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### A Nobel Prize-grade result

## ACADEMICIAN OF THE NAS OF UKRAINE VADYM EVGENOVYCH LASHKARYOV: THE OUTSTANDING PHYSICIST OF THE 20-th CENTURY, THE DISCOVERER OF A *p-n*-JUNCTION (to the 55-th anniversary of the foundation of the Institute of Semiconductor Physics of the NAS of Ukraine)

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Academician of the AS of the UkrSSR  
V.E. Lashkaryov

This paper contains the scientific and biographic data concerning Vadym Evgenovych Lashkaryov, the outstanding Ukrainian physicist of the 20-th century. He became a discoverer of *p-n*-junction, what is a Nobel

Prize-grade result. V.E. Lashkaryov is a founder and the first Director of the Institute of Semiconductor Physics of the NAS of Ukraine; the 55-th anniversary of its foundation was on October 7, 2015. The paper was initiated by the Academic Council of Semiconductor Physics of the NAS of Ukraine, with V.E. Lashkaryov having been its first chairman.

The major results at the initial stage of his scientific activity were obtained by V.E. Lashkaryov, while studying the surface of solids by the low-energy electron diffraction method and, after having returned from the exile, the photoelectric properties of semiconductors, a new class of substances at that time, on their surface and in the bulk [1–4]. As long ago as in 1940, still before the World War II, V.E. Lashkaryov, by using the method of differential thermoelectric effect (structure with a double probe) developed by himself, observed, for the first time in the world, the change of the effect sign associated with the formation of *p-n*-junction near the semiconductor surface and gave a physically substantiated explanation for its mechanism. The corresponding results were published in the known physical journal [2]. The result was reprinted in a special issue “Golden pages of Ukrainian physics” of the *Ukrainian Journal of Physics* [2] and in the *Europhysics News* journal (“100

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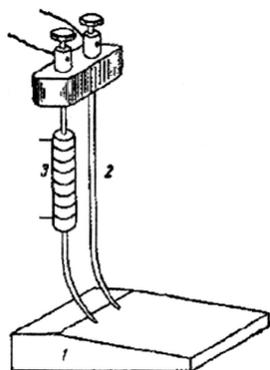


Fig. 1. Experimental specimen (1) with a double thermo-probe

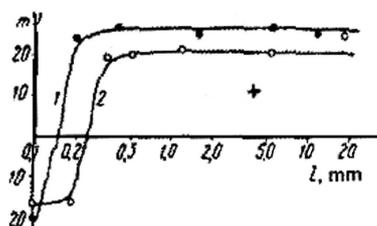


Fig. 2. Variations in the magnitude and sign of the probe thermal emf depending on the distance on the specimen surface, which means the change of charge carrier sign from “+” near the surface to “-” in the specimen bulk. In these experiments, the depletion layer length ( $< 10^{-3}$  cm) was experimentally determined and agrees with modern measurements

years of semiconductor science. Ukrainian contribution” authored by V.G. Litovchenko and M.V. Strikha) [3].

Unfortunately, the World War II, which began in two months, did not allow the world science to estimate this result, which was of the Nobel-Prize grade. In 1947, it was a similar “probe” structure created on the basis of a Ge semiconductor that was used to discover the transistor effect (Brattain, Bardeen, and Shockley). For this work, which marked the beginning of the transistor era, the mentioned scientists were awarded the Nobel Prize. Although V.E. Lashkaryov’s work was not widely known, it comprises an important stage in the formation of modern solid-state (semiconductor) electronics, which is a dominating direction nowadays.

The rather long scientific way of V.E. Lashkaryov consisted of several symbolic stages. Let us consider them below.

## 1. Kyiv and Leningrad Periods

Vadym Evgenovych Lashkaryov was born in Kyiv on October 10, 1903 in lawyer’s family. After graduating from the Kyiv University in 1924, he continued his study at the postgraduate course of the Kyiv Polytechnic Institute (1924–1927). Then, he worked as a senior lecturer at the KPI till 1930. During this period, he studied X-ray radiation and was engaged in the development of X-ray-optical facilities. Simultaneously, he performed a cycle of original works on the influence of the gravitation field on the matter motion. In 1930–1934, he worked at the Leningrad Physico-Technical Institute as Head of the Department of Diffraction of X- and Electron Beams.

## 2. Exile (1934–1939)

In 1934, V.E. Lashkaryov was subjected to the repression and sent to exile at the town of Arkhangelsk, where he worked as Head of the Chair of Physics at the Arkhangelsk Medical Institute (1935–1939) under the open surveillance of the People’s Commissariat of Internal Affairs. Here, V.E. Lashkaryov studied the biophysics of nerve fibers. He remained “unreliable” for the authorities till the end of his life. Only once, he was allowed to make a trip abroad (to Bulgaria), but being accompanied by supervisors.

## 3. Prewar Period in Kyiv (1939–1941)

After returning to Kyiv, V.E. Lashkaryov continued to work at the Academy of Sciences. He held a position of Head of the Department of Semiconductors at the Institute of Physics of the Academy of Science. Vadym Evgenovych founded the Chair of Semiconductor Physics, the first in the USSR, at the Kyiv University, where he organized the researches of photoelectric and contact phenomena in complex semiconductors such as AgS, CuO, Cu<sub>2</sub>O, Se, Te, and others.

**The Nobel Prize-grade discovery was made in Kyiv in the prewar time (1940–1941).**

At the beginning of 1941, V.E. Lashkaryov published his original works in the central scientific journal of the USSR: *Izvestiya Akademii Nauk SSSR*. They were devoted to the study of a blocking space charge layer that arises near the semiconductor surface at the interface between the hole- and electron-type semiconductor regions (the researches themselves were carried out in 1940). Those publications

meant the discovery of a  $p$ - $n$ -junction, which provides the basic mechanism of current rectification in semiconductor-based devices. In particular, this explains the photovoltaic effect. The discovery was made at the Kyiv laboratory. The emergence of a  $p$ - $n$ -junction was observed in a  $\text{CuO}_2$  layer, by using an original double probe. The original setup of experiment, the experimental dependences of the thermoelectric power on the thickness, and the corresponding energy diagram are depicted in Figs. 2 to 4, respectively.

In 1947, the  $p$ - $n$ -junction was used by Bardeen, Shockley, and Brattain, while discovering the transistor effect (the Nobel Prize). Till now, it remains the main structure of semiconductor electronics.

#### 4. War Period

When being in the town of Ufa (1941–1944) during the war, V.E. Lashkaryov worked at a scientific research institution of the Ministry of Electronics. Here, he created and developed powerful cuprous-oxide rectifiers for feeding military radio equipment.

#### 5. Post-War Period in Kyiv (1945–1974)

After returning to Kiev in 1944, V.E. Lashkaryov was soon elected Academician of the Academy of Sciences of the UkrSSR. For some time, he headed the Chair of Physics of Semiconductors of T. Shevchenko Kyiv University.

At once, Vadym Evgenovych began wide-ranging theoretical and experimental studies dealing with photoconductivity, photo-emf of the barrier-layer and bipolar-diffusion origins and the influence of fields at the metal-semiconductor contact. He determined the nature of a condenser photo-emf, the injection properties of a  $p$ - $n$ -junction, and used this method to study the spectra of surface levels [4–6].

V.E. Lashkaryov continued the researches of surface phenomena, which were begun with Lyashenko and Fedorus as long ago as before the war, and how the adsorption affects them. Together with V.I. Lyashenko, he published a large review on the physics of semiconductor surface (in 1955).

Large-scale researches of germanium and silicon diodes, transistors, and integrated circuits, which were carried out under the direction of V.E. Lashkaryov, provided a high prestige to the department headed by him. In particular, this concerns the re-

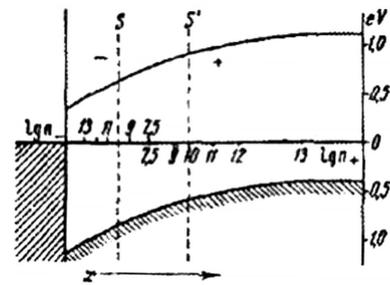


Fig. 3. Energy diagram of the  $\text{CuO}_x$  photo cell with a  $p$ - $n$ -junction

searches performed on the topic “Researches in the surface physics of semiconductor ultra-high-frequency detector” at a new special laboratory of ultrahigh frequencies at the Kyiv University. The researches were executed under the direction of V.E. Lashkaryov, and I participated in them in 1955–1957. Together with V.E. Lashkaryov, the results obtained were reported in a number of scientific papers; some of them were published in leading journals [5, 6].

Owing to high Lashkaryov’s authority, the Institute of Semiconductor Physics was founded in 1960 on the basis of the Department of Semiconductors of the Institute of Physics of the AS. Vadym Evgenovych was its Director from 1960 to 1970 [1]. Simultaneously, he headed the Chair of Semiconductors at the Kyiv University (in 1944–1958) and lectured an original course on semiconductors, one of the first in the world. He was the chairman of the Academic council in the problem “Semiconductor physics” of the AS of the UkrSSR (which is active till now) and the chairman at scientific seminars. V.E. Lashkaryov possessed a high scientific and public authority.

#### 6. V.E. Lashkaryov’s Collaborators and Disciples

V.E. Lashkaryov created the well-known scientific school in semiconductor physics. This school unites the staff of the Institute of Semiconductor Physics of the NAS of Ukraine (Kyiv) and scientists from the universities in various towns (see Photos 5 and 6). The scientific heritage of Vadym Evgenovych includes about 120 publications, reviews, and monographies.

The scientists who worked with V.E. Lashkaryov for a long period of time can be conditionally classed into his colleagues and collaborators, and his disciples. The former group included Vasylii Ivanovych



**Photo 1.** Administration and employees of the Chair of Semiconductor Physics and the special laboratory of ultra-high frequencies at the Faculty of Radiophysics of the Kyiv University (1950s). In the first row (from left to right) are Ya. Karkhanina, V.I. Lyashenko, V.E. Lashkaryov, Yu.I. Karkhanin, G.A. Kholodyar, and Yu.I. Grytsenko; in the second row are I.G. Sambur, G.M. Zubril, G.P. Peka, V.I. Strikha, and R.M. Bondarenko; in the third row at the center is Yu.I. Kozhevnikov



**Photo 2.** Scientific seminar at V.E. Lashkaryov's office (1960). From left to right are V.I. Lyashenko, G.V. Lashkaryov, I.M. Dykman, V.G. Litovchenko, M.K. Sheinkman, G.A. Fedorus, K.D. Glinchuk, N.B. Luk'yanchykova, and V.E. Lashkaryov

Lyashenko (who supervised the direction of semiconductor surface physics), Grygorii Avramovych Fedorus (photoelectric devices), Omelyan Gervasievych Miselyuk (bulk properties of semiconductors), Iryna Borisivna Mizetska (semiconductor chemistry), Yurii Ivanovych Karkhanin (in time, the Dean of the Faculty of Radiophysics at the Kyiv University), Sergii Vasylyovych Svechnikov (optoelectro-

tics), and Mykhailo Pavlovych Lisitsa (semiconductor optics). Among his disciples, there were Petro Ivanovych Baranskyi, Mykhailo Kivovych Sheinkman, Evgen Andriyovych Salkov, Valentyn Oleksandrovych Romanov, Oleg Vyacheslavovych Snitko (doped semiconductor surface), Volodymyr Grygorovych Litovchenko (recombination properties of the surface), Vitalii Illarionovych Strikha (Schottky contacts), Volodymyr Antonovych Brodovyi (physics of complex semiconductors), and Valentyn Mykolayovych Dobrovolskyi (galvano-magnetic processes). The latter worked at the Chair of semiconductors at the T.G. Shevchenko University of Kyiv.

Many of well-known specialists in semiconductor science, who belong to V.E. Lashkaryov's scientific school, which remains active till now, continue to work. In particular, recently, a group of employees from V.E. Lashkaryov Institute of Semiconductor Physics (V.G. Litovchenko, B.M. Romanyuk, and V.P. Melnyk) were awarded the Prize of the Presidium of the NAS of Ukraine for a cycle of works "Photoelectric effects in nano-sized structures created using the ion-beam technology". Those works are a direct continuation of the topic started by V.E. Lashkaryov.

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