

TYPE II SUPERCONDUCTORS ARE 70 YEARS OLD

>>> DOI 10.1051/EPN:2008301

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It is already 70 years since the outstanding physicist L.V. Shubnikov together with his colleagues at the Ukrainian Physical - Technical Institute, Kharkov, have experimentally discovered the type II superconductors [1,2]. Their work has exerted a considerable effect on the development of current physics and engineering. This paper presents a short account of some historical events that accompanied the discovery and the appraisals given by prominent physicists of the world.

Although Lev Landau and Lev Shubnikov, two prominent physicists, were friends and the “two Levs’ tandem” had been discussing from 1932 through 1937 all the works in progress at Shubnikov’s Cryogenic Laboratory, Landau did not assist Shubnikov in “pushing” the work in question through, and so it has been published no sooner than 3 months later. The reason for that is set forth in V.L. Ginzburg’s Nobel lecture [3]: as regards superconducting alloys “an understanding of the situation was lacking”. The prevailing concept of that time was the influence of composition/structure inhomogeneities (including the “Mendelssohn sponge” model) and internal stresses on the alloy properties. It is worthy of note that type II superconductors have found significantly wide application (in this connection, it should be enough to mention the development of large-scale magnetic systems for charged-particle accelerators and thermonuclear reactors).

Not long ago, the centenaries of births of Lev Shubnikov (1901-1937) and his first postgraduate student Georgiy Shepelev (1905-1942) were celebrated. They both died at the age of 36. Shubnikov died on November 10, 1937, at the time of Stalin’s Terror, the horrors of which were described as soon as in 1951 by such well known scientists as F.Houtermans, K.F. Shtepa and A.Weissberg-Cybulsky [4]. Shepelev was drafted into the army as a volunteer the day after fascist Germany attacked the USSR. He became one of the officers of the 928th Antiaircraft Battery of 61st Artillery Regiment of the Black Sea Fleet. And he was killed on April 21, 1942 during the defense of Sevastopol.

Shubnikov had been working for 4 years at the Kamerlingh Onnes Laboratory and revealed together with W.J. de Haas the first quantum oscillation effect, which now bears their names. In 1931, while based at the Ukrainian Physical - Technical Institute in Kharkov (UPhTI or National Scientific Center “Kharkov Institute of Physics and Technology” nowadays), he organized the first Cryogenic Laboratory in the USSR, where he obtained together with his colleagues a number of results of world-wide significance, which included such a pearl as the experimental discovery of type II superconductors [1]. Besides which, they studied the magnetic properties of thoroughly prepared single-phase, single-crystal alloys, discovered and studied in detail the phases when a magnetic field penetrates into (H_{c1}) and destroys

the superconductivity (H_{c2}) of such alloys, as well as the changes in H_{c1} and H_{c2} in the case of a doping-level increase (in modern language, the increase of κ , the so called Ginzburg-Landau parameter, entails a corresponding change in the algebraic sign of the surface energy emerging between the superconducting phase and the normal phase that causes the superconductor magnetization curve to change completely). Making reference to this work, the members of International Conference on the Science of Superconductivity (Colgate Univ., Hamilton, N.Y. August 1963) addressed IUPAP to “advise the use of the symbols H_{c1} and H_{c2} to express the limits of the mixed state in Type II superconductors. H_{c2} is taken to be the upper field limit while H_{c1} is reserved for the lower field limit. This notation (in the Russian version, H_{k1} and H_{k2}) is that introduced by Shubnikov in 1937, who was the first to give names to the critical fields.” [5].

After Shubnikov was groundlessly arrested on August 6, 1937 and subsequently executed, Shepelev was put in charge of the Cryogenic Laboratory from September 1937 until November 1938. In November 1938, by virtue of the Order of People’s

▼ L.V. Shubnikov



► Commissariat of Heavy Industry, he was appointed, in place of M. Ruhemann exiled from the USSR together with other foreign specialists, as the Head of the Deep Freezing Experimental Station (DFES) being at the same time the Deputy Director of UPhTI. In November 1939, due to a critical defense assignment given to UPhTI by the Navy, Shepelev concentrated on this work together with V.I. Khotkevich (appointed subsequently to the position of Rector of Kharkov State University).

What happened to the above-mentioned experimental work, the theoretical explanation of which, as well as the analysis of its experimental results, was made by Abrikosov [6] 20 years later, is as follows. While the first experimental demonstration of Shubnikov and his colleagues' work was performed, as we know, by J.D. Livingston [7] at GE Research Labs. in 1962, Abrikosov's work was brought to attention by B.B. Goodman [8] at the IBM Conference on Fundamental Research in Superconductivity (T.J. Watson Research Lab., Yorktown Heights, N.Y.) as early as June 1961. The break-through in understanding the significance of Shubnikov and his colleagues' work [1] seemed to take place in 1963 at the International Conference on the Science of Superconductivity (Colgate University, Hamilton, N.Y.), which fact was noted by J. Bardeen, the Chairman of the Conference, the only doubly-nominated Nobel Laureate in Physics, and by R.W. Schmitt, the Conference Secretary [10]: "It should be noted that our theoretical understanding of type II superconductors is due mainly to Landau, Ginzburg, Abrikosov, and Gor'kov, and that the first definitive experiments were carried out as early as 1937 by Shubnikov". The significance of the work [1] was also noted in the reports of such authoritative scientists as C.J. Gorter, K. Mendelssohn, B.B. Goodman, and T.G. Berlincourt. Besides, of great importance was the definition of the materials in which superconductivity remained sustainable in very large magnetic fields (the first publication [9]). P.G. De Gennes [10] was the first to introduce the notion "Shubnikov's phase" to describe the state of a superconductor between H_{c1} & H_{c2} , and after that this notion has come into use in the literature.

At the Superconductivity in Science and Technology Conference (University of Chicago, May 1966) J.Bardeen indicated in his presentation of the history of type II superconductivity [11]: "The phenomenon was discovered experimentally by the Russian physicist, Shubnikov, around 1937". K.Mendelssohn [12], a classical scholar, estimated the 1937 work as follows: "The real trouble here is that it is extremely difficult to make a homogeneous alloy, containing no lattice faults. Of the laboratories engaged in low temperature research in the thirties, Shubnikov's group in Kharkov had evidently the best metallurgical know-how". By the way, when Mendelssohn met A.G. Shepelev at the 10th International Conference on Low Temperature Physics (Moscow, 1966) and looked at his badge, he exclaimed at once: "Shubnikov, Chotkewitsch, Schepelew, Rjabinin" - although 30 years had passed! So, it was necessary to explain to him that it was Shepelev-the son, and that Shepelev-the father was killed when defending Sevastopol. Mendelssohn expressed his deep regret and continued by speaking of his high estimation of the 1937 work and of Shubnikov's scientific achievements. He also said that his book [12] describing that work was about to come out.

The situation relating to the McCarthy Era, "The Iron Curtain", and superconductivity studies was described with great humor by P.W. Anderson, the Nobel Laureate who noted that A.A.Abrikosov's theory "as well as the data of Shubnikov[1] together founded and almost completed the science of type II superconductivity" [13]. At the H.Kamerlingh Onnes Symposium on the Origins of Applied Superconductivity – the 75th Anniversary of the Discovery of Superconductivity (Baltimore, MD, September 1986) T.G.Berlincourt estimated [1] as follows: "Shubnikov et al. had done the crucial experiment and had interpreted it correctly" [14]. Presenting his report at the Fundamental Problems in High-Temperature Superconductivity Conference (Moscow, 2004), V.L. Ginzburg [15] has clearly stated: "Shubnikov and his students and colleagues accomplished a lot within only a few years, and I should specially mention his studies of superconducting alloys and the factual discovery of type II superconductors... I am sure that Shubnikov would have achieved even greater success in science, and one cannot but feel bitterness about his untimely (at the age of only 36!) and quite guiltless death under the axe of Stalin's terror". ■

Acknowledgements

The authors are thankful to Academician V.L. Ginzburg, Professor M. Azbel, and Professor Yu.N. Ranyuk for interesting discussions.

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