Perspectives of Materials Education Development in Russia for the New Century

Yu. D. Tretyakov

> Russia has grown to the demand for freedom, but this freedom should be imperatively bound to everyday labour and doing one's duty.
>
> —D.I. Mendeleev

> Every one of my students is a jewel. Every one will bring invaluable benefit, will put his life to alter the world to the better.
>
> —Lady Ester

Long-term forecasting is an ungrateful occupation even when it concerns weather forecasts. How much more complicated it is to forecast progress in human society. When viewing society as a system, its evolution follows the rules of nonlinear dynamics, leading inevitably to bifurcations. From that stage, the outcomes are unpredictable. Nevertheless, the temptation to foresee the future is part of human nature, beginning with Jules Verne, founder of science fiction, and ending with scientists who are certain of favorable results from biological cloning. Alas, the efficiency of forecasts is far from precise. Missing from the technologies and materials predicted by leading U.S. experts during the years of the Great Depression were TV, plastics, jets, and lasers.

The success of long-term forecasting depends considerably on the evolution rate of the system. The more slowly the system evolves, the more accurate are our predictions. Fortunately, in the system under consideration—materials science, materials engineering and technology, and materials education—the rate decreases consistently. For example, the new generation of ceramic superconductors initiated a scientific revolution 15 years ago, in which we were able to obtain an increase of transition temperature from 23 K to 135 K within seven years. We were at the frontier of a wide-ranging technical revolution that would transform energy, transportation, medicine, and many other areas. However, despite considerable financial support and research projects, especially during the first five or six years following the discovery by J.Y. Bednorz and K.A. Muller, an unexpected problem arose. The materials engineering and technology needed to achieve a high critical current density in long-length wires are still being researched. Although the problems seem solvable, it will take much time. This should not be surprising. It required half a century to move from discovery to wide application of metallic low-temperature superconductors even though these materials were much simpler both physically and chemically. Without these superconductors, it would be impossible to create modern tomographs.

Let us turn to the problems of materials education, a system that evolves even more slowly than that of materials engineering and technology. Taking into account the basic scientific knowledge required in mathematics, physics, and chemistry taught in secondary school, and the 20 years or more it takes to create education programs up to the PhD level, we can just now begin to lay the foundation of what will be achievable in 2020 or maybe much later.

Students are under the impression that graduates in materials science and technology from the best Russian schools can find high-paid employment abroad.

In Russia, we spent the last 10 years transforming the materials education system from highly specialized technical schools into technical universities, their number now exceeding 300. However, these changes did not yet lead to considerable positive results because our good intentions collided with economic reality. In Russian society in which education is free for a majority of students but in which the government budgets annually what is equal to only 100 USD per student in a technical profession, it is possible to calculate how small the budget is in comparison to the United States, Japan, or Western Europe. For this reason, it is important to develop interdisciplinary materials education programs at the 40 traditional classical universities in Russia, having strong schools in mathematics, mechanics, physics, chemistry, and biology. The basis of such a program was laid 10 years ago in Moscow State University (MSU) with the creation of the Higher School of Materials Science (HSMS). With the success of HSMS, we introduced a combination of chemistry, physics, mechanics, and materials into the National Education Standard so that the program is incorporated in most of the advanced classical universities in Russia. This educational program aims to form a body of scientists focused on developing new materials and technologies in the areas of energy, information technology, ecology, and medicine. The best way we saw to achieve this goal was by setting an environment in which each student attains long-term, continuous contact with high-level specialists—individual "face-to-face" supervision. For details on this program at MSU, see the August 2000 issue of *MRS Bulletin* (page 97).

While developing a generation of scientists through this materials education program at MSU, we are also preparing specialists for government and private enterprise. Presently, ~150,000 specialists graduate from technical universities, despite their uncertain employment prospects. A great number of these specialists will be lost to the so-called internal and external "brain drain"; that is, they will seek scientific positions outside of Russia or stay within the country but in careers such as marketing or management.

As we attempt to evaluate the materials education system for the next five to seven years, we will take the following three factors into account. During the last few years in Russia and other countries of the former Soviet Union, we have seen an increase in the total number of university students, which is due to two factors. Either students are pursuing higher education in order to avoid military service or because of the recently generated perception that education is valuable and should be achieved by every young person. In 2001, the number of students in all universities in Russia exceeded one million. The interest for a technical education has grown considerably since the economic collapse in Russia in 1998. Students are under the impression that graduates in materials science and technology from the best Russian schools can find high-paid employment abroad. The third factor is that the extremely low salary of all professors enables the universities to attract many highly qualified scientists to materials education programs. The ability to hire many highly qualified scientists would be inconceivable in Western countries because it would cost them much more than in Russia. These factors produce an optimistic scenario for the development of materials education in Russia for at least the next 10 years.

To evaluate the status of materials education in the long-term is more complicated and uncertain as we take into account basic changes occurring in Russia. Among them are, first of all, a low birth rate and deterioration of health quality, especially among the young due to the increase in drug addiction and the aged due to dipsomania. These health conditions will lead to a noticeable reduction of life expectancy. Taking into account current social and political factors, these conditions are expected to continue for the next several decades. Recent opinion of expert sociological estimations shows that they will lead to a noticeable reduction in population and possibly an abrupt reduction in the number of students as well as professors. This tragedy is not expected to affect us in the near future as two-thirds of the 300,000 students who entered the technical universities this year are expected to complete their education successfully.

However, another serious problem concerns possible negative effects of the education reform now in process in Russia. If graduates from Russian schools have traditionally received an education in mathematics, physics, and chemistry superior to many other countries, this situation may deteriorate during the next several years. The number of students accepted into technical high schools may be reduced sharply, too, due to poor basic education. The persistent realization of the education model for secondary school developed by the well-known psychologist A.G. Asmolov may help preserve and even raise the level of education necessary for transition into the materials education programs in technical and academic universities. However, the number of students able to study successfully will decrease sharply. The principal goal will be to develop interdisciplinary materials education programs similar to that at MSU.

Suggested Readings:

1. Yu. D. Tretyakov, *MRS Bull.* **26** (8) (2000) p. 97.
2. S.P. Kapiza, S.P. Kurdumov, and G.G. Malinezky, *Synergetics and Prognosis for the Future* (in Russian) (Nauka, Moscow, 1997).
3. V.E. Shukshunov, *New Role, Place, and Mission of Education in the 21st Century* (in Russian) (International Academy of Science and Higher School, Moscow, 1998).

> The prospect of materials education in the new century depends on the economic choice of Russia to continue as an open society or to become closed, that is, between globalization and anti-globalization.

The prospects for specialists in materials engineering and technology and materials science engineering—such as metals and alloys or electronic materials—will progress if the scientists are able to assimilate the following in their materials education. They will require an extensive foundation in materials science with an accent on the chemical aspects of the development of modern materials, which implies a basic chemical education, especially in solid-state chemistry. They will require knowledge on the theory of physical phenomena determining the properties of functional and constructional materials, which implies a basic physical education, especially in solid-state physics. They will need a mathematics and mathematical simulation background in order to create meaningful materials design. They will need to learn the systems approach for the creation, investigation, and application of new materials, which requires skills in modern physical and chemical experiments. They will also require the necessary skills in information retrieval and foreign languages enabling them to work, without difficulty, in international teams.

With this type of materials education, specialists will be able to resolve key materials science problems in Russia and abroad. Evidently, broad realization of this basic materials education cannot be achieved in a closed university system. It will be necessary to maximize the best traditions of Russian secondary school, especially in mathematical and natural science education.

The six-year experience of the Soros program for supporting teachers in Russia has demonstrated that despite an economically failing environment, we have thousands of devoted teachers nationwide who are able to educate gifted students. The problems we will face in the future are how long they can last without substantial government support and who will replace them 10 or 15 years from now.

Another important factor for the positive development of materials education in Russia will be the state of Russian science in the coming years. The problem lies in maintaining leading scientific schools that have exclusively contributed to the development of the country's industrial and defensive status. Unfortunately, the progress in applied sciences suffered irreparable losses during the last 10 years and it is not known if the basic sciences can survive in the institutes of the Russian Academy of Sciences (RAS). Government support of science decreased abruptly in post-Soviet years, preventing the 600 scientific and research institutes of RAS from performing properly. During the last 12 years, the number of scientists dropped by a factor of 4 or 5 (from three million to 600,000 or 700,000) as a result of the internal and external brain drain processes.

A radical solution to these problems would be an integration of efforts among secondary schools, universities, and the scientific and research institutes of RAS. Some steps have been taken in this direction by a federal program called "Integration." However, the program is insufficient because the universities and RAS institutes do not have modern experimental facilities. For example, they are unable to compete in new branches of study such as nanotechnology. The laboratories lack the new generation of electron microscopes; atomic force microscopes; instruments for high-performance magnetic, electrical, and optical measurements; and other equipment. There is not a single semiconducting quantum interference device magnetometer in Moscow, and powerful magnetic systems for fields over 10 T1 are not used due to the high costs of liquid helium. Thus, integration of the various educational and research institutes is necessary but insufficient.

The prospect of materials education in the new century depends on the economic choice of Russia to continue as an open society or to become closed, that is, between globalization and anti-globalization. It would be hasty to conclude that the decision made 10 years ago is definitive. In his book *Why Russia is not America* (Krymsky Most Publ. Co., Moscow, 2000), which received wide public resonance upon its publication, A.P. Parshev argues that Russia's inability to compete in the world is a consequence of rigorous natural conditions and proposes that Russia close off its economy from the world's economy. The author advocates that the country forbid non-Russian credits and the export of Russian capital. Taking into account that Russian society is displeased with its present economic status and with the large withdrawal of finances from the country, we cannot ignore that the concept of a closed society may find favor with the people. If a few representatives from Russia took part in anti-globalist actions during the G-7 Summit in Italy, their numbers might increase considerably as the authorities fail to protect the open society against crime, autocracy, and bureaucracy.

Several routes could be taken in the area of materials education to help ensure that Russian society, in the future, is open and competitive. One way is to receive external support such as through the Soros Foundation. During the most critical period, this Foundation provided 40,000 grants to scientists, and financially supported 22,000 teachers and ~4000 professors and assistant professors, as well as over 11,000 students and postgraduate students in the universities.

Rather than view the phenomena of external brain drain as a negative factor, it is possible to imagine the development of materials science and education with the help of Russian scientists in leading university and scientific centers in the United States, Japan, and Western Europe. It would be important for these scientists to keep close relations with their *alma mater*, following the example set by P. Kapitza, L. Landau, and Ya. Frenkel. In this way, the expected annual flow of over 1000 Russian materials scientists to foreign universities during the next several years will be mutually beneficial.

An open society in the future can also be established as a result of governmental financial support, ensuring that the activities of 600 key scientific schools and several tens of Russian universities will be able to generate highly qualified scientists in the interdisciplinary area of materials science and engineering. The way to an open society completely corresponds to the strategic interests of Russia as expressed, in particular, in the government document "National Education Doctrine of Russian Federation."

To forecast the development of materials education in Russia in the new century, it is necessary to consider that we now possess, after an immense economical crisis, a quarter of a million specialists with a PhD level of education, ~900 state and private universities with three million students, and several hundreds of scientific journals among which one-sixth of them are in the areas of materials science and engineering and materials education. This year, over 1800 scientific congresses and conferences are planned in Russia, a large portion in the areas of materials science and engineering and materials education. Unfortunately, scientists abroad see only a "tip of the iceberg." Russian materials science and education has received little recognition, even in the excellent text, *The Coming of Materials Science* (Pergamon, London, 2001) by R.W. Cahn. This indicates that the world will need to be made aware of the contribution of Russian scientists and engineers to the international system of materials science, engineering, and education.

> Rather than view the phenomena of external brain-drain as a negative factor, it is possible to imagine the development of materials science and education with the help of Russian scientists in leading university and scientific centers in the United States, Japan, and Western Europe.

***Yu. D. Tretyakov**, a professor at Lomonosov Moscow State University in Russia, is dean of the Higher School of Materials Science (HSMS°, chair of the Inorganic Chemistry Division, and has supervised the Advanced Materials and Technologies Program in the Department of Chemistry since 1988. He became a Corresponding Member and a Full Member of the Russia Academy of Science in 1984 and 1987, respectively, and has received the Kurnakov prize in chemistry from the Russia Academy of Science and the Lomonosov prize (twice) from Lomonosov Moscow State University. Tretyakov's research activities and interests have been in the areas of chemistry and thermodynamics of solid-state reactions, nonstoichiometry of oxides and chalcogenides, chemistry and technology of materials with nonconventional magnetic and electric properties, cryochemical technology of advanced materials, and high-temperature superconductors. He graduated from Rostov-on-Done University in 1954 and received his PhD degree in 1958 and DrSci degree in 1965. He currently offers a special course titled "Materials: Past, Present, Future" for students in HSMS that reviews the materials applied in science and technology based on the classification of chemical elements and substances used to create the materials.*