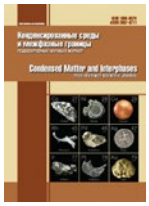

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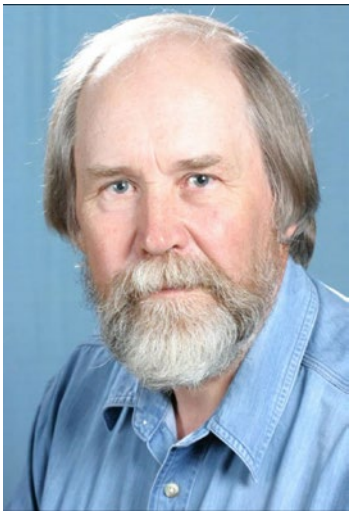
Chronicle

In memory of Vladimir Andreevich Terekhov on the 80-th anniversary of his birth (September 20, 1946 – November 1, 2024)

Honored Scientist of the Russian Federation, Professor E. P. Domashevskaya – Teacher of Professor V. A. Terekhov

Vladimir Andreevich Terekhov, Honorary Worker of Higher Professional Education of the Russian Federation, Corresponding Member of the Russian Academy of Natural Sciences, Doctor of Physical and Mathematical Sciences, Professor, Teacher, renowned scientist, excellent educator, and a man devoted entirely to science, the Voronezh State University, Faculty of Physics, and the Department of Solid State Physics and Nanostructures.



Vladimir Andreevich, a prominent representative of the first post-war generation, was born on September 20, 1946, in the village of Arkhangelskoye, Voronezh Region. He received his higher education in the Department of Solid State Physics of the Physics Faculty of Voronezh State University in 1969, defended his candidate's (1978) and doctoral (1994) dissertations, and received the academic titles of associate professor and professor. Chairman of one and a member of two other doctoral dissertation councils, author of several hundred scientific papers, supervisor of 15 doctors and candidates of physical and mathematical sciences, including the current head of the Department of General Physics and Physical Materials Science, Doctor of Physical and Mathematical Sciences S. Yu. Turishchev and Deputy Dean of the Physics Department for Educational Work, Candidate of Physical and Mathematical Sciences K. A. Barkov.

Vladimir Andreevich, a world-renowned scientist, had an exceptionally broad scientific interest. Professor Terekhov pioneered the use of new, unique Russian X-ray spectrometers and pioneering methods for their use with synchrotron radiation sources in the study of new materials over forty years ago. After graduating from Voronezh State University, he completed extensive internships at Leningrad State University (the birthplace of the RSM-500), and then at the only synchrotron in the USSR in Novosibirsk. Since the early 1970s, the new method of ultra-soft X-ray spectroscopy has been pioneered in Voronezh for the first time in active research into interatomic interactions and the electronic structure of semiconductors. This was primarily due to the acquisition, at the initiative of E. P. Domashevskaya, of a unique instrument—the RSM-500 X-ray spectrometer-monochromator, developed at Leningrad University by Professor A. P. Lukirsky, son of the renowned Academician P. A. Lukirsky, a colleague and collaborator of Academician A. F. Ioffe, Director of the Physical-Technical Institute of the USSR Academy of Sciences in Leningrad.

The Voronezh instrument (the 13-th) was built in Leningrad at the Burevestnik Scientific Production Association's experimental plant under the supervision of its General Director N. I. Komyak. At VSU, the instrument was constantly improved by a young assistant, V.A. Terekhov, a student of E. P. Domashevskaya, who converted it to oil-free high-vacuum technology, modernized the recording equipment, and achieved the best sensitivity in the USSR (Fig. 1).

The unique features of this new experimental approach to determining the nature of interatomic interactions and band structure in solids consisted of the integrated use of two methods: X-ray spectroscopy (XRS) and X-ray photoelectron spectroscopy (XPS). This combination of methods creates a unique opportunity to obtain information on the distribution of both the integrated density of states of valence electrons responsible for chemical bonding and the local partial density of states, which contributes to the integrated density of states of all valence electrons with different state symmetries across atoms of all types of a given compound.

X-ray spectral studies were performed in Voronezh using a unique RSM-500 laboratory instrument. X-ray photoelectron spectra, meanwhile, had to be recorded in Moscow, primarily in the laboratory of Academician V. I. Nefedov at the N. S. Kurnakov Institute of General and Inorganic Chemistry of the USSR Academy of Sciences or in the laboratory of Professor Yu. A. Teterin at the Kurchatov Institute of Nuclear Physics. These centers were the first in the USSR to use X-ray electron spectrometers from Varian and Hewlett Packard.

It was through the combination of two methods – X-ray electron spectroscopy and X-ray spectroscopy – on numerous semiconductor binary and ternary compounds that the Voronezh Scientific School experimentally discovered and theoretically substantiated previously unknown patterns of interaction between *d*-electrons of metals and *s*,*p*-electrons of non-metals. These patterns are resonant in nature and are determined by the relative positions of the interacting elements, metals and non-metals, in the Periodic Table of Elements.

It was also during this time (the 1970s) that V.A. Terekhov achieved an outstanding result in

Fig. 1. Assistant V. A. Terekhov, a future professor of VSU, obtains the first results on a new X-ray spectrometer – the RSM-500 monochromator (early 1970s)

Voronezh using the RSM-500 instrument: the detection of δ-shaped localized maxima in the band gap in the partial density of states spectra of silicon single crystals, caused by the presence of donor impurities with a concentration of approximately 10^{-4} at.%. It was only ten years later that these results were reproduced in the United States, and then only using synchrotron radiation.

Since then, the Department of Solid State Physics has been developing the physics of localized states, which play a decisive role in the electrical and optical properties of heavily doped and disordered semiconductors. The developed approach has been successfully used to study the total local and partial densities of state of atoms in disordered condensed matter: from heavily doped to amorphous semiconductors and dielectrics. Particular attention was given to the study of localized states in the band gap, which provide direct information on the nature and number of defects in real materials: heavily doped, ion-implanted semiconductors, hydrogenated amorphous silicon, and other materials and heterostructures. The successful development of this field is reflected, first and foremost, in the content of Vladimir Andreevich Terekhov's doctoral dissertation, "Local Density of Electron States in Disordered Semiconductors" (1994).

The methods developed within the framework of this research were successfully used to analyze thin-film systems, coatings, and composites in collaboration with leading universities

(Lomonosov Moscow State University, Leningrad State University, Lobachevsky University of Nizhny Novgorod, etc.), with academic institutes in Moscow, Leningrad, Novosibirsk, and Minsk, and major research and production associations in Voronezh (NPO Elektronika, VZPP-Mikron, NIIET, VZPP-Sborka, NPO RIF, etc.), and were reflected in 328 published papers, including publications with Nobel laureate Academician Zhores Ivanovich Alferov, and in subsequent candidate and doctoral dissertations.

The Department of Solid State Physics and Nanostructures at Voronezh State University, numerous graduates and students, and close colleagues from Voronezh University and many other universities, academic institutes, and industrial enterprises in Russia and Belarus, as well as neighboring and far-flung countries, with whom Professor V.A. Terekhov closely collaborated, will always remember Vladimir Andreevich's outstanding abilities as an experimental researcher, a wise teacher and mentor, and the inexhaustible spiritual energy that he exuded (Fig. 2).

Head of the Department of General Physics and Physical Materials Science, Doctor of Physical and Mathematical Sciences S. Yu. Turishchev

Professor Vladimir Andreevich Terekhov is my mentor. All my theses, from my bachelor's thesis to my doctoral dissertation, were prepared under Vladimir Andreevich's supervision. But the term "scientific supervision" becomes almost a formality when discussing the teacher's role in a student's work. Identifying and energetically developing the most relevant research areas, organizing and supporting all possible activities, a unique gift for foreseeing the most sought-after research areas, the ability to teach, and explain incredibly complex concepts in simple and accessible terms—all these are the true qualities of a true mentor and wise educator.

Even in the most difficult moments, Vladimir Andreevich always found words that inspired, and like a true mentor, he provided all possible support not through words but through actions. But without delving into endless personal

Fig. 2. The staff of the Department of Solid State Physics with Nobel Prize Laureate Zh. I. Alferov in the laboratory of Professor V. A. Terekhov (2007)

discussions, which would be a given for any university graduate, I'd like to highlight a few characteristic traits of the work of a true scientist, educator, and mentor like Vladimir Andreevich.

A scientist. The opening of the BESSY-II synchrotron laboratory and megascience facility in Berlin in 2002 was attended by VSU scientists: Evelina Pavlovna Domashevskaya, professor and head of the renowned scientific school "Atomic and Electronic Structure of Solids," also internationally known, head of the VSU Department of Solid State Physics, and Vladimir Mikhailovich Kashkarov, associate professor of the same department.

This was a breakthrough, in which Vladimir Andreevich played a key and indispensable role! The result was the opportunity, less than a year after the opening, to use unique equipment for synchrotron research on silicon-based functional nanostructures, which were relevant at the time (and, in some respects, still are today). The result is a whole series of publications, multiple experiments on this (and other) mega-science facility, articles, dissertations, and research projects. All under the supervision of Evelina Pavlovna and Vladimir Andreevich as the leading scientist. But the main method we used then and actively use today—namely, fine-structure spectroscopy near the absorption edge of ultra-soft X-ray synchrotron radiation—was developed on the RSM-500 instrument in laboratory conditions under the supervision of Professor Terekhov!

And quite successfully, several years before the dawn of "synchrotron research." This development, even if in some cases only at a "qualitative" level, provided a long-lasting understanding of how to proceed, despite the numerous difficulties associated with using the extensive synchrotron equipment. And the combination of electron-energy spectrum research with the capabilities of the unique RSM-500 and a comprehensive view of existing research capabilities ensured international validation and demand for the results at the highest level.

Teacher. Vladimir Andreevich's lectures can safely be considered exemplary, exemplary, and a model to emulate. They conveyed complex issues clearly, concisely, and, most importantly, in simple terms. So complex that only after experiencing, for example, a large mega-science semiconductor manufacturing facility, in the workshop, or at a major mega-science research facility—a synchrotron center, with its unique, sophisticated research equipment—do you understand how important these lectures were, how profound the knowledge Professor Terekhov imparted. It was Vladimir Andreevich who taught the course on synchrotron radiation at a time when we had no idea about the modern research being conducted today, and the Teacher already had this experience under his belt.

Mentor. The ability to see the essentials, to identify the key points, to reason solely based on facts, and to make informed predictions – these are invaluable skills for which we, his students, are eternally grateful to Vladimir Andreevich. It's important to always ask the right questions, find the right answers, to seek and understand the essence, to see beyond the horizon.

Thanks to these skills, nurtured by Vladimir Andreevich, today we, scientists at Voronezh University, have access to and the opportunity to use the most advanced and diverse research technologies, both at the laboratory level and at large megascience research facilities, the launch of which is only just planned. **This is the future of Russian science!**