

PRINCIPLES OF OPERATION AND HISTORY OF THE MOLECULAR-ELECTRONIC SENSORS

R-sensors' measurement instruments are based on the physical principals of signal transformation in molecular-electronic (electrochemical) cell.

The feature of the molecular-electronic transducers is the very high sensitivity to the external acceleration due to the using the liquid as an inertial mass and due to the high steepness of the transformation of mechanical signal into electrical current. This is followed by wide operational frequency band and dynamic range. These properties in particular give possibility to create high sensitive seismic sensors with the low-frequency cut-off down to thousandth of a hertz.

Lack of the moving high-precision mechanical parts and relative simplicity of design give the molecular-electronic devices high reliability and resistance to external impacts unavoidable at transportation and operation of the seismometers in field conditions.

The first attempts to develop electrochemical transducers using a liquid inertial mass date back to the 1940s in Germany. These attempts were not very successful. Nevertheless, between 1950 and 1960 the electrochemical transducer research resumed in the United States under the direction of the U.S. Navy and in Soviet Union where these research concentrated mainly around Moscow Institute of Current Sources and Moscow Frumkin Institute of Electrochemistry.

The main objective of the research in U.S. guided by C.W. Larcam was to develop highly sensitive, low power seismometers that could be used in particular at the ocean bottom. Unfortunately, the common level of technology did not allow the Larcam's team to reach the assigned objectives in full. Nevertheless, Larkam's work became a significant step forward.

In Soviet Union at the same time was founded the whole scientific school that was named "molecular electronics" under the guidance of corresponding member of the Academy of Science N.S. Lidorenko and the devices were named "molecular-electronic". Prof. Lidorenko made a very significant contribution to developing of the molecular-electronic sensors of different types. Nevertheless, in 1980s with the beginning of Perestroika in USSR the molecular-electronic research in fact were stopped.



prof. N.S.Lidorenko



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The new breath and a real breakthrough in molecular-electronic sensor design is associated with the name of the professor of the Moscow Institute of Physics and Technology Vladimir A. Kozlov and his team who in the mid 1990 achieved a significant progress in designing of the molecular-electronic devices and qualitative rise of their technical parameters. Prof. Kozlov's team for the first time made the molecular-electronic seismometer as a commercial product. And his partnership with American companies helped to present the developed seismometers at the overseas market.

The next step in development of molecular-electronic technique and technology is connected with the scientific production company "R-sensors" that in the beginning of 2000s started serial industrial production of the molecular-electronic sensors. The company has been involved into development of the new measurements instruments as well as into fundamental investigation of the physical processes in molecular-electronic transducers and research of new production technologies. Now the company offers the customers the whole family of short-period and broadband seismometers including boreholes and ocean-bottom models, as well as unique rotational seismometers and compact size seismic sensors and accelerometers.

The principles of operation of the molecular-electronic motion sensors are based on the convective-diffusion charge transfer between transducer electrodes at appearance of an external mechanical impact. The main difference of this type of sensors from all others is the liquid inertial mass — the solution of the electrolyte that flows through the transducer in result of the external mechanical signal. Just using of the liquid inertial mass makes molecular-electronic sensors extremely sensitive at low frequencies.

The schematic view of the molecular-electronic transducer (MET) is shown at Fig.1. Inside the tube 1 made of dielectric and chemically resistant material and filled with electrolyte solution 2, two pairs of perforated metallic electrodes 3,4 are fixed. The perforated electrodes allow the liquid electrolyte to flow through the electrode system in case of an external mechanical influence.

In the work mode a small constant voltage is applied to each electrode pairs of the transducer that produces flowing of some background current between anodes and cathodes of each electrode pairs due to the reversible redox reactions at electrodes. If the liquid flow appears in the tube because of external influence, the convective component of the current between electrodes changes. Conversion coefficient of the mechanical signal into electrical current is very high, that makes the highest sensitivity of the transducer.

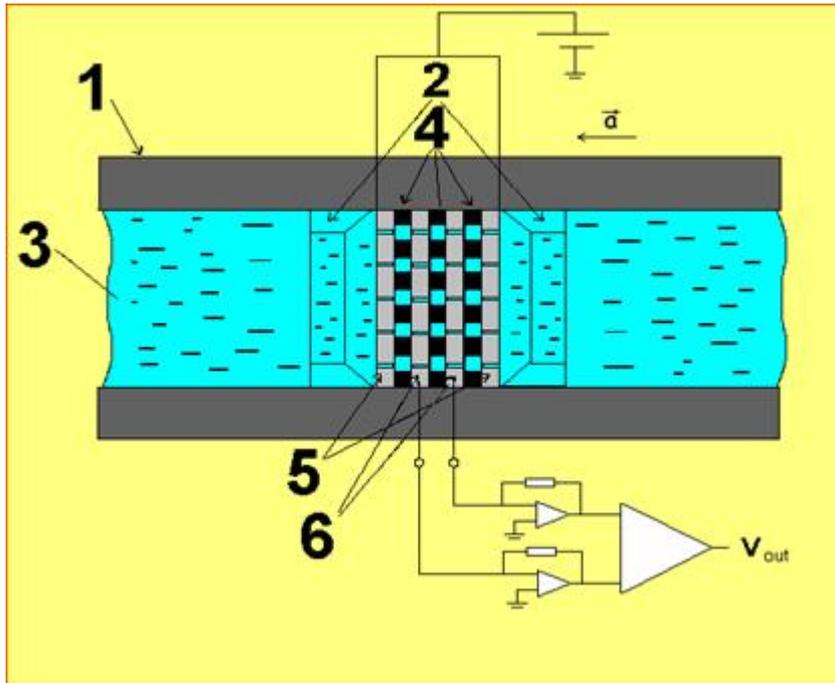


Fig. 1. Molecular-electronic transducer: 1 — dielectric tube (the case of the transducer); 2, 4 — stoppers; 3 — electrolyte solution, 5, 6 — electrodes.

In order the transducer can be used as sensor of linear motion, the ends of the tube (1) should be closed with elastic membranes (Fig.2). Then, at external acceleration, the electrolyte in the channel of the transducer start flow making charge carriers go to or go from the electrodes, that makes the change of the current in the external circuit.

If the ends of the tube (1) close into torus, that fully filled with the electrolyte solution, we get the sensor of the rotational motion (Fig.3).

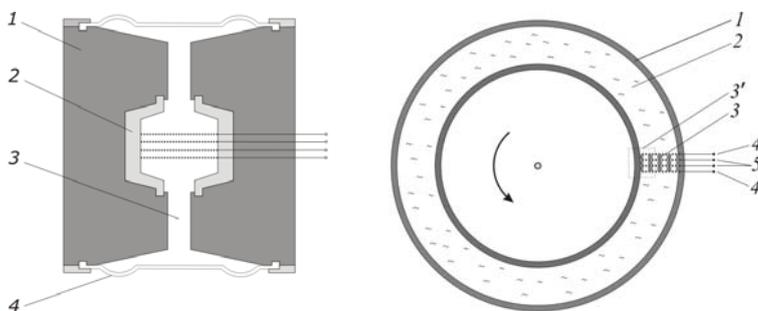


Fig. 2, 3.

Basing on the physical principles of the molecular electronics briefly described above, we developed a technology that allowed to create the whole family of the linear and rotational motion sensors (Fig. 4,5) unique in their technical parameters. Particularly, the first rotational seismometers were created that allows the direct measurement of the rotational component of the seismic wave.

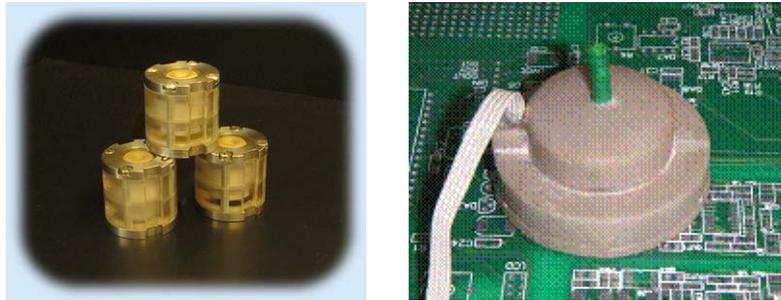


Fig. 4, 5.

The superior technical parameters of the developed molecular-electronic sensors open very good opportunity of their application in various important practical field of use, such as seismology and field geophysics, 3D-seismics, the monitoring of the vibration of high-rise buildings, bridges and others complex engineering constructions, inertial navigation, the seismic control of the guarded territory.

Now the company is involved into the active investigation aimed at the further improving of the reliability of the seismic instruments in severe operations. Another important direction of our investigation is the development of the new type of the transducers based on the modern microelectronic technologies and the advanced nano-electronic technologies. Using these technologies it is possible to achieve qualitatively new molecular-electronic measurement instruments including compact and highly sensitive seismic sensors, and the characteristics of some our developed prototypes confirm these expectations.