

Boris Nikolaevich Kabanov **(In Commemoration of His Centenary)**



Boris Nikolaevich Kabanov (1904–1988) was a professor, doctor of chemistry, merited scientist and engineer of the Russian Federation, and a close collaborator to academician A.N. Frumkin.

Kabanov graduated from the Chemistry Faculty, Moscow State University (1930). When a student, he was laboratory assistant in a chemical bacteriology laboratory at a factory. Having graduated, he worked for ten years as scientific-staff member at the Karpov Institute of Physical Chemistry. In 1940–1958, he was head of Laboratory of Electrode Processes, in Department of Electrochemistry headed by Frumkin, at Institute of Physical Chemistry, Academy of Sciences of the USSR. In 1958, he left with his laboratory for the Institute of Electrochemistry, Academy of Sciences of the USSR, founded by Frumkin, where he headed Laboratory of Electrode Processes in Chemical Power Sources, which was later named Laboratory of Electrochemistry of Metals and Semiconductors.

By his character and convictions Boris Nikolaevich inclined to fundamental science. However, the situation forced him to develop problems aimed at solving practically orientated tasks, e.g. design and modification of power sources, development of methods for electrochemical machining metals, etc. During the war years Kabanov provided useful guidance to factories manufacturing power sources and invented several simplified methods for metal corrosion protection for defense factories. When solving application problems, Kabanov conceived and implemented them so perfectly that many of his findings became cornerstones of modern electrochemistry.

In his first fundamental work Kabanov explored a solid/liquid/gas three-phase boundary at an electrode surface. He studied effects of forces emerging at such an interface on the behavior of gas bubbles and, in collaboration with Frumkin, developed a quantitative theory for the balance of forces at the boundary. The equation, derived for linking acting forces to the contact angle between a bubble and the electrode surface, became known as the Frumkin–Kabanov equation. The results of those studies are widely used for interpreting mechanisms of flotation, electrolytic degreasing of metals, phenomena caused by the bubble formation at boiler walls, etc. The method for the contact angle measuring, developed in those studies, opened way for determining the potential of zero charge (PZC) of solid electrodes. Progress in the electrode kinetics and theory of metal corrosion demonstrated that PZC is an important electrochemical constant. Kabanov paid much attention to this problem: his laboratory determined values of PZC for many a metal.

In 1934, Kabanov busied himself studying the hydrogen overvoltage. For a hydrogen overvoltage theory, of crucial importance was to determine the slope of Tafel lines at higher current densities. Taking measurements under such extreme conditions encountered seemingly insurmountable difficulties caused by heat evolution, gas evolution, and concentration polarization in the near-electrode layer. Kabanov developed an ingenious procedure for accurately measuring the overvoltage at current densities of up to $\sim 100 \text{ A/cm}^2$. A study that used this procedure, which defined fundamental questions in the electrode kinetics, was used by him twenty-five years later for solving electrochemical machining problems.

Research into the processes in lead-acid batteries, which was started in 1935 under Kabanov's guidance,

culminated in formulating basics for modern theory of such batteries. Numerous suggestions for improving exploitation characteristics of the batteries were put forth. The seemingly applied research solved, when studying the lead electrode, such fundamental problems as the mechanism and kinetics (ADP) of anodic dissolution and passivation of metals.

The research in the lead passivation began a large cycle of studies on the interrelation between ADP of metals and the adsorption processes. The extent of those studies, fundamental for electrochemistry and corrosion, was remarkable in Kabanov's laboratory and included such practically important metals as iron, zinc, silver, aluminum, magnesium, and so on. The metals were selected primarily on the basis of their current or expected use in industry. The series of works was begun by examining ADP of iron in alkalis. The research led to the development of conceptions on a multistage character of ADP of metals that nowadays are viewed as classic. For the first time it was demonstrated that iron can be passivated anodically by less than a monolayer of adsorbed oxygen.

The results, together with the earlier studies on the hydrogen overvoltage at superhigh current densities, laid foundation of theoretical concepts for controlling electrochemical machining processes. We single out a series of works on the anodic anionic activation of metals, which Kabanov started in the 1940s as applied to theory of metal corrosion; in the 1960–1980s, the series led to the development, in his laboratory, of one of the basic theoretical concepts of electrochemical machining.

In the mid 1950s, Kabanov turned to an exceedingly pressing problem of processes in silver–zinc batteries. At that time, the silver–zinc battery was thought of as a very promising power source to be developed as soon as possible; the work coincided in time with foundation of the Institute of Electrochemistry. Processes at silver and zinc electrodes were studied.

B.N. Kabanov's brilliant scientific intuition played a part in the discovery of electrochemical incorporation of metals into solid electrodes at potentials much more positive than equilibrium potentials of these metals.

The electrochemical incorporation was Kabanov's favorite brainchild and the most important result of the last three decades of his scientific work. Undoubtedly, he believed the advances in this field to be the major deed of his life, and not only because it cost him enormous effort to demolish popular opinion but also because he was the first to fully appraise the importance of electrochemical incorporation of alkali metals for the progress of electrochemistry and managed to convert many electrochemists. Kabanov drew attention to some strange phenomena observed by him and others during the cathodic hydrogen evolution, in particular, the slow change of overvoltage with time, the hysteresis during forward and reverse recording of the current-density dependence of the overvoltage, and the elevated

slope of the dependence of overvoltage on the logarithm of the current density. These phenomena had usually been attributed to random factors, e.g. impurities, presence of oxygen, or formation of surface hydrides. In a paper published by Kabanov and coworkers in 1962, they positively stated that the time changes of the hydrogen overvoltage at silver, zinc, and lead were due to the formation or decomposition at the cathode surface of chemical compounds formed by the cathode metal and an alkali metal. The process of electrolytic deposition of alkali metals at solid electrodes with the formation of alloys in a single act with the electron transfer, accompanied by the penetration of the alkali metals into the electrode, was labeled the electrochemical (cathodic) incorporation. Nowadays, these notions are commonly accepted.

The discovery of cathodic incorporation of alkali metals was of utmost significance for the electrochemistry of aqueous solutions, as it changed common views on many electrode processes, which relied on experimental data obtained in supporting electrolytes containing ions of alkali metals. The interaction of alkali metals with solid cathodes often changed rates of processes and even the nature of both the processes and the electrodes. The experimentally found significant effect of the electrode potential on the incorporation rate defined the direction of further research. The effect definitely pointed to electrochemical nature of the process and opened new ways of its practical use. It was found that the incorporation was a new electrochemical reaction distinguished by the participation in it of neutral defects (vacancies) of the crystal lattice of the electrode metal.

The studies of Kabanov and coworkers on electrochemical incorporation continued concurrently with closely related electrochemical investigations into the underpotential deposition and intercalation into electrodes. However, the works on the incorporation were not integrated into the body of research performed in other countries. In the meantime, all the three above scientific lines represent but different approaches to the same phenomenon. The term “underpotential deposition” fails to reveal the essence of the phenomenon; it only emphasizes in a purely phenomenological manner its feature that confounded its first researchers: a metal was deposited on a cathode at potentials much less negative than their equilibrium potential of the metal as a phase. The term does not formally specify whether one deals with the formation of an intermetallic phase (as with the incorporation proper) or metal adatoms at the electrode surface. In the latter case, “underpotential” emerges during the deposition at the expense of the chemisorption energy. The concept of “intercalation” is closer to the incorporation, because it always implies the process in the bulk, rather than at the surface. However, the intercalation objects are usually materials with a “loose” (layered) crystal lattice, which makes it easier for the foreign atoms to penetrate into the electrode. As to the electrochemical incorporation, it is the phenom-

enon of a more general nature, as no restriction is imposed on the structure of the electrode material.

B.N. Kabanov always supported novel scientific trends in his laboratory: the electrochemistry of semiconductors, photoelectrochemistry, and so on.

Kabanov was an excellent experimenter. He would invent experimental procedures, design electrochemical cells, and adapt electrical instruments sometimes changing their design.

Kabanov had never taught or lectured; however, his educational activity was quite extensive. In the 1940–1950s, the principal textbooks on the electrochemistry were those he edited or furnished with comments and augmented. Among these was his appendix *Elektrodneye protsessy i stroenie dvoynogo sloya* (Electrode Processes and Electrical Double Layer Structure) to S. Glasstone's monograph *An Introduction to Electrochemistry* (New York, 1947) translated into Russian in 1951. In it Kabanov presented for the first time current views on the link between the electrical double layer structure and the electrochemical kinetics. A year later,

the well-known *Kinetika elektrodnykh protsessov* (The Electrode Kinetics), edited by A.N. Frumkin, was published in 1952, for which Kabanov wrote the introduction and three chapters. His book *Elektrokhimiya metallov i adsorbtziya* (The Electrochemistry of Metals and the Adsorption) published in 1966 attracted considerable attention of the electrochemists. Under Kabanov's guidance over thirty persons received candidate's degree.

For his service in science and engineering, B.N. Kabanov was bestowed with orders and medals of the USSR.

The most striking feature of Kabanov's character was probably benevolence, which was felt by anyone at first contact. It is remarkable that he was at the same time a man of principle and strictness in both scientific and everyday activities.

Boris Nikolaevich Kabanov had left his mark on science and his friends and colleagues.

**A.D. Davydov, Yu.V. Pleskov,
B.M. Grafov, and D.I. Leikis**