great variety of social and political barriers to the replacement of antiquated plant facilities by more productive new ones.

While there are no quantitative data that can be used to assess the comparative states of technology here and abroad, I am convinced that even where our industrial technology lags that of competition, our capability does not. American engineers are capable of accomplishing more than what is actually built and made in many of our factories. It is not that our technology is weak or lagging. It is that we are failing to push as rapidly ahead as we could as a nation.

On the scientific scene, our science is still the envy of the world. Only last year our spacecraft took the most extraordinary pictures and measurements of the planet Jupiter and its moons, and made in one mission more extraordinary observations in planetary science than had been made since Galileo. The preeminence of our microbiology is unchallenged and the beginnings of its industrial potential are now in sight. The combination of our solid-state science with our industrial electronics engineering has done much to create the most spectacular growth industry the world has seen. Geological sciences have not only brought us understanding of the dynamics of the earth's crust that have shaped our continents, but have also contributed much to U.S. world leadership in the scientific search for oil and other minerals.

Despite this record, the energies of our best scientists seem too much devoted to debates over the shutting down of major research facilities and the choice between going abroad for the best facilities or facing a long, drawn-out effort to acquire them here, stretched out not by technical challenge but by financial restraint. American scientists admire and applaud the new leadership achievements of European nations in providing first-rate new facilities for their scientists, and envy the Japanese scientists and engineers their nation's wholehearted support and admiration. We would not have it otherwise. But we are in a serious, if friendly, global competition with our allies. America no longer can take technical strength for granted.

We have entered an ambivalent period. The press reports our scientists still winning Nobel Prizes from a foreign government, along with "Golden Fleece Awards" from their own. Scientists are concerned that their energies are increasingly diverted by administrative encrustations, such as faculty time recording under OMB circular A-21. They remain committed to the most rigorous competition to ensure that the best ideas receive funding support, and they are understandably confused by persistent questions about the legitimacy of peer review as the mechanism for that competition.

Thus, the picture of American science and technology today is one of great strengths yet deep doubts, of strong foundations and timid commitment, of critical importance to the economy and uncertain political priority. If indeed our domestic and our foreign trade performance are poor, is lagging technology the symptom or the cause? And if technology lags, is this because the steam has gone out of our science? Or because of a failure of economic policy and industrial will?

There is plenty of room for debate, but there is an obvious conclusion: whatever the cause and effect relation between scientific, technological, and industrial performance, our nation should commit itself to excellence in all three areas. No less a goal is worthy of us.—LEWIS M. BRANSCOMB, *IBM Corporation, Armonk, New York 10504*

Excerpted from a commencement address at the Polytechnic Institute of New York, Brooklyn, 29 May 1980.