Physics – Uspekhi **43** (4) 427 – 429 (2000)

PERSONALIA

PACS number: **01.60.+q**

In memory of Vladimir Aleksandrovich Molchanov

DOI: 10.1070/PU2000v043n04ABEH000725

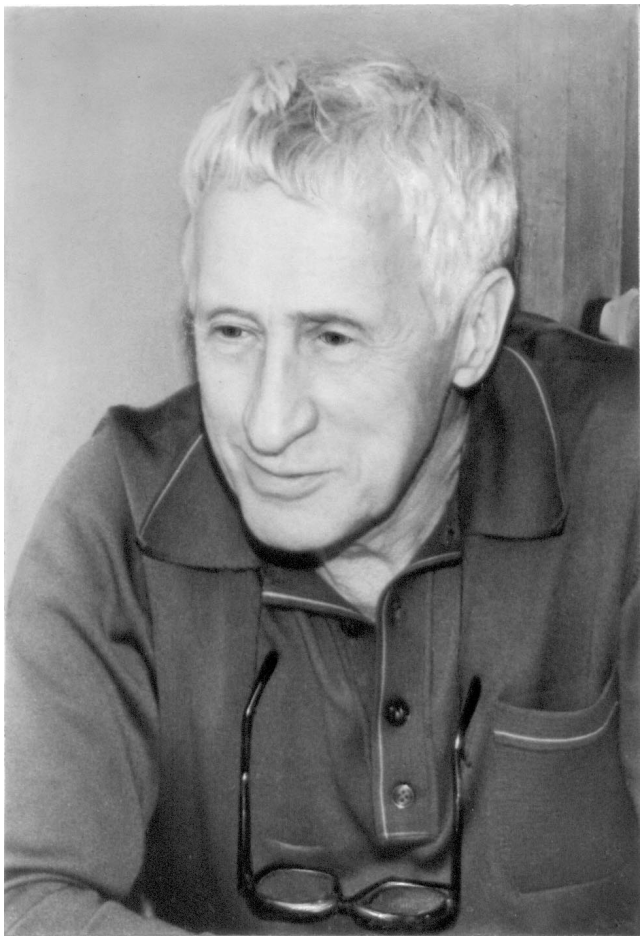
Vladimir Aleksandrovich Molchanov, an outstanding physicist, DSc in physics and mathematics, a professor of Moscow State University, who was very well known in the field of ion interaction with solid surfaces, died on September 27, 1999.

Vladimir Aleksandrovich Molchanov was born on November 2, 1930 in the village of Ivoĭlovo in the Novo-Petrovks district of the Moscow region, in the family of a school teacher. He enrolled in the physics faculty of the M V Lomonosov Moscow State University (MSU) in 1948. Molchanov did his diploma research work under the guidance of I L Fabelinskiĭ. V A Molchanov always regarded I L Fabelinskiĭ as his mentor in physics and held him in the greatest respect and gratitude until the very end. After graduating from the university, V A Molchanov worked for two years at the chair of general physics of the MSU physics faculty, where he took part in creating a number of optics practical studies for students.

In 1955 L A Artsimovich created the chair of atomic physics and electronic phenomena in the MSU physics faculty. On Artsimovich's request, Molchanov was transferred to this new chair. Task number one was to create the atomic physics laboratory work, then start colloquia and research work. V A Molchanov played a very active role in this effort. With Artsimovich's invaluable support and huge help from the mechanical and electrical workshops of the Department of Plasma Research of LIPAN (the director of which was Artsimovich), Molchanov created a setup for the study of ion beam interactions with solids at the Institute of Nuclear Physics MSU (INP MSU)[1], one of the first in the world (the earlier studies were done typically in gas discharge).

It was very early days for the physics of atomic collisions at solid surfaces, so V A Molchanov and a number of other physicists in the USSR and other countries found themselves creating the field almost from scratch. The main purpose of his work was to identify and investigate in detail the mechanisms of the phenomena caused by ion bombardment of solid surfaces treated as both quasi-elementary phenomena (such as ion scattering by the solid surfaces and emission of fast recoils) and as essentially non-elementary processes (such as sputtering and emission of secondary electrons, ions and photons).

One of the results of work on ion-electron emission was the discovery, together with E S Mashkova, D D Odintsov, V M Chicherov, V G Telkovskiĭ, in 1960 of the phenomenon of the anisotropy of ion-induced electron emission of monocrystals[2]. This phenomenon consists in a sharp decrease in the number of electrons emitted from a crystal being bombarded by ions when the direction of bombardment coincides with the crystallographic axes of the crystal.



Vladimir Aleksandrovich Molchanov
(02.11.1930 – 27.09.1999)

The anisotropy of the ion – electron emission proved to be one of the first among the discovered directional effects of interaction between atomic particles and crystals; together with a number of other orientational effects, including channeling (1963), this anisotropy effect formed the basis of a new field of solid state physics — the radiation physics of ordered media. L A Artsimovich had a very high opinion of V A Molchanov's experimental wizardry and regarded his as one of the very few top experimenters. V A Molchanov's speed of research was overwhelming; his capacity for work

[1] The atomic physics chair was a part of the department of nuclear physics in the physics faculty while the research by the staff was and is carried on at the D V Skobeltsyn Scientific-Research Institute of Nuclear Physics at the M V Lomonosov Moscow State University (NIIYaF MGU — in Russian, and INP MSU as an international abbreviation).

[2] Discovery diploma No. 126 in the State Depository of Discoveries, effective from October 13, 1960).

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Translated by V Kisin

was phenomenal. The experimental data he reported were highly reliable and soon reached the status of classics. They were reported in a large number of monographs and were used to test new equipment designed at newly organized laboratories.

In 1965 Molchanov presented his PhD thesis on the results of the study of the angular features of metal surface sputtering by monoenergetic ion beams. In his DSc thesis, presented in 1967, he summed up the angular dependences of ion scattering, ion – electron emission and sputtering of polycrystalline and single-crystalline solid surfaces under ion bombardment.

For further advancement of the work in INP in this field, the INP director S N Vernov suggested that V A Molchanov transfer to the plasma physics department of INP (1969).

Molchanov was always attracted to the problem of sputtering of solid surfaces and to the history of these studies. It was not accidental that he regarded as one of his important achievements the publication of the translation into Russian of the well known three-volume monograph *Sputtering by Particle Bombardment* (1984, 1986, 1998), which greatly helped the progress in the work on interaction of atomic particles with solids at INP MSU and at other research centers in our country. Molchanov's work on sputtering in recent years dealt with the spatial distribution of the sputtered material. This work is of fundamental interest since the debates on sputtering mechanisms are still continuing. Most of the modern technologies that make use of sputtering of solid surfaces badly need data on the spatial distribution of the sputtered atoms.

An extensive series of publications of V A Molchanov and his post-graduates and colleagues was devoted to scattering of medium-energy ions, that is, to the energy range in which one needs to take into account both mechanisms of energy loss by a particle moving through matter, namely the elastic and non-elastic mechanisms. Though this may sound strange nowadays, at the early stage of research of ion scattering by solid surfaces the path to deducing the binary nature of collisions of scattering ions with solid atoms was quite difficult. The well-known Danish physicist Peter Sigmund wrote, remembering his first meeting with V A Molchanov at Harwell in 1964 at the Symposium on Atomic Collision Cascades in Radiation Damage, that Vladimir Molchanov's lecture was the gospel, because nobody knew more about the rather new field of ion scattering at that time.

While continuing to work intensely on the reflection of ions from random media, and realizing the interrelations between various processes in the interaction of ions with solid surfaces, V A Molchanov turned to the study of the scattering of ions by single crystals. A number of important directional effects were thus established. In 1965 Molchanov and his co-authors discovered and investigated in great detail the effect of double scattering of ions by crystals. This effect consists in the formation of a system of sharp peaks in the energy distribution of scattered ions, with the position of one of these peaks on the energy scale corresponding to that calculated in the approximation of a single collision of the scattered ion with an atom of the crystal. Another peak's position corresponds to the prediction in the approximation of two collisions of an ion with atoms of the crystalline target. This phenomenon is interesting for a number of reasons, including its application potential for analyzing the composition and surface structure of solids; this stimulated numerous studies in various research centers (which continue to this day) and a search for analogous effects in related fields of physics.

In 1970 V A Molchanov and his colleagues discovered the effect of ion focusing, namely, when the direction of incidence of the beam of bombarding particles is parallel to the axes of the surface semichannels formed by densely packed atomic rows on the crystal surface, the flux of reflected particles may be compressed much more strongly than in the case of a random orientation of the beam relative to the crystalline target.

When studying the reflection of molecular ions from the crystals, V A Molchanov and his colleagues observed that the relative fraction of reflected molecular ions may increase sharply if the direction of incidence of the beam of bombarding particles is parallel to the axes of the surface half-channels; the effect reaches a maximum when the conditions correspond to the maximum ion focusing. These studies demonstrated that, in view of the exceptionally strong angular dependence for molecular ion beams (much sharper than for atomic ions), it becomes possible to orientate the crystal much better in the process of irradiation; another possibility was to investigate the structure of crystals, its peculiarities and damage to it, and also to use crystals as devices for creating sharply focused and practically monochromatic beams of polarized molecular ions.

For a series of publications on ion scattering, V A Molchanov was elected a member of the Böhmische Physical Society in 1992: "For fundamental studies on ion scattering by the solid surfaces".

A large number of Molchanov's studies were devoted to the effect of phase transitions in solids on the specific features of ion reflection, sputtering, ion-electron and ion-photon emission, and to developing new methods for studying structural phase transitions (amorphization) in solids using the directional effects of ion-solid surface interactions, including the annealing of radiation damage in the course of irradiation, not post-irradiation, as was typical in traditional techniques.

Molchanov's research was and still is continued in many laboratories of the world; his results were and still are widely used by theorists in developing theories of ion scattering, sputtering and ion-electron emission. For instance, O B Firsov used them to work out the well-known theory of small-angle ion scattering.

Molchanov's results largely defined the progress of ion-scattering spectroscopy and recoil spectroscopy in their applications to the study of composition, atomic structure, morphology and the dynamic properties of solids, including phase transitions and the thermal vibrations of surface atoms.

Much of Molchanov's research was done in collaboration with colleagues at INP MSU and the physics faculty of MSU, and also with physicists of the I V Kurchatov Institute of Atomic Energy (now Russian Research Center 'Kurchatov Institute'), the Fiziko-Energeticheskiĭ Institute in Obninsk (now Obninsk Institute of Physics and Energy), the Moscow State Engineering Physics Institute (Technical University — MEPhI), the Institute of Electronics, Uzbekistan, the Max-Planck-Institute für Plasmaphysik, Garching (Germany), and University of Calabria, Cosenza (Italy). Vladimir Aleksandrovich attracted both experimenters and theorists, and also experts in the computer simulation of ion-solid interactions. He was known for his non-trivial formulation of problems that required solution, and discussions with him always generated new approaches and studies. He eagerly

embraced both the specific studies of certain types of behavior and general problems of ion-solid interaction, which he actively discussed both in joint meetings and in correspondence with Jens Lindhard, Mark Robinson, G Falcone and many other physicists of the day. Molchanov worked in research centers in Germany, France and Italy; scientific and friendship-based ties with colleagues abroad were strong to the end of his life.

Four monographs that Molchanov co-authored were devoted to ion scattering; they were published in Moscow (Atomizdat 1980, Energoatomizdat 1985, 1995) and in Amsterdam (North-Holland, 1985). They became a must have item for those who worked on the interactions of atomic particles with solids not only in the USSR, and later Russia, but also abroad. G Falcone wrote this in his condolences on the passing of Vladimir Aleksandrovich: "It is difficult to find adequate words for the loss of a friend, but that for the scientist is very simple. The contribution of Volodya, both for quality and quantity, has no equal in the field of ion-solid interaction. If you add to this aspect the books that he has written, it is difficult to find a similar scientist in our field".

Working with Vladimir Aleksandrovich was never easy, since he demanded total dedication from his colleagues and post-graduates, but it was always exciting. Molchanov was never indifferent to the fate of students, post-graduates and colleagues who worked with him at some stage, and he invariably applauded their successes. His unlimited capacity for work, the strict standards he applied to the quality of results shown to the world earned V A Molchanov the highest respect and were formative factors for the younger generation of researchers. His communications with colleagues and his scientific debates occurred not only in the working environment of laboratories, conferences and home, but also during vacations in Crimea which he knew very well and loved deeply.

The memory of Vladimir Aleksandrovich Molchanov — outstanding scientist and teacher, a wonderful person who believed with conviction that good work can only be done by your own hands — will live on in the hearts of his friends, colleagues and disciples, all those who came to know him at work and in daily life.

V A Kurnaev, Yu V Martynenko, M I Panasyuk,
V D Pis'mennyĭ, U Kh Rasulev, E A Romanovskiĭ,
Yu A Ryzhov, V A Sadovnichiĭ, A F Tulinov