

## Presentation

### Scientific, educational and social activities of Academician H. B. Abdullayev

Hasan Mamed Bagir oglu Abdullayev (20.08.1918-01.09.1993) – due to transliteration in many Western sources name was spelled as Gasan Mamed-Bagir Abdullaev – was a prominent Azerbaijani and Soviet physicist, founder of semiconductors physics school in Azerbaijan, one of the leading scientist in electronics and new technologies in the world. His fundamental studies and scientific achievements laid the groundwork for the modern mobile communication and internet systems. H. B. Abdullayev was a professor and doctor of physical-mathematical sciences, he created new scientific trends in physics of Se-based (Selenium) semiconductors and related materials. The results of these studies are widely known all over the world.

In 1950 being the Director of Institute of Physics and Mathematics of the Academy of Sciences of Azerbaijan SSR that specialized in the oil industry, H. B. Abdullayev started to establish the Institute of Physics of semiconducting trend (IPAS). The Institute was confirmed by Soviet government as a leading research institute in the USSR on physics of *Se* (Selenium) and *Te* (Tellurium) and devices on their basis. Later IPAS became also the leading institute on molecular and atomic spectroscopy. Academician H. B. Abdullayev was at the head of IPAS until 1993, up to end of his life and more than 60 doctors and 100 candidates of physical-mathematical sciences theses (according to the data as of 1984) were defended under his supervision.

In 1954 in Azerbaijan State University (Baku State University), H. B. Abdullayev set up and headed one of the first semiconductor department in the USSR, then the first department of astrophysics in the republic.

Scholar and founder of new scientific applications, academician H. B. Abdullayev was the President of Azerbaijan Academy of Sciences from 1970 up to 1984; associate Member of Academy of Sciences of USSR and Russian Academy of Sciences; leading expert in semiconductors and dielectrics in the Soviet Union, since 1953 was the member of Dielectric Commission in the USSR; the member of Scientific Council in complex problem on “Physics and Chemistry of Semiconductors” under Presidium of Academy of Sciences of USSR; member of General Physics and Astronomy of Academy of Sciences of USSR; Chairman of Republican Scientific Councils ”Problems of Physics” and “Problems of Physics and Chemistry of semiconductors”; Chairman of specialized council on doctor thesis defense of Institute of Physics of Azerbaijan Academy of Sciences; member of Awarding Commission of state youth organization (VLKSM) in science and technology of Republican Society Board “*Znaniye*”; member of All-Union

Attestation Commission of USSR; deputy of Supreme Soviet of USSR of 8<sup>th</sup>, 9<sup>th</sup>, and 10<sup>th</sup> convocations.

H. B. Abdullayev is one of the founders of electronics in the world, the author of the first basic book on physics of semiconductors in Azerbaijani language published in 1952; one of the authors and editor-in-chief of first terminological dictionary of physics in Azerbaijani, editor of academic journals “*Vesti*” and “*Nauka i Zhizn*”, the author of more than 1000 publications, about 400 Soviet and foreign patents for inventions including in USA, Japan, Germany, Great Britain, France, Sweden, Italy, Netherlands, and India. The works on production of new semiconducting single crystals of complex chemical composition for the creation of optical quantum generators were included in the most important results of Soviet science for 1964-1965.

A lot of the credit must go to G. B. Abdullayev in development of adjacent trends of fundamental sciences, as electrochemistry, biochemistry, biophysics, molecular biology, molecular genetics etc.

H. B. Abdullayev achieved prominent results in creation and study of properties of *p-n* junctions. In 1945 for the first time, he revealed the dynamic potential jump in the vicinity of anode, as well as the static jump nearby cathode at high temperatures. As a consequence of complex investigations, he established the physical nature and barrier layer formation processes of rectifiers.

The results of further investigations in 1952 led to better understanding of some peculiarities of physical properties of *p-n* junction:

- created the first man-made *p-n* junction in Se elements;
- developed physical mechanism of dependence of average value of rectified current on the frequency;
- derived the empirical formula of conductivity in ultrastrong fields in diode structure:

$$\sigma = \sigma_0 e^{bv^2}$$

These works formed the basis of dynamical theory of semiconductor rectification.

Main knowledge of physics of A<sup>III</sup>B<sup>VI</sup> compound semiconductors and related materials is associated with H. B. Abdullayev.

In 1959 H. B. Abdullayev made two discoveries:

- thermoelectric generator on the basis of natural galenite;
- selenium photocells with increased parameters.

Abdullayev's works on *Se* are considered to be distinguished in the world. He gained the recognition and fame due to his fundamental works on the production of *Se*, *Te* crystals, their complex compounds, comprehensive study of their physical properties and creation of new semiconductor converters;

- developed methods of selenium purification;
- obtained single crystals of hexagonal and monoclinic modifications;
- determined the cause of "anomalies" in *Se* properties;
- developed methods of control of conduction type of mono- and polycrystalline, amorphous and liquid selenium;
- found out the origin of *Se* p-type conductivity;
- developed the model, responsible for conductivity mechanism in *Se*;

These results are the fundamental contribution to the physics of condensed systems and revealed new perspectives towards understanding of polymer semiconductor and nanocrystalline system properties.

Under the leadership of H. B. Abdullayev

- by method of radioisotopes the quantitative characteristics of diffusion and state of diffusing atom in selenium are determined;
- first time electronographically shown that the mechanism of rectification in photocells and rectifiers is due to the formation of heterojunctions in them owing to electrical forming;
- scientific bases of improvement the existing technologies and creation new high-effective technologies for manufacturing of selenium diode structures are developed.

H. B. Abdullayev together with his followers revealed new groups of binary and ternary compounds of *Se* and *Te*:

- production technology of perfect single crystals of  $A^3B^6$  compounds has been developed;
- $A^3B^6$ -based X-ray and neutron radiation detectors have been created;
- a great number of new more complex compound semiconductors of  $A^3B^6$  analogs have been predicted and produced
- general change character of electronic properties of  $A^3B^6$  compounds, their solid solutions and complex analogs has been established;
- complex semiconductors, suitable for detectors in visible and infrared regions have been obtained
- piezo-photoresistive effect that allows to considerably extend the capabilities of semiconductor tensometry has been revealed

A series of basic works on optical properties and energy structure of  $A^3B^6$  - type semiconductors extended the capabilities of semiconductor electronics:

- it is established that gallium selenide crystals are substantially outperform in many parameters other existing nonlinear crystals in IR-region and are perspective for quantum electronics, nonlinear optics and creation of generators with tunable frequency;
- there has been worked out the system of optical communication with using the frequency modulation of laser radiation. In receiver of communication system, the “Decoder” on GaSe- based crystal served as a converter of frequency- modulated signals to amplitude –modulated ones.

A series of works on thermoelectricity gave rise to creation of new complex semiconductors, efficient for thermal converters.

On the basis of studies of physical properties of  $A^1B^3$  chalcogenides and processes in diode structures for the first time:

- controlled effects of polarity-dependent and independent switching and memory have been revealed;
- diodes with controlled electric memory have been developed

On the basis of  $A^3B^6$  compound single crystals:

- practically perfect bistable device where high-resistance state has metallic conduction have been designed;
- devices controlled by electric field with threshold switching and triple memory has been designed.

As a result of studies of first group chalcogenides:

- it is established that controlled effects of polarity –dependent switching and memory in semiconducting crystals of chalcogenides of the first group are based on the injection of *Cu* and *Ag* ions of high mobility.
- information storage of 256-bit for permanent storage unit with electric re-record of information on the basis of switching with long-time electric memory has been first developed.

On the basis of comprehensive investigations of electronic generation-recombination processes in *p-n* junction :

- method of determination of main parameter of electronic generation-recombination processes in *p-n* junctions has been suggested;
- unit for automatic recording of *p-n* junction capacity-voltage characteristics and the phenomenon of capacity behavior inversion of reactivity into inductance one has been designed:
- a great number of unknown groups of ternary and four –fold anisotropic semiconducting compounds suitable for microelectronics and laser technology has been first obtained

- phenomena of light storage and switching effect in Cd In<sub>2</sub>S<sub>4</sub> single crystals have been revealed;
- possibility of switching effect control by light has been shown

One of the fields of science developed by H. B. Abdullayev's close participation is Biophysics. By his initiative laboratory "Biophysics of brain", then Department and finally Institute of Microbiology, promoting extensive work in biophysics and molecular biology have been organized. H. B. Abdullayev developed the unique trend of investigations where, series important data on Se distribution in biological objects, its role in fermentative processes and particularly, in the increase of optical sensitivity of visual analyzer have been obtained. These studies are of important significance in understanding of eye function mechanism.

In the sphere of biophysics and molecular biology there have been established:

- unknown phenomenon of amplification of electric potential of retina caused by light under Se effect, participating in mechanism of transforming the radiant energy into electric one.
- the fact of Se selective inhibition of first group ferment, catalyzing the synthesis of ribonucleic acid (RNA) on the matrix of desoxyribonucleic acid (DNA).

In 1972 for series of works on production of new complex semiconductors, creation of various devices on their base, as well as for the works in biophysics on determining the role of selenium in vision process H. B. Abdullayev and group of his followers were awarded by the State Prize of Azerbaijan.

As a result of H. B. Abdullayev's works on selenium, a big specialized industry on Se mass production of high purity and new high-efficient Selenium converters and tens of devices on their base have been set up in USSR. These devices in quality rating were up to the world standards and had USSR State "Quality Symbol". Semiconductor devices, principally new kinds of product for republic industry have been started up in Azerbaijan.

H. B. Abdullayev's works in physics of selenium and selenium devices gain a world fame and are published in journals of USSR Academy of Sciences, International journals "Physical Review", "Chemical Physics", "Selenium and tellurium Abstracts", "Japanese Journal of Applied Physics" and highly appreciated in monographs of B. I. Boltax, D. M. Chijikov and V. P. Schastliviy, I. Ray Drabble and H. Julian Goldsmid. Nobel Prize winners N. Semenov (1956), A. Proxorov (1964), Jh. Alferov (2001), Kenneth G. Wilson (1982), well-known American scientist Lutfi A. Zadeh, W. Charles Cooper - president of International Association in developing physics of selenium and tellurium, academicians H.

Bogolybov, D. Blokintsev, E. Velikhov, R. Sagdeyev and many other scientists highly appreciated H. B. Abdullayev's works on selenium.

By H. B. Abdullayev's initiative and his leadership one of the first in USSR special experimental design office and other technological parks were set up. Step by step scientific centers were established in Sheki, Ganja, Nakhchivan, biolaboratory in Lenkoran (now Regional scientific Center), the first laboratories in the Institute of Physics, Azerbaijan Academy of Sciences. Later on their basis Department of Radiation Investigation, Department of molecular biology, Observatories in Shemakha, Agdere (vil. Tivi), Shakbuz, a number of research institutes, scientific and productive enterprises, Institute of Microelectronics the first Institute for Space investigations of Natural Resources and Scientific and Productive Enterprises of space research. All of them have been established on the base of Institute of Physics of Azerbaijan Academy of Science.

Hasan Abdullayev is considered as the founding father of Azerbaijan physics. He devoted all of his life to the development and arrangement of science, strengthening and progress of scientific relations, international scientific collaboration. Analytical mind, deep scientific intuition, craving for innovation in science went with his great organization talent. Azerbaijan Academy of Science headed by H. B. Abdullayev became one of the biggest in USSR development center of fundamental branches of knowledge, laying the foundations for progress in many fields of science and national economy.

E. P. Velikhov, academician, vice-president of Russia Academy of Sciences.

"Academician Hasan Abdullayev is the patriarch of physics in former Soviet Union and Azerbaijan, world-class scientist, raised an entire generation of talented physicists. During the presidentship of Academy of Sciences of the republic, he demonstrated his outstanding leadership abilities, and in fact, he has provided wise guidance for the core part of its activity. New scientific-research institutes and research centers have been established in Baku and throughout Azerbaijan on his initiative".

Academician N. N. Semenov - the Nobel Laureate in 1956:

"Institute of Physics is the most modern institute in the Soviet Union. Research in Institute in the field of semiconductor physics is carried out at high theoretical level" (1964, Session of Presidium of USSR Academy of Sciences, Vestnik of USSR Academy of Sciences, N1, 1965).

Academician A.M. Prokhorov, the Nobel Laureate:

“Institute staff headed by H. B. Abdullayev made a lot for creation of new memory systems for computers. In particular, this is the semiconductor memory system based on Selenium. It is a unique and very important direction. Nonlinear crystals are of great importance in quantum electronics. These crystals now being used in quantum electronics, have been created under the leadership of H. B. Abdullayev” 1970, Presidium of Azerbaijan SSR Academy of Sciences.

“...The Institute of Physics of the Academy of Sciences of the Azerbaidzhan SSR under the direction of academician H. B. Abdullayev is the leader in this country in research on selenium and instruments based on it. An entire industrial sector on the production of high-purity selenium and highly efficient selenium transducers, which are exported to many countries in the world, has been created in Azerbaidzhan. A large number of previously unknown groups of ternary and quaternary anisotropic semiconducting compounds, which are promising for microelectronics and laser technology, were first predicted to exist and obtained at the Institute of Physics. Methods for decoding and interpreting aerocosmic information about the environment for the interests of geology, geography, oceanography, and aqua- and agricultures were developed here.” Source: Uspekhi Fiziki, 1983.

1. Academician Zh. I. Alferov , the Nobel Laureate 2001:  
“He [Hasan Abdullayev] enriched the world through the remarkable scientific achievements.”
2. “Academician, corresponding member of USSR Academy of Sciences from Division of Physics and Astronomy, the director of the Institute of Physics that is established by himself and President of Azerbaijan Academy of Sciences... H. B. Abdullayev is the outstanding physicist of our days. Undoubtedly, H. B. Abdullayev is founder of Azerbaijan physics school. First of all, Abdullayev founded his own direction in semiconductor physics. (Interview ANS TV, 2003).

Academicians Zh. I. Alferov (the Nobel Laureate), E. P. Velikhov, B. M. Vul, A. M. Prokhorov (the Nobel Laureate), M. A. Topchibashev, V. M. Tuchkevich: «Important result of research carried out by H. B. Abdullayev is the establishment of possibilities and obtaining of new class of semiconductor compounds. The valued feature of this research is successive and detailed development of monocrystal growth technology, determination of the energy spectrum of charge carrier, explanation of electrical, thermal, optical etc. phenomena, creation of various typed converters». Uspekhi Fiziki, Vol.126, iss.2, 1978.

D. I. Blokhintsev, founder of Joint Institute for Nuclear Research, Chairman of Scientific and Technical Council of JINR, Dubna, associate member of USSR Academy of Sciences:

«Many scientific results belonging to H. B. Abdullayev determined the development of new applied fields in physics».

H. B. Abdullayev, the most outstanding physicist whose reputation is closely connected with the development of a variety of fundamental directions in condensed matter and semiconductor physics and semiconductor electronics. Many scientific results belonging to H. B. Abdullayev determined the development of new applied fields in physics. H. B. Abdullayev laid the foundations of modern technology of semiconducting converters and other electronic devices... H.B. Abdullayev established a strong scientific school in solid state physics... While heading Azerbaijan SSR Academy of Sciences for many years, H. B. Abdullayev carries on huge scientific-organizational activity. Institute of Physics, Azerbaijan SSR Academy of Sciences founded and headed by him is the leading research institute of USSR in physics of selenium and tellurium as well as the devices on their basis. By active involvement of H. B. Abdullayev, research on astrophysics, molecular biology in the republic has been promoted in country... By his initiative, new Problem laboratory of high energy physics has been founded in Baku”.

Academician Roald Sagdeyev, Russian Academy of Sciences: “It is impossible to overestimate of influence and role of Hasan Abdullayev on development of science in Azerbaijan. It is fact that under his guidance, the national science reached the world levels”. Letter to the Presidium of Azerbaijan SSR Academy of Sciences.

Witold Nowacki - Vice-President of Polish People's Republic, later President of the Polish Academy of Sciences: “During my visit to the USSR, I also visited many institutes of Academies of Sciences, but two of them made a deep impression on me - it is the Institute of Cybernetics of Ukrainian SSR Academy of Sciences and Institute of Physics of Azerbaijan SSR Academy of Sciences. Academy of Sciences of Polish People's Republic adopted the five year program to reach standards of these leading institutes.” Warsaw, 1969.