CONFERENCES AND SYMPOSIA

PACS numbers: **01.65.+g**, **07.35.+k**, 61.50.Ks; **01.65.+g**, **07.35.+k**, 61.50.Ks; **01.65.+g**, **07.35.+k**, 64.70.kd; **01.65.+g**, 61.50.Ks, 64.70.kd; 61.50.Ks, **62.50.−p**, **74.70.−b**; **01.65.+g**, **71.18.+y**, **73.20.−r**; **71.15.−m**, **74.20.−z**, **75.10.−b**

On the 50th anniversary of the L F Vereshchagin Institute for High Pressure Physics, RAS
(Scientific outreach session of the Physical Sciences Division of the Russian Academy of Sciences, 23 April 2008)

S M Stishov; L G Khvostantsev, V N Slesarev; S V Popova, V V Brazhkin, T I Dyuzheva; L N Dzhavadov, E L Gromnitskaya, G N Stepanov, Yu A Timofeev; E M Dizhur, V A Venttsel, A N Voronovskii; V N Ryzhov, A F Barabanov, M V Magnitskaya, E E Tareyeva

DOI: 10.1070/PU2008v051n10ABEH006796

A scientific outreach session of the Physical Sciences Division of the Russian Academy of Sciences (RAS) was held on 23 April 2008 at the Institute for High Pressure Physics, RAS, Troitsk, Moscow region. The session was devoted to the 50th anniversary of the Institute. The following reports were presented:

(1) **Stishov S M** (Institute for High Pressure Physics, RAS, Troitsk, Moscow region) "The Institute for High Pressure Physics is now 50 (opening address)";

(2) **Khvostantsev L G, Slesarev V N** (Institute for High Pressure Physics, RAS, Troitsk, Moscow region) "Large-volume high-pressure devices for physical investigations";

(3) **Popova S V, Brazhkin V V, Dyuzheva T I** (Institute for High Pressure Physics, RAS, Troitsk, Moscow region) "Structural phase transitions in highly compressed substances and the synthesis of high-pressure phases";

(4) **Dzhavadov L N, Gromnitskaya E L, Stepanov G N, Timofeev Yu A** (Institute for High Pressure Physics, RAS, Troitsk, Moscow region) "Studies of the thermodynamic, elastic, superconducting, and magnetic properties of substances at high pressures";

(5) **Dizhur E M, Venttsel V A, Voronovskii A N** (Institute for High Pressure Physics, RAS, Troitsk, Moscow region), "Quantum transport at high pressures";

(6) **Ryzhov V N, Barabanov A F, Magnitskaya M V, Tareyeva E E** (Institute for High Pressure Physics, RAS, Troitsk, Moscow region) "Theoretical studies of condensed matter";

(7) **Bugakov V I, Antanovich A A, Konyaev Yu S, Slesarev V N** (Institute for High Pressure Physics, RAS, Troitsk, Moscow region) "Designing new construction and superhard materials and related tools."

An abridged version of reports 1 – 6 is presented below.

Uspekhi Fizicheskikh Nauk **178** (10) 1095 – 1124 (2008)
DOI: 10.3367/UFNr.0178.200810g.1095
Translated by S N Gorin and E G Strel'chenko; edited by M V Magnitskaya

PACS numbers: **01.65.+g**, **07.35.+k**, 61.50.Ks
DOI: 10.1070/PU2008v051n10ABEH006614

The Institute for High Pressure Physics is now 50 (opening address)

S M Stishov

Today, 23 April 2008, we celebrate the 50th anniversary of the founding of the Institute for High Pressure Physics (IHPP). In fact, the corresponding paper of the Presidium of the USSR Academy of Sciences, the USSR Council of Ministers, and the Central Committee of the Communist Party of the Soviet Union was formally signed on May 23, 1958. I believe that no one will blame us for this slight deviation from the formal date. The point is that at the end of May there will be a general meeting of the Russian Academy of Sciences with a more elaborate program. But let us turn to our jubilee.

Sometimes the question is asked as to what end these or those institutions are created at all. Someone can say that they are created for solving important scientific problems. In reality, this appears to be a delusion, since there cannot exist an organization, a council, or people who have decided to meet and have said that there is a problem, or a talented person that can solve this problem and that, therefore, an institution should be founded so this person could develop this scientific area. In reality, events occur in quite a different way; usually, a new institution is created due to the efforts of a single talented person or a small group of people. They are real initiators, going through various stages, applying to various authorities, organizing advertising campaigns, etc. We should also understand that in order to found an institution it is insufficient to possess only scientific talent. One should also have some quite special talents. Leonid Fedorovich Vereshchagin, the founder of our institute, possessed such talents to the full extent. I believe that the history of the creation or organization of our institute should be traced from the period when L F Vereshchagin was working at the Kharkov Physico-Technical Institute, which suffered heavily in 1939, when part of its workers were arrested and part were shot, so that many people left. While working in Kharkov, Vereshchagin designed an efficient apparatus for creating high pressures (hydrocompressor,

Figure 1. L F Vereshchagin with his hydrocompressor.

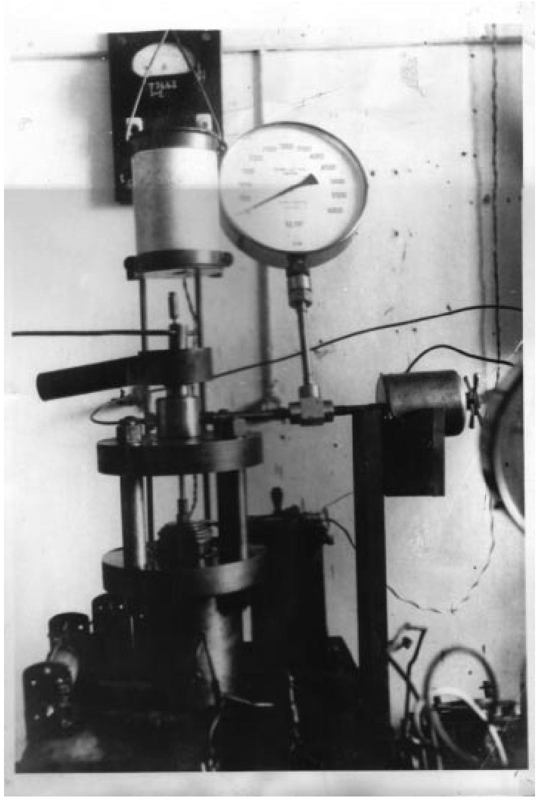

Figure 2. Hydrocompressor for generating high pressures.

Figs 1, 2). He then moved to Moscow, bringing along his apparatus. The only place where his knowledge was needed and where he could work at that time was the Institute of Organic Chemistry, USSR Academy of Sciences, where Academician N D Zelinskii had then been working. Zelinskii had initiated the establishment of the Laboratory of Ultrahigh Pressures, which became headed by L F Vereshchagin. But soon World War II began and Vereshchagin's compressor proved to be quite useful for military needs. High pressures produced by the compressor made it possible to provide autofrettage for gun barrels, as well as to produce explosives of enhanced power. In general, L F Vereshchagin participated in a number of defense projects; during this work, he made many acquaintances among all sorts of people, which helped him in his subsequent activity. In 1948 a high-pressure technology for producing polytetrafluoroethylene (teflon) was developed at the laboratory, and was successfully introduced into industry; a number of workers who participated in this work obtained government awards and L F Vereshchagin received a Stalin Prize in 1951 for the development of the hydrocompressor. In 1954, the independent Laboratory of Physics of Ultrahigh Pressures was organized at the USSR Academy of Sciences. Figure 3 illustrates from what this laboratory was begun. The building shown in Fig. 3 is now located behind the Institute of Inorganic Chemistry, Russian Academy of Sciences. In 1954, this building was a storage room; traces of the initial building work aimed at its accommodation for the laboratory are seen. At the front of the photo, L F Vereshchagin and his father-in-law, Academician N N Andreev, can be seen. Quite quickly, the laboratory received the status of an institute. Note that in 1958 the Institute had no towering scientific achievements. Correspondingly, L F Vereshchagin had to prove himself in many new fields. He tried to develop many disciplines, such as hydroextrusion and supersonic streams, and even attempted to take part in the issue of thermonuclear synthesis, but unfortunately without success. But it so happened that in 1955 the General Electric Company and, simultaneously, a Sweden research laboratory of the ASEA Company reported on a successful synthesis of artificial diamond. It is interesting

Figure 3. Laboratory of High-Pressure Physics, USSR Academy of Sciences. From left to right: N N Andreev, L F Vereshchagin, an unknown person, and G A Seviyants.

that, as it became known later, the small diamond crystal that was described in the first communication published by the General Electric Company as a result of the synthesis proved to be the crystal of natural diamond. Actually, it was used as a seed, then the same crystal was found by the experimenters and the result was published. Forty years later, the researchers, who had already retired by that time, discovered this crystal in the archives, analyzed it, and decided that they were wrong in the 1950s and that this was a natural diamond. Nevertheless, artificial diamonds were later prepared at General Electric.

In the Soviet Union, the problem of synthesis of artificial diamonds was addressed by the Institute of Crystallography, USSR Academy of Sciences, which could not solve it for a long time in view of many (mainly subjective) causes. To the best of my knowledge, the then Director of the Institute of Crystallography A V Shubnikov willingly and gladly handed over this subject matter to L F Vereshchagin, to the deep disappointment of the 'diamond' group of the institute, which was liquidated.

Thus, this research area went to L F Vereshchagin and, strangely enough, this problem was solved quite fast. Why is this strange? This is strange because at that time there was no single person in the institute who understood anything about materials science. I mean mainly the methods of characterization of a material (optical properties, density, X-ray diffraction, etc.). All this was a result of the specificity of the institute personnel at that time. At the same time, young researchers who possessed good educations and began to play a progressively more important role in 'diamond affairs' began to appear

In any event, the problem was solved and in the spring of 1960 L F Vereshchagin announced the successful synthesis of diamonds (Fig. 4) and, later, of cubic boron nitride (borazon). The synthesis of diamond and borazon proved to be possible due to the successful design of a new very efficient high-pressure cell of the 'chechevitsa' (lentil) type, which has been widely used even up to now. The synthesis of diamond and borazon at the IHPP triggered the development of an industry of superhard materials in the Soviet Union. Already in the autumn of 1960 the technology developed was introduced to various enterprises of the country. In particular, equipment developed at the institute was taken to the Kiev Central Design Technological Bureau for Superhard Alloys and Tools, which later was transformed into the Institute of Superhard Materials, Ukrainian Academy of Sciences. The equipment was mounted there and the personnel was taught by our workers.

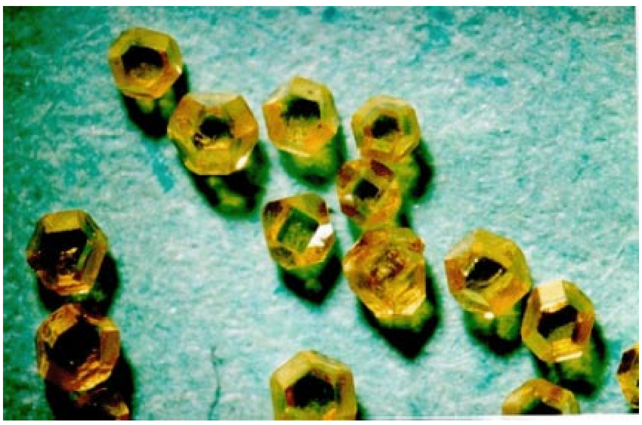

Figure 4. Crystals of diamond synthesized at high pressure.

In 1961 L F Vereshchagin, V A Galaktionov, and Yu N Ryabinin received the Lenin Prize for their work on the synthesis of diamond. In 1963, L F Vereshchagin became a Hero of Socialist Labor and the institute was awarded with an Order of Labor Red Banner. Many other specialists at the institute were awarded with orders and medals. Note that a prize is, naturally, an important thing, but obtaining it requires a thorough effort while it is also important because the people that award prizes later become spell bound by the 'magic' of the prizes, and it becomes easier for a person who has obtained a prize to live and guide an institute.

As was said above, the institute was first located in a small building on Leninskii Prospect in Moscow; later, it moved into the old building of the Institute of Crystallography on Pyzhevskii Pereulok. In 1962, a resolution was adopted on the construction of the modern complex of buildings in Pakhra (today Troitsk), a small town 40 km away from Moscow along Kaluga Shosse, where at that moment the Institute of Earth Magnetism and Propagation of Radio Waves, USSR Academy of Sciences, already existed. In 1966, the Institute moved to Pakhra (Fig. 5). At the same time, unsuccessful attempts were undertaken to sharply turn the direction of investigations toward the field of semiconductors and even lasers. In addition, research was carried out on the effect of high pressures on the properties of metals (an electron-topological transition in zinc was revealed); studies of phase transitions under pressure in elements and compounds were performed; and X-ray diffraction, ultrasonic, optical, and low-temperature investigations under pressure were developed.

After the sudden death of L F Vereshchagin in February 1977, the institute was sequentially headed by deputy directors, first E N Yakovlev and later Yu S Konyaev. From 1989 to 1991, the director of the institute was A A Abrikosov (2003 Nobel Prize in physics; has lived in the United States since 1991).

Below, I give a brief list of our achievements, which represent a real contribution to the science world. An exhaustive review of our activity will be given in the subsequent reports.

So, the most important achievements of our institute are as follows.

• Development of a high-pressure chamber of the lentil type and the subsequent synthesis of diamond and cubic boron nitride (Vereshchagin L F et al., 1960).

• Synthesis of dense silica — the substance in the Earth's mantle (Stishov S M, Popova S V, 1961).

Figure 5. Building of the Institute for High Pressure Physics, Russian Academy of Sciences, in Krasnaya Pakhra, Moscow region.

• Ultrasonic investigations of solids at pressures up to 100 kbar (Voronov F F et al.).

• Invention of a high-pressure cell of the 'toroid' type (Khvostantsev L G et al., 1977).

• Investigations of phase transitions in liquids (Brazhkin V V, Popova S V, Voloshin R N,1989).

• Synthesis of superconducting diamonds (Ekimov E A, Sidorov V A, 2004).

Most of our achievements are based on the invention of a high-pressure cell of the lentil type. It was used to synthesize diamond and cubic boron nitride (see Fig. 3). Later, this cell was employed to prepare dense silica (Fig. 6), which made our institute famous. Quite soon after the dense silica was obtained in the laboratory at our institute, it was discovered in the Arizona meteorite crater (Fig. 7) and was called stishovite in honor of the present writer. In view of the very important role of silica as the main component of the depths of the Earth and other planets and because of a quasi-detective situation related to the discovery of its dense modification, this story had huge resonance.

F F Voronov has done very much in the field of ultrasonic investigations. L G Khvostantsev and his colleagues invented a high-pressure cell of the toroid type (Fig. 8), which is now the main tool for high-pressure processing, both in this country and abroad. V V Brazhkin, S V Popova, and R N Voloshin published an important paper on phase transitions in liquids. Recently, a superconducting diamond was synthesized (Figs 9, 10). This activity is now being intensely developed; this is one of the most important achievements in the field of the solid state physics in recent years. Apart from the physics itself, there is a quite clear potential for industrial applications here.

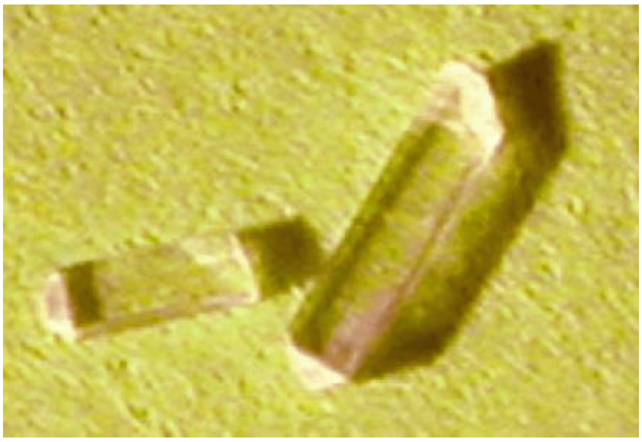

Figure 6. Crystals of dense silica (stishovite).

Figure 7. A meteorite crater in Arizona, USA.

Figure 8. High-pressure cells of the toroid type.

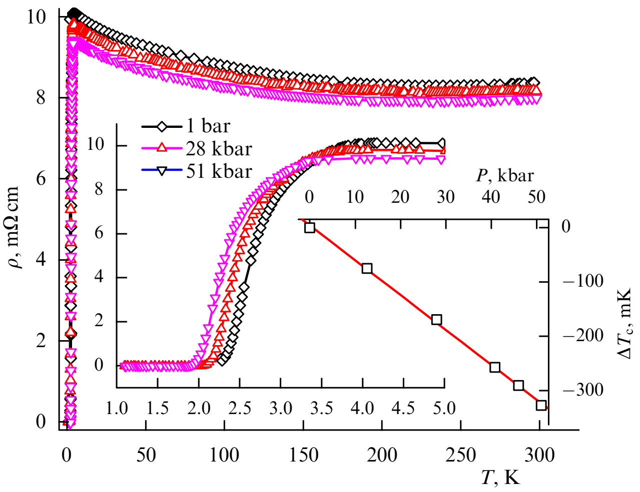

Figure 9. Superconducting transition in diamond doped with boron.

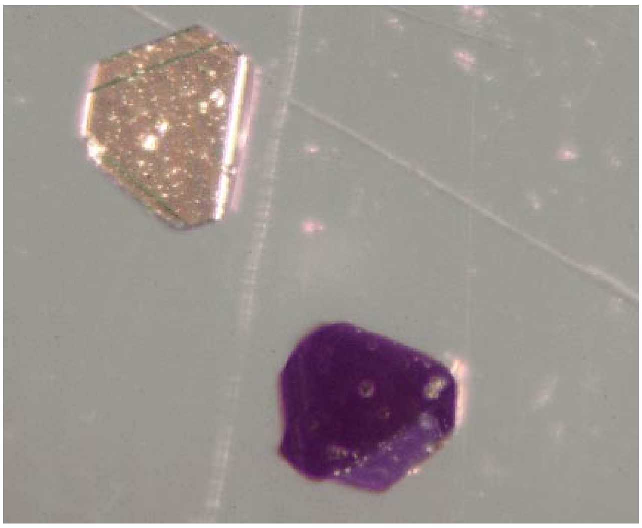

Figure 10. Diamonds doped with boron.

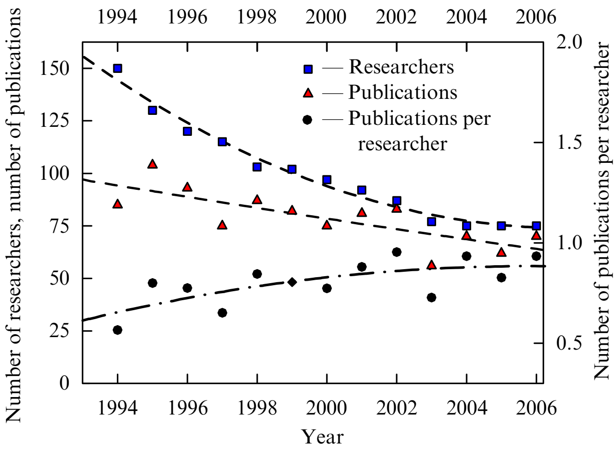

Figure 11. Variation of the number of researchers and number of scientific reports at the IHPP.

At present, the proportion of fundamental research is increasing noticeably at the institute. Although high-pressure materials science and the development of apparatuses remain among the main scientific focuses of the institute, the emphasis in investigations has shifted toward the fundamental problems of the physics of condensed matter, including phase transitions at high pressures, quantum critical phenomena and strongly correlated electron systems, the thermodynamics and kinetics of phase transitions in disordered systems, and the physics of nanosized forms of carbon.

Unfortunately, the institute is not free of the problems that are common to all academic institutions. In the last 15 years, the number of workers at the institute has decreased by a factor of more than three. Figure 11 displays the dynamics of the changes in the number of researchers at the institute, the total number of publications per year, and the number of publications per researcher per year. A certain optimism comes from the fact that, as is seen from the figure, the number of publications per researcher has increased quite noticeably. However, the fraction of young researchers remains insufficient, in spite of the existence of a base chair in the Moscow Physico-Technical Institute (The Physics of Condensed Matter under Extreme Conditions) and of academic postgraduate courses, as well as of intimate cooperation with the Moscow Institute of Steel and Alloys and the Departments of Physics and Chemistry at Moscow State University.

PACS numbers: **01.65.+g**, **07.35.+k**, 64.70.kd
DOI: 10.1070/PU2008v051n10ABEH006615

Large-volume high-pressure devices for physical investigations

L G Khvostantsev, V N Slesarev

In this report, we briefly describe the development of domestic high-pressure engineering (above 5 GPa) in large volumes for physical investigations. We give the technical characteristics of the high-pressure cells of the 'toroid' and 'chechevitsa' (lentil) types invented at the institute and show their experimental potential in studying the structure and properties of condensed matter. We describe a number of examples of studying solids and liquids by various methods using these devices. The possibility of efficient application of the lentil and toroid cells in industry for the synthesis of superhard materials is noted.

High-pressure physics deals with studying a large totality of phenomena in condensed matter under high compression. As the density of solids and liquids increases, noticeable changes in their physical properties, their crystal and electronic structures, and the mutual arrangement of atoms in them are observed. Studying these phenomena, especially in combination with low and high temperatures and magnetic fields, yields valuable information necessary for the further development of concepts of the structure of condensed matter. On the other hand, this information is important for solving the main problem of materials science — preparation of new materials with unique properties — which is related to the synthesis of high-pressure phases that are formed as a result of irreversible polymorphic transformations.

The choice of phenomena to be studied is determined by the capabilities of the high-pressure equipment. High-pressure cells are characterized by the ranges of working pressures and temperatures and by the magnitude of the working volume. Large volumes are necessary for obtaining more complete and reliable information, since in cells with a large volume homogeneous pressure and temperature fields can be produced, samples of a desired size can be used, and various sensors, including pressure and temperature gages, as well as heaters, thermal isolation, and coils for generation of magnetic fields, can easily be mounted.

To produce high pressures reaching thousands and tens of thousands of atmospheres, two types of high-pressure devices have been used from the beginning of the 20th century, namely, the piston–cylinder apparatus and Bridgman anvils (Fig. 1) [1, 2]. In apparatuses of both types the pressure is created due to a decrease in the volume of the substance to be pressed. In the piston–cylinder cell the compression of the substance can be any size: the production of maximum pressures is limited by the strength of the construction materials. Devices of this type make it possible to perform investigations in large volumes ($1-100$ cm^{-3} and greater) at pressures that are, as a rule, no more than $3-5$ GPa. In the apparatus of the anvil type, Bridgman used the principle of a compressed seal, which consists in the fact that a thin gasket placed in the gap between approaching parts of the apparatus can keep the high pressure created in the working volume. Since the gasket (compressed seal) unavoidably has a small thickness, the volume of the compressed substance is also small. The anvils, made of a hard alloy, make it possible to easily reach pressures of more than 10 GPa, but only in very small volumes of $10^{-2}-10^{-3}$ cm^3 at a sample thickness of ~ 0.1 mm.

The problems of physics, geophysics, and materials science, the most important of which was the problem of synthesizing artificial diamonds, required the development of cells of a larger volume (0.1 cm^3 and greater) capable of sustaining high pressures (> 5 GPa) and temperatures ($> 1500\,^{\circ}$C) for long periods. These problems were solved in different ways, which finally led to the development of numerous devices of various constructions, combining (in various proportions) ideas that were laid in the initial variants, i.e., in the apparatuses of the anvil and piston–cylinder types.

In the West, apparatuses of two main types, namely, of the belt type and multianvil type, have been developed (see Fig. 1)