

CONFERENCES AND SYMPOSIA

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Scientific session of the Physical Sciences Division of the Russian Academy of Sciences dedicated to the centenary of Academician A I Shal'nikov's birth (11 May 2005)

A scientific session of the Physical Sciences Division of the Russian Academy of Sciences (RAS) dedicated to the centenary of Academician A I Shal'nikov's birth was held in the Conference Hall of the P L Kapitza Institute for Physical Problems, RAS on 11 May 2005. The following reports were presented at the session:

(1) **Keshishev K O** (P L Kapitza Institute for Physical Problems, RAS, Moscow) "Aleksandr Iosifovich Shal'nikov and the physics of quantum crystals";

(2) **Edel'man V S** (P L Kapitza Institute for Physical Problems, RAS, Moscow) "Scanning tunnel microscopy and spectroscopy of an atomically clean bismuth surface";

(3) **Mezhov-Deglin L P** (Institute of Solid State Physics, RAS, Chernogolovka, Moscow region) "Impurity nanocluster structures in liquid helium".

An abridge version of reports 2 and 3 is given below.

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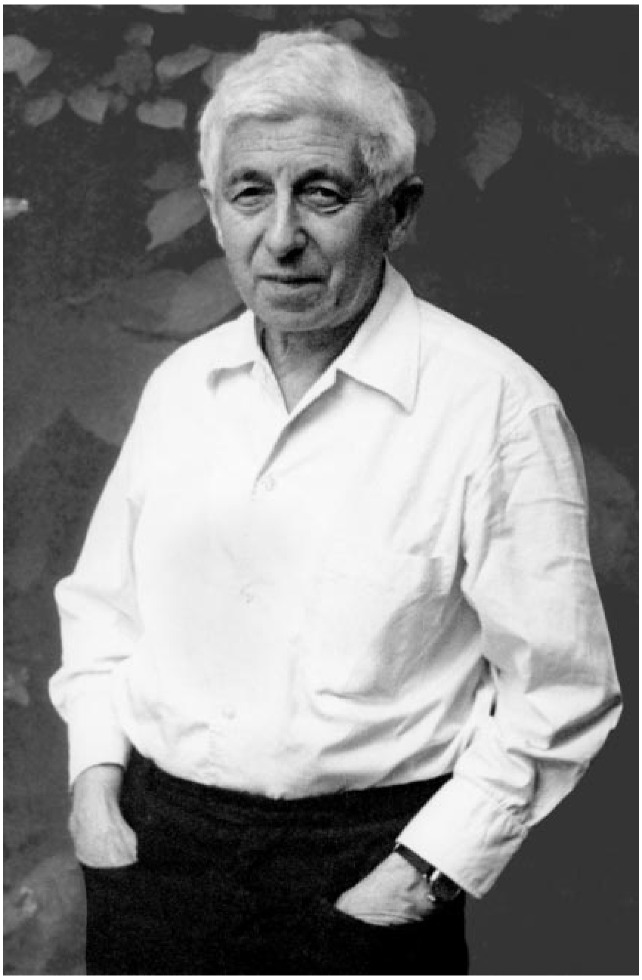
About Academician Aleksandr Iosifovich Shal'nikov
(opening address)

L P Mezhov-Deglin

On 11 May 2005, a session of the Physical Sciences Division of the Russian Academy of Sciences was held in the P L Kapitza Institute for Physical Problems, RAS, which was dedicated to the centenary of Academician Aleksandr Iosifovich Shal'nikov's birth (1905 – 1986), "a great physicist and a wonderful personality, ...a skillful experimenter and an outstanding teacher", as noted in the report of Academician-Secretary of the Physical Sciences Division and Director of the Institute for Physical Problems, A F Andreev, who opened the session.

Shal'nikov's whole life was an example of selfless service to science. In his autobiography, written in 1979, he told his story: "Born in Petersburg in 1905. In 1923 entered the Physics and Mechanics Department of the Petersburg Polytechnical Institute, which I graduated from in 1928 with the title of engineer-physicist. Beginning in 1923 up to 1935 I worked in the Physical-Technical Institute, occupying several



Aleksandr Iosifovich Shal'nikov
(10.05.1905 – 06.09.1986)

positions, from laboratory assistant to head of a laboratory. In 1929 – 1935, I advised in the 'Svetlana' plant and in the Physical-Agronomical Institute. During the same years I was a lecturer in the Leningrad Polytechnical Institute, occupying positions ranging from assistant to assistant professor. In 1935, I was sent by Narkomtyazhprom[1] on an assignment to the Institute for Physical Problems of the USSR Academy of Sciences, where I am working as head of a laboratory. In 1935, the VAK (Supreme Certifying Commission — *Transla-*

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[1] An abbreviated name of the People's Commissariat of the Heavy Engineering Industry. (*Translator's comment*.)

L P Mezhov-Deglin and A I Shal'nikov at the entrance to the Institute for Physical Problems of the USSR Academy of Sciences (1966).

tor's comment) confirmed my appointment as a full member of the Institute; in 1937, I was conferred the degree of Doctor of Sciences without upholding a thesis. In 1944, the VAK conferred the title of professor on me. In 1946, I was elected a Corresponding Member of the USSR Academy of Sciences. I have been decorated with the Badge of Honor, five Orders of the Red Banner of Labor, and the Order of Lenin. In 1947, 1949, and 1954, I was awarded the State Prizes of Second Class''.

It is pertinent to note that the first prize was awarded for the investigation of the intermediate structure of superconductors, and the next two for research in the area of defense technology. In 1972, Shal'nikov was decorated with the P N Lebedev Gold Medal for his investigation in the area of quantum crystals physics; in 1979, he was elected a Full Member of the USSR Academy of Sciences; in 1985, he was awarded the second Order of Lenin, and in 1986 he received the fourth State Prize for the development of a series of devices for cryogenic medicine.

Although Shal'nikov spent the greater part of his life in Moscow, strong scientific and friendly ties with his native town always persisted. The citizens of Leningrad never regarded him as a stranger — but as a representative of the Leningrad school of physics begot through the care of Abram Fedorovich Ioffe, 'father Ioffe', as Shal'nikov would frequently say. The first paper, which was published by student Shal'nikov of the Polytechnical Institute jointly with the future Nobel Prize Winner in Chemistry N N Semenov, was concerned with chemical reactions in the solid phase. Next, there followed a series of papers dedicated to the investigation into the mechanisms of condensation and formation of colloidal solutions and alkali metal sols, as well as to methods of producing and studying the properties of thin metallic films. Semenov, Yu B Khariton, S Z Roginskii, M I Gen, and I L Zel'manov were co-authors of these papers. It comes as no surprise that Khariton and his colleagues knew precisely whom they had to turn to when in the early 1950s they came up against the problem of depositing thin metal coatings on as-fabricated uranium hemispheres in a factory situated within several hours' flight from the capital. Naturally, Shal'nikov had to make a substantial part of the facilities from improvised means on the site. The skill to produce thin metallic films and fine disperse powders with his own hands proved useful to him in the study of magnetic field distribution in superconductors. The decoration technique as applied to magnetic field distribution on the surface of a sample employing fine disperse magnetic powders is widely used nowadays as well, for instance, when studying the distribution of magnetic vortices in high-temperature superconductors.

In 1934, Shal'nikov was due to go to England together with P L Kapitza to work as an intern in Rutherford's laboratory. But fate decreed otherwise. At the invitation of Kapitza, Shal'nikov became the first research fellow of the Institute for Physical Problems and actively participated in the construction and equipping of the future institute in Moscow. Even in the 1970s, Shal'nikov remembered perfectly the arrangement of all the institute's circuits, and electricians would ask for his advice when it was required, for instance, to replace a power cable buried somewhere in a trench.

Shal'nikov's scientific accomplishments during the first 30 years of work are most accurately described in the reference signed by L D Landau in mid-1950:

"Encyclopedic knowledge in physics and a great breadth of interests enable A I Shal'nikov not only to render substantial assistance to many Soviet physicists who ask for his advice in overcoming the difficulties encountered in research work, but also to pursue with invariable success diverse physical investigations in his laboratory. Aleksandr Iosifovich Shal'nikov has the generally recognized reputation as one of the best physics experimenters in our country. His masterly art of experimenting and amazing resourcefulness, which underlies his ability to arrive at quite unexpected methods of solution of scientific problems, have enabled him to obtain during his almost 30-year long scientific activity a wealth of scientific results, which have brought him worldwide recognition. Shal'nikov's works are characterized by an exceptionally wide diversity of research areas. There is scarcely any realm of physics which he has not addressed in one way or another, his acquaintance usually relying not on literary data but on his personal experimentation. It would therefore be an intricate task to touch on all aspects of A I Shal'nikov's activity, and I will restrict myself to mentioning only those of his works which had the greatest impact on science and technology.

The first period of A I Shal'nikov's activity (1922 – 1934) was devoted primarily to the problems of experimental techniques. The profound significance of the results then obtained is adequately characterized by the fact they have become customary and, despite the considerable amount of time passed, are widely used nowadays. In particular, in the area of colloid physics he elaborated a technique for obtaining the alkali metal colloids, which now is outlined in textbooks, a new method of butadiene polymerization, which found use in the synthetic rubber industry in its time. Another series of A I Shal'nikov's works was concerned with high-vacuum physics. In particular, he developed a method of obtaining the films of different substances by vacuum evaporation. He pioneered obtaining molecular mixtures in this way — the subject later elaborated extensively in S A Vekshinskii's works which were awarded a Stalin Prize. These works led A I Shal'nikov to several inventions which found wide application in the electrovacuum industry. For biophysical purposes, A I Shal'nikov developed extremely sensitive UV photon counters which nowadays enjoy wide use in atmospheric optics.

Beginning in 1934, low-temperature physics, and particularly the superconduction phenomenon, came to be the main concern of Shal'nikov's work. In this area, he performed several investigations which are among the most significant ones. For instance, Shal'nikov was first to discover the superconduction in very thin films of superconducting metals and a sharp rise of the critical magnetic field in these films in comparison with the critical field for bulk samples. Subsequently, these experimental findings led to the establishment of the fact, which is of fundamental significance to superconduction phenomenon, that the magnetic field penetrates rather deeply into superconductors. A I Shal'nikov completely solved the problem of the nature of the intermediate state of superconductors. In exceptionally subtle experiments, he managed to directly discover superconducting and normal domains which make up a superconductor in the intermediate state. Most recently, Shal'nikov carried out experiments which allowed him to directly measure for the first time the field penetration depth in the superconductor, which now is considered to be the most important characteristic of the superconduction phenomenon... .''

The last two papers by Shal'nikov, which were published in the mid-1980s, were also concerned with the preparation technique and investigation of the properties of palladium hydride superconducting films.

Beginning in the early 1960s, Shal'nikov and his collaborator learners conducted a series of pioneering investigations in the area of quantum crystals physics. These investigations are topical in our time, too, and largely determine the face of the contemporary P L Kapitza Institute for Physical Problems, RAS.

Beginning in 1938 through 1970, Shal'nikov was a professor at Moscow State University (MSU). Under his observation, a special-purpose building equipped with facilities for the production of liquid helium and hydrogen was constructed at MSU for the Chair of Low-Temperature Physics. This allowed organization of practical training in low-temperature physics for MSU students and set up serious scientific investigations at the Chair. In May 2005, one of the lecture halls of the Physics Department building was named after Shal'nikov in memory of the educator of many generations of highly qualified physicists, who would not only generously impart his knowledge and expertise to his students, but would quite often help students and postgraduates in the solution of their everyday problems as well.

In 1956, Shal'nikov organized the publication of the new scientific journal *Pribory i Tekhnika Eksperimenta* (*Instruments and Experimental Techniques*) — one of the first-rate and most authoritative journals of the RAS, dedicated to the techniques of physical experiment, of which he was editor-in-chief until his last days.

And, finally, it should be remembered that during the last years of his life A I Shal'nikov elaborated, in collaboration with physicians, a whole series of modern cryosurgical instruments, whose design is underlain by ``brilliant experimental resourcefulness, masterly craftsmanship, and admiration for narrow gaps'', which also characterized his first works.

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Scanning tunnel microscopy and spectroscopy of an atomically clean bismuth surface

V S Edel'man

The electronic properties of bismuth have been under investigation for many decades. The spectrum of in-bulk conduction electrons has been studied in close detail (see review [1]). Considerable success has been achieved in the calculation of the band structure [2], as witnessed by the attainment of remarkable agreement with experimental data in the most sensitive region — near the Fermi surface, which requires a millielectron-volt accuracy of energy calculations. The main special feature of bismuth as a metal is that conduction electrons have a low density on the order of 10^{-5} atom^{-1}, their wavelength and Debye screening radius are far longer than the interatomic distance and range into the hundreds of angstroms, so that the system of conduction electrons should undergo complete rearrangement over distances of about this extent. On this basis, one would expect a radical rearrangement of the electron spectrum at the surface. Therefore, the scanning tunnel microscopy and spectroscopy (STM, STS) of the bismuth surface is of heightened interest.

The pursuance of research is facilitated by the fact that it is possible to prepare high-quality bismuth single crystals which are easily cleaved along the basal trigonal plane due to their natural brittleness. In this case, an atomically clean surface opens, where the density of foreign atoms is on the order of 1 μm^{-2}. And this purity persists under high-vacuum conditions for a long time.

First and foremost, it is required to elucidate the general pattern of the surface structure formed in the crystal cleavage [3]. Bismuth is known to possess a rhombohedral structure, and its lattice may be represented as a result of the stretching of a simple cubic lattice along one body diagonal of the cube and the relative displacement of two face-centered sublattices along the same diagonal. Under this transformation, out of the four initially equivalent (111)-type planes of the cube only three remain equivalent, but they lose their trigonal symmetry and the triad axis is retained only in a single plane, the one perpendicular to the stretching direction. In what follows, these two types of planes will be referred to as quasitrigonal and trigonal, respectively.

The first results were obtained in the pursuance of investigations under room temperature conditions [4, 5]. A typical STM image of the cleavage surface is illustrated in Fig. 1. The surface is formed by atomically plane terraces, with a level difference between them being equal to or a multiple of 0.4 ± 0.02 nm, because cleavage always occurs between two planes spaced further apart (see Fig. 1, at the bottom). The terrace boundaries are quite often close to the straight lines which follow the directions of atomic rows on the surface. But there also are terraces with sharply curved boundaries and nanometer-sized roundish islets (dents). One can see that at room temperature there are two systems of terrace boundaries — atomically straight (b), and made fuzzy by thermal motion (a). This difference arises from the