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Eugene Leyarovski
Founder of the Contemporary Low Temperature Physics in Bulgaria

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Abstract. The low temperature physics has a long history in Bulgaria. After the beginning at the Sofia University at the end of 19 century, it grew up successfully at the Bulgarian Academy of Sciences during the last 50 years. This article is dedicated to Eugene Leyarovski, founder of the Low Temperature Physics Laboratory at the Georgi Nadjakov Institute of Solid State Physics. His activities – as head of the Laboratory, as a deputy director of the Institute and as a deputy director in the International Laboratory of High Magnetic Fields and Low Temperatures in Wroclaw, Poland reveal enviable skills and energy. The scientific achievements of Leyarovski in the field of low temperature physics and superconductivity are a cause of proud and a deep respect. His research in duralumin-alloy resistance at liquid nitrogen temperatures, magnetic susceptibility of Van Vleck paramagnets, and superconductivity in transition metal borides has a big success. His group achieves ultra-low temperatures (<1 K) in experiments with strong magnetic fields (up to 15 T). A new method for separation neon and helium from the air and industrial gas mixtures is proposed and developed under his leadership. This method is patented in Bulgaria, the United States of America, the United Kingdom, and Australia.

INTRODUCTION

Low temperature physics and superconductivity owes its development in Bulgaria during the second half of 20 century to Eugene Leyarovski, a scientist with significant results. In 2018, we celebrate his 85th anniversary. During the years, different authors published their vision and memories for low temperature physics research in Bulgarian scientific organizations. M. Bushev tells about the history of superconductivity [1]. V. Kovachev [2-3], D. Uzunov [4], and E. Nazarova [5-6] give their historical review about the superconductivity in Bulgaria. A. Apostolov writes history of the solid state physics at the Sofia University [7-8]. T. Nurgaliev analyses preparation of high-temperature superconducting thin films at the Institute of Electronics Bulgarian Academy of Sciences [9]. N. Tonchev, B. Nikolov, and K. Kolentsov examine low temperature scientific school at the Institute of Solid State Physics [10-11]. Documental research about superconductivity in Bulgaria has been done as well [12-13]. All these publications and some additional sources [14] are used in this work.

There are three stages in Bulgarian low temperature physics during the second half of 20 century: low temperature and magnetism (1959–1972), conventional superconductivity (1973–1986), and high-temperature superconductors (since 1987). The first stage starts with creation of the Laboratory of Low Temperature Physics (as a technical unit) in the former Physical Institute with Atomic scientific experimental base at the Bulgarian Academy of Sciences (1959). In 1961, research group has been formed which became scientific laboratory in 5 July 1963. One of its first significant achievements was development of technology of production and conservation of liquid Neon and Helium. The Sofia University created a second center of superconductivity and low temperature techniques. Magnetic investigations started there during the 60s of 20 century and the Laboratory of Low Temperature (1971) and Group of Magnetic and Structure Investigations (1975) grew up in the Faculty of Physics. Our partnership with

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International Laboratory of High Magnetic Fields and Low Temperatures in Wroclaw provided modern equipment and international collaboration.

Superconductivity has been developed in Bulgaria during the second stage. A new laboratory "*Magnetism and low temperatures*" was created by the United Center of Physics unifying the Sofia University and the Bulgarian Academy of Sciences laboratories of "*Superconductivity and Superconducting Materials*", "*Cryogenics and Cryogenic Engineering*", and "*Low Temperature and Magnetism*". The program "*Physical problems of magnetic and superconducting materials*" has been initiated in 1973. The Laboratory focused its efforts on preparation and investigation of conventional superconductivity and later on high temperature superconductivity materials in different form: mono- and poly-crystals, thin and thick films, multi-structures, tapes and wires. Production of liquid Nitrogen, Helium and Neon by the processes of gases liquefaction, purification, congregation and storage has been realized. Unsuccessful attempt has been made technological center of high temperature superconductivity to be organized.

The third stage is marked by preparation and investigation of high temperature superconducting materials. After the political changes (1989), some Bulgarian scientists went to work abroad and the common research activities of the Bulgarian Academy of Sciences and the Sofia University stops. Up to now, superconductivity is topic of research in many Bulgarian institutes and laboratories as Institute of Solid State Physics, Institute of Electronics, Institute of General and Inorganic Chemistry, University of Chemical Technology and Metallurgy, and Sofia University Faculties of Chemistry and Physics.

The scientist who created first low temperature physics laboratory at the Bulgarian Academy of Sciences is Eugene Leyarovski. He is a founder of investigations in the area of low temperature physics and techniques in Bulgaria. Leyarovski was an excellent engineer, physicist, and scientist at the Bulgarian Academy of Sciences. The aim of this work is to present his biography, his scientific results and achievements.

BIOGRAPHY

Eugene Iliev Leyarovski (5 July 1933 – 23 April 1999) was born in Sofia. He comes from an old Macedonian family of moulders. E. Leyarovski was very curious erudite and knowledgeable man. He studied in the Institute of Chemical Technology in Sofia (1953–1957) in the Faculty of Physics at the Sofia University (1961) and he worked in the Chemical Factory of Dimitrovgrad and in the Metallurgic Factory of Pernik. He was appointed by the Bulgarian Academy of Sciences as engineer of low temperature (27 August 1959) and leaded the Low Temperature Laboratory at the Physical Institute (1959–1972) and the Laboratory of magnetism and low temperature at the Institute of Solid State Physics. Bulgarian Academy of Sciences elected him to assistant (1966–1972), associate professor (1972–1978), and professor (from 1987). He was scientific secretary (1976–1978, 1982–1989), deputy director (1989–1991), and chair of its Scientific Council (1991–1994). E. Leyarovski was a deputy director of the International Laboratory of High Magnetic Fields and Low Temperatures in Wroclaw (1974–1977), and he was a member of its International Scientific Council (1968–1990). Polish Academy of Sciences awarded him with silver medal (1979). With his family, Prof. Leyarovski went to United State of America, where he was appointed at scientific position at the University of California Riverside (April 1997–1999). Unfortunately, very soon, he was stricken by illness which interrupts his successful scientific research. Bulgaria lost one of its bright scientists which work has great value up to day.

SCIENTIFIC RESULTS

Professor Leyarovski was a scientist with great erudition and broad scientific interests. We will present here only few of scientific areas in which he and his team achieved impressive results. In the beginning his interests concern the electrical resistivity of duralumin after plastic deformation at 77 K and subsequent annealing at 310^0C [15-16]. He found, that the introduced point defects have caused structure dislocation. The new phase formatted by plastic deformation causes electrical resistivity variation at the liquid nitrogen temperature. By these experiments Leyarovski started low temperature investigations at the Bulgarian Academy of Sciences.

Metal borides are next important topic of his research. They are a separate group superconducting compounds. Superconductivity with T_c=4 K has been observed in TaB for the first time in 1949 [17]. However, many binary and ternary borides compounds have been synthesized and investigated in 1970's and 1980's. Compounds including different metal elements (transition metal, rare-earth metal, and some elements of platinum group) demonstrate critical temperature not exceeding 12 K. The work of Bulgarian superconductivity research group in metal borides is very impressive [18-19]. It is pointed out that these compounds (with optimal electronic concentrations of 3.7–3.9 electrons $atom^{-1}$) do not fulfill the well-known Matthias rule. The optimal electronic concentration for superconductivity (5 and 7 electrons $atom^{-1}$) is related to a high critical temperature. In spite of that, large series of compounds with formula MeB_2 (Me=Ti, Zr, Hf, V, Nb, Ta, Cr, Mo) have prepared and investigated. However, superconductivity has been observed only in NbB_2 with T_c=0.62 K and surprisingly high value of H_c(O), about 1600 Oe. Other compounds with the formula MeB (Me = Ca, Sr, Ba), W_2B_5, CrB, Cr_5B_3, UBs, UB_4, and UB_{12} have been also synthesized and tested. None of these compounds have proved to be superconducting above 0.42 K. Today, we know that the compound MgB_2 has not been synthesized by chance and the group of Leyarovsky missed the possibility to discover the conventional superconductor with the highest critical temperature of 39 K at that time. Investigations of magnetic and thermal properties of CrB_2, CrB, and Cr_5B_3, have been performed over wide ranges of temperature and magnetic fields. The obtained results give relation with the model of itinerant-type of anti-ferromagnetism. These investigations and results have their value being cited up to now [20].

Enormous work has been done by Prof. Leyarovski and his collaborators from the laboratory for the construction of cryostat and obtaining of ultra-low temperatures. The cryostat presents a top loaded insert for a 15 T superconducting magnet [21]. Temperatures as low as 0.3 K were achieved based on $^3He/^4He$ dilution refrigeration and maintained for approximately 40 h. Original magneto-mechanical thermal switches were constructed, operating under the magnetic field necessary for the experiment. The construction allows two types of experiments to be carried out: specific heat measurements and adiabatic demagnetization from a starting temperature 0.3–0.35 K at magnetic field 14–14.5 T. At the time of this work, specific heat measurements below 1 K temperature in magnetic field 15T have not been accomplished yet. Specific heat measurements were performed on the first high temperature superconducting materials ($YBa_2Cu_3O_{7-x}$ and $YBa_{1.3}Cu_{4.2}O_{7-x}$) obtained by nitrate synthesis in this laboratory [22-23]. The specific heat coefficient was determined and the role of strong coupling effects was underlined.

The worldwide euphoria connected with discovery of high temperature superconductors gives the effect on the scientific investigations of the group. Many samples from YBCO and Bi-based superconducting systems were synthesized. Investigation of their superconducting and mixed state properties has been performed.

In 1970, Leyarovski published for the first time his idea for obtaining neon and helium from air (or gas mixture in oxygen industry) by adsorption at nitrogen temperatures [24]. The method allows obtaining high purity neon (99.98%) and helium (99.90%) without any intermediate fractions and high coefficient of extraction for both gases. It is based on adsorption – desorption processes at low temperatures and increased-partially reduced pressure respectively. The advantage over the other methods is that both gases (neon and helium) are obtained simultaneously and there is no need to purify the mixture from hydrogen independently of its concentration [25]. During the years, authors experimented other methods for separation of gas mixtures. They used different solubility of neon and helium in liquid nitrogen and under increased pressure [26] and thermal diffusion [27-29]. The thermal diffusion column gives possibility of consequent enrichment of vertical gas flows, induced by the natural convection in gravitational field in the column. This mass transfer process has used as gas separation techniques. The method for separation of gas mixture was patented in Bulgaria, the United States of America, the United Kingdom, and Australia [30]. The team headed by Prof. Leyarovski received golden medals in the International Exhibition of Inventions, Patents and Innovations in Geneva (1973) and Brussels (1975). Leyarovski has 30 patents in Bulgaria.

CONCLUSION

The golden age of low temperature physics at the Bulgarian Academy of Sciences is due to Eugene Leyarovski. He was an excellent experimenter with innovative imagination and bright scientific ideas. His investigations in four areas (high temperature superconductivity, low temperatures, Van-Vleck paramagnetism, and separation of gas mixtures) have international recognition. He found conventional superconductivity in transition metal borides. In the area of low temperatures, he prepared experimental techniques and methods for obtaining temperatures below 1 K (300 nK). In the area of Van Vleck paramagnetism for the lowest magnetic fields (B = 0,1 mT, 0,3 mT, 4,5 mT) he obtained for polycrystalline $PrNi_5$ clear deviations from Van Vleck type behavior of the ac susceptibility in a static field that is typical for ferromagnet [31]. In the area of semi-industrial production and conservation technology he created a new adsorption methods and apparatuses for cryogenic separation of Neon and Helium from the air and industrial gas mixtures.

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