Culture and Materials Innovations — U.S. versus Japan

David Kingery

About 40 people met at the University of Arizona in December 1990 to discuss the influences of Japanese and U.S. cultures on technological innovation in advanced materials. Roughly half the conference participants were equally divided between Japanese and U.S. scientists/engineers who have been and are successful researchers, managers, and innovators playing leadership roles in materials research and development. A quarter of the participants were active or former successful managers of materials development and/or serious scholars of innovation and technology transfer. The final quarter consisted of anthropologists and sociologists, most with little or no background in technology or technological innovation. The conference was an experiment in an emerging field that I shall call the "anthropology of technology."

The paradigm of materials science and technology is that materials synthesis and processing lead to structure and properties that determine performance. Only a little reflection will show that this model mixes apples and oranges. Structure and properties are material attributes. Processing and performance are socio-technical activities involving human perceptions, human behavior, and social organization. The engineering community is beginning to recognize and accept this: the 1990 National Academy of Engineering Annual Meeting Symposium considered "Engineering as a Social Enterprise."

Our meeting began with a discussion by Stephen Kline of Stanford University about how and why we should be concerned with the nature of the socio-technical systems within which technology is embodied. Such systems are complex, and innovation may involve changes not only in products and processes of manufacture but also in the social arrangements of the system, fiscal and legal matters, the socio-technical systems of distribution and use, and the overall system as a whole. Kline proposed a paradigm for innovation that involves a number of different feedback loops.

In discussing technological innovation at some depth, we are on the horns of a dilemma. We need the participation of the scientific and engineering craftsmen who are out there doing innovation and have firsthand knowledge of what's actually happening. But their model for such a discussion tends to be one of technological determinism and an almost inevitable sequence of events that we know to be false or misleading. We addressed this problem by bringing technologists and managers together with anthropologists who have little knowledge of technology, but a sensitivity to the social and cultural context of technological activities and change. In a further restriction on the scope of our meeting, the topic was limited to influences of cultural differences—between Japan and the United States. We chose to focus on Japan vis-à-vis the United States for two reasons: 1. There are distinct cultural differences which many books and articles have associated with relative success in science, technology, and corporate management; 2. Japan and the United States are world leaders in the field of advanced materials.

Discussions focused on the invention of new products and processes and the early stages of product development as nascent and infant industries. At this stage of the innovation process, there has been little comparison between Japan and the United States even though the nucleation and growth of new industries may well be a critical step in the development of new high-value-added manufacturing. In order to focus our discussions we selected three advanced materials that are widely considered to be harbingers of the future. The discovery and confirmation of high-temperature oxide superconductors in 1986 unleashed extensive international research which has led to these materials being on the threshold of commercial innovation. Synthetic diamonds formed at low pressures have been undergoing technological development for about 10 years and commercial products are now being manufactured on a limited scale. Silicon nitride and related structural ceramics have been actively pursued for almost 40 years and are now in regular production in what may be described as an infant industry. As a group, these advanced materials provide insights into the progression from invention to nascent commercialization to infant industry.

Culture refers to the framework of behavior, beliefs, and customs common to a society; the structure within which events and behavior are interpreted; and the values and expectations within which the world is ordered. Japan and the United States have national cultures, but there are also various subcultures associated with smaller social organizations such as universities, national laboratories, and corporations within which technological innovation occurs.

Cultures are shaped by a variety of influences and change over time. In the United States, the changing role of women has led to revolutionary modifications in the family and the workplace. In Japan, women are rarely seen in technological and managerial roles, but this seems to be changing. Some U.S. and Japanese managers are actively attempting to modify their laboratories or corporate cultures. Traditional Japanese researchers and managers have lifetime employment, and work is often considered the most important life activity. However, some fraction of the generation under age 30, the "shinjinrui," are not afraid to change jobs and are said to care more about their pleasures than their work. Cultural contexts are deeply imbedded and difficult to alter, but one should keep in mind that this conference was populated by successful innovators and managers in the 35-65 age group.

When we question how culture and social context affect innovation, we may inquire as to the effectiveness of communication between designers, engineers, and users. We may ask if the record shows that Americans are better at bold new theory and the Japanese better at incremental improvement. Americans generally believe that design by committee is catastrophic while the Japanese seem much more comfortable with that process. Does this suggest that the styles of Japanese and American innovation differ rather than their contents? Can there be group consensus innovation in Japan which is as effec-

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tive as directed team innovation in the United States? We may ask what accounts for the innovative success of Japanese national laboratories. We may ask whether advanced materials innovations occur in the same mode as agricultural innovations or as innovations in mature industries. We may ask if laboratory, village, corporate, and household mobilization of labor follow the same patterns. Two major differences are the strong "vertical" social structure in Japan and Japanese group consensus decision-making versus the U.S. directed team approach. We may ask how these cultural differences affect innovation and invention. We must recognize that the interactions of culture and technology constitute a multiple, variable, complex social-culture-technological process that is not subject to facile, reductionist, one-line conclusions.

All the discussions at our meeting argued against giving too much credence to simplistic statements based on anecdotal evidence. That said, the conference did make some progress in initiating a process leading to a better understanding of these issues. There was unanimity among those present that each participant took away a sense of benefit.

In the space available, it's not possible to summarize a week's discussion of a complex subject.* But let's take one example: The idea that Americans are highly creative and that the Japanese have taken U.S. breakthroughs and transformed them into commercial success has come to be accepted wisdom in many circles. Our discussion of the discoveries associated with high-temperature superconductors and with low-pressure diamond synthesis provided no support for this view. In the field of high-temperature superconductivity, where Japanese and U.S. researchers left the starting gate together, the rate of new discoveries has been remarkably equal. Japanese research has been as creative as its American counterpart and vice versa. In the discovery phase of low-pressure diamond synthesis, the Japanese have taken the lead. It seems that many analyses of U.S. versus Japanese creativity as resulting from different educational systems, etc., may be based on a faulty premise and largely without merit.

It is clear that U.S. scientists have garnered an overwhelmingly large fraction of Nobel prizes in the basic sciences. Conference discussions suggested that this may result from a profound difference in Japanese and U.S. concepts of "science" and of learning. The essence of U.S. science is taken as the development of principles and laws that can serve as fundamental concepts underlying future experiments and provide a basis for technological development. Science in Japan is taken rather as the process of methodological experimentation that leads toward learning. Experimental results are important because an experimental fact is "truth"; explanations and interpretations are less important. In advanced materials this concept of science has led researchers in Japan to focus more strongly on synthesis and processing of materials, in contrast to U.S. research dominated by characterizations based on condensed phase physics. This fundamental conceptual difference, deeply embedded in U.S. and Japanese cultures, was influential in many aspects of our discussions.

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The U.S. national consensus is that basic science inevitably leads to applied science, technology, innovative manufacturing, and a better quality of life. Although shown to be myth by many historians of technology, it is a widely and deeply held view by most scientists, policymakers, CEOs, legislators, and ordinary people.

In Japan, by contrast, science and engineering is seen as a single community. In Japan, there is an air of technology enthusiasm which has already passed into history in the United States. In his book *American Genesis,* Thomas P. Hughes quotes Perry Miller, who describes the American exhilaration with technology at the turn of the century: Americans "flung themselves into the technological torrent, how they shouted with glee in the midst of the cataract, and cried to each other as they went headlong down the chute that here was their destiny...." This period exists now in Japan and is exemplified by what has been described as a "ceramic fever" engaging all segments of the population during the 1970s. In Japan, the national consensus shared by scientists, engineers, corporate CEOs, politicians, legislators, and ordinary people is that Japan has a national imperative to place itself at the forefront of evolving technologies.

These different cultural visions of science and technology have profoundly influenced the course of technological innovation in advanced materials. As one example, U.S. national laboratories have been mainly centers of science; Japanese national laboratories focus on technological advancement.

The Japanese cultural mindset of "learning by doing" as compared with the U.S. mindset of "learning from principles" seems to have strongly influenced advanced materials innovation. The U.S. emphasis on individual achievement versus the Japanese emphasis on group achievement has also influenced advanced materials innovation. In the United States, characteristics of individuality have led to intense specialization, strong disciplinary boundaries, and effective networking *within a scientific field,* reinforcing and strengthening the effectiveness of the science establishment but isolating scientists from materials innovation. Japanese culture promotes a much more generalist set of interactions.

The strong "vertical" social organization in Japan exerts influences in many ways. One result is the deep trusting relationships that develop between suppliers and manufacturers and between manufacturers and customers. Many important feedback loops for technological innovation come from customers and customer perceptions.

The conference discussions all recognized technological innovation as a long-term process rather than an event. The preference in Japan for 5-10 year funding of development programs, compared with the one-year review period common in the United States, has influenced the results achieved.

Our discussions made clear that people do matter and that there is a strong opportunity for a new anthropology of technology. Technological innovation is a process that involves aspects of social organization and human behavior that are equally or more important than technical considerations. The conference and this approach toward thinking about technological innovation is best seen as an initial uncertain beginning.

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*A complete conference proceedings is available: *Japanese/American Technological Innovation,* edited by W.D. Kingery, Elsevier Science Publishing Co., 1991.

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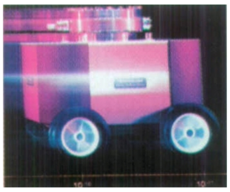

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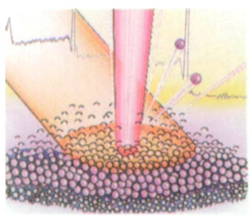

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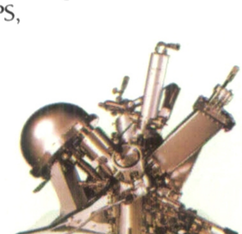

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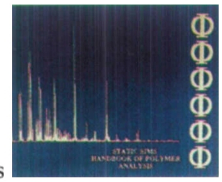

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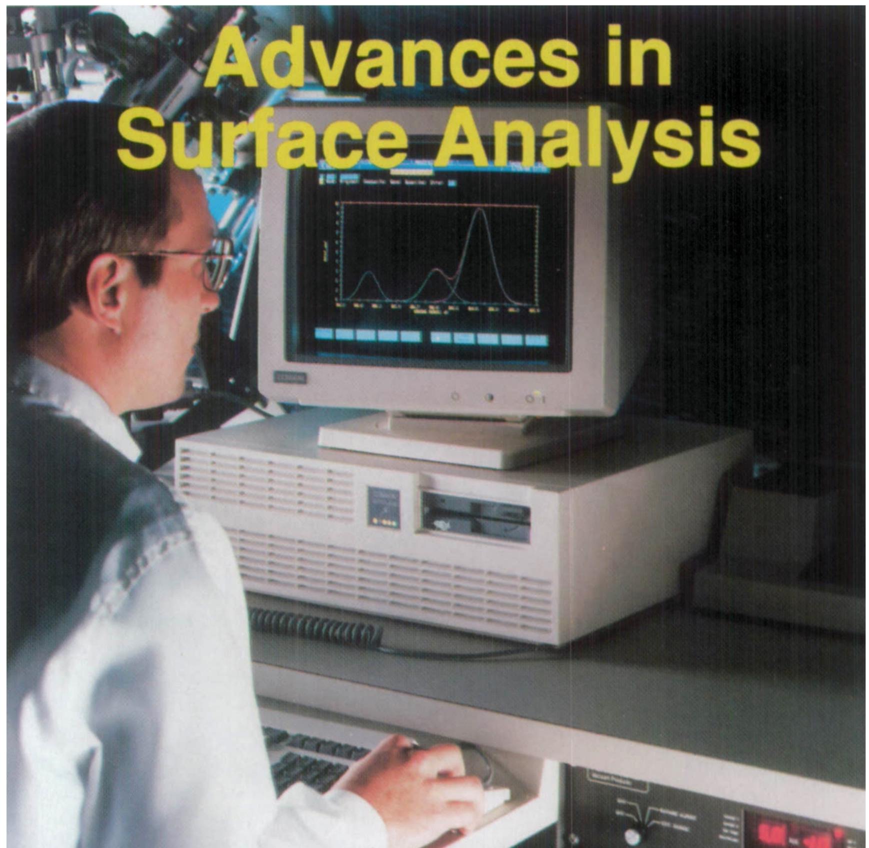

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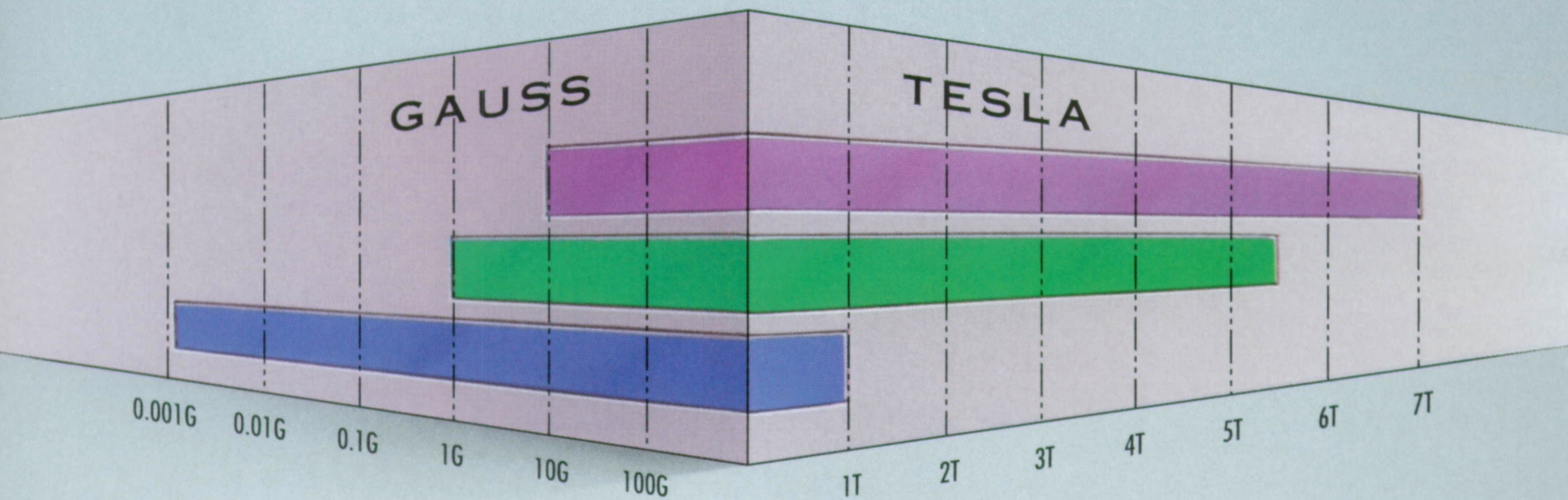

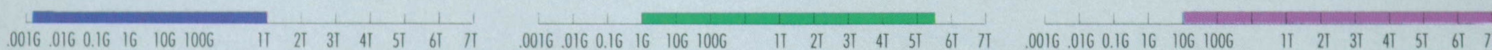

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