JOINT INSTITUTE FOR NUCLEAR RESEARCH
Laboratory of Neutron Physics named after I.M. Frank

FINAL REPORT ON THE
SUMMER STUDENT PROGRAM

Development of the hydroelectric converter on electret substrate

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Abstract

Development of a new electricity generation techniques is one of the most relevant tasks, especially nowadays under conditions of extreme growth in energy consumption. Adsorption energy is a new promising direction in alternative energetics. The problem of new renewable energy sources is becoming more and more urgent in connection with the depletion of traditional energy resources. In this aspect, of interest are ways of extracting energy from the external environment / thermostat, other than in hydropower (mechanical energy of the flow of rivers, oceans, wind) or solar energy (thermal, electrical). In particular, for alternative energy, the adsorption of atmospheric moisture is of scientific and practical interest, as a potential channel for the extraction of energy from the external environment, in particular, by objects of industrial and residential human infrastructure. The exothermic heterogeneous electrochemical energy conversion to the electric energy through interaction of the ZrO_2 *based nanopowder system with atmospheric moisture is one of the ways of electric energy obtaining. In this work, a technology is being developed for producing a chemo converter based on* ZrO_2 + *3mol%*Y_2O_3 *(YSZ) and YSZ + 50 wt.%*$CaSiO_4$ *powders and an electret substrate. A technology has been developed for obtaining electret substrates as a basis for the working layer of a chemo converter. The time dependences of the voltage of the chemo converters were studied during their long-term use.*

Introduction

The water is well known conventional source of electrical energy used by mankind. In liquid state, it is traditionally used for the electric energy conversion by an external thermostat of hydropower plants. However, direct conversion of water in gas state, (atmospheric moisture) to electric energy, remained unrealizable for centuries as a top scientific and practical aim. With the development of nanotechnology, the implementation of these ideas becomes potentially possible. In this regard, a nanopowder system based on zirconia dioxide (ZrO_2) is the best candidate for the direct conversion of the energy of water adsorption into electric energy [1]. It is well known [1-2] that the ZrO_2 surface is an extremely nonequilibrium thermodynamically, the surface of the ZrO_2 based nano dispersed oxide systems is exist in a state of dynamic charge and adsorption equilibration. I.e., the change of quantity of adsorbates is accompanied by a changing of the total charge in the system. In the case of nanoscale powder of zirconia dioxide, on its surface are preferably water is absorbed, and certain stages of a matter exchange between the system and external environment have an exothermic behaviour. Hence, in a cyclic mode, the nanopowder system based on ZrO_2 can convert the chemical energy of water molecules adsorption to an electric form [1-4]. The method of obtaining the energy considered is the phenomenon of injection of hot electrons (the mechanism of transfer of electric energy to the semiconductor crystal, which is realized during the course of a heterogeneous catalytic chemical reaction on its metalized surface) (fig. 1) [5].

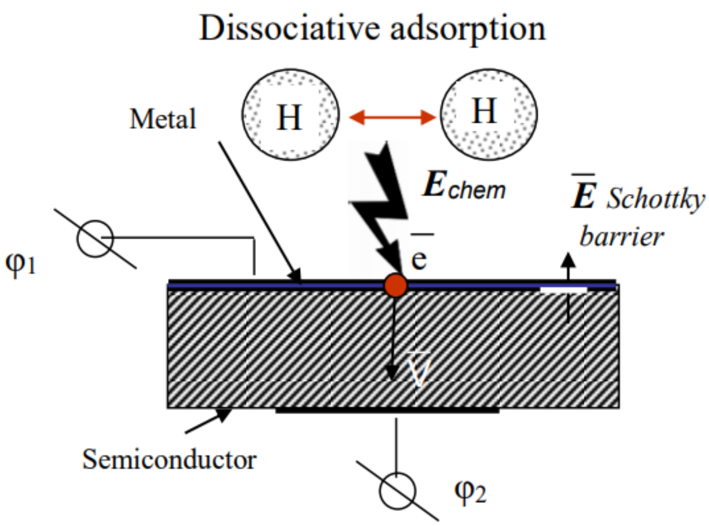


Figure 1. Scheme for the realization of the mechanism of ballistic electron transport on a metal-semiconductor transition during chemical adsorption.

The phenomenon of energy conversion of heterogeneous exothermic chemical reactions by analogy with photo-EMF [3] was called chemo-EMF (the prefix of chemo-, like photo-, emphasizes the nonthermic origin of the phenomenon) [6-9]. This way of converting chemical energy into an electrical form is good because the transformation from the chemical form of energy into electrical energy occurs directly, bypassing the intermediate stages. However, until now it is not clear in which act of a physic-chemical process a free electron is formed. It can be assumed that when a surface of a nanoparticle interacts with a water molecule, a process similar to that realized in redox processes takes place. The chemo electron converter is a promising new source of electricity. The results of work within the framework of international projects indicate the presence of a more effective, but more science-intensive approach to solving the problem of generating electricity from atmospheric moisture through the use of powder nanotechnology and a multidisciplinary approach to research. These are processes at the micro level, in particular, the use of a sequence (chain) of physicochemical, physical and electro physical processes that take place at the interface in nanostructured oxide materials when interacting with atmospheric molecules. The technology in question will make it possible to obtain electricity directly from the interaction of moisture with the surface, bypassing intermediate energy transformations.

The use of nanotechnology opens up prospects for the creation in the foreseeable future of adsorption chemo electronic converters with a reasonable efficiency. Within the framework of the HUNTER project, an attempt was made to practically implement a converter of the adsorption energy of water molecules into an electrical form with direct conversion based on nanosized particles of dielectrics. Using the high chemical activity of the surface of porous objects based on YSZ nanoparticles and their polymorphism, as well as new physical principles for constructing a functional converter cell, arising from size effects, it was possible to successfully solve the problem. To date, experimental samples of chemo - voltaic converters have been obtained.

However, this system can also be upgraded. The essence of the idea is to create an internal electric field in the space between the electrodes of the functional medium through contact with the surface of the electret film, which has the required potential relief.

The goal of these summer student practice was to develop a technology for obtaining a chemo electronic converter based on the electret substrate.

Materials and methods

To develop a chemo electronic converter standard epoxy polymer substrates were subjected to polarization at a voltage of 1.5 to 2 kV, at temperatures (150 - 200 ° C), with a step of 25 ° C, and different exposure time (60 - 120 minutes), with a step of 30 minutes. Powders of stabilized zirconium dioxide composition ZrO_2 + 3mol.% Y_2O_3 (YSZ) were used as a working area with a PVA polymer concentration of 0.5 g to 20 mg (composition No. 1) and 0.5 g to 40 mg (composition No. 2), and YSZ + 50wt.% $CaSiO_4$ powders with the same PVA concentrations (fig. 2).

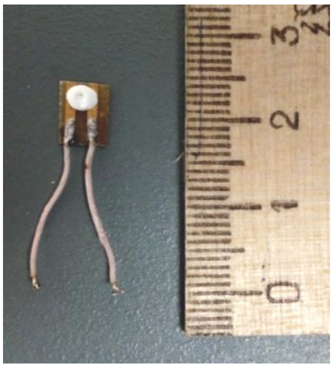


Figure 2. Laboratory version of the chemo converter

The study of the electrification process showed that the best polarization characteristics were in polymers that passed electreting at a voltage of 2 kV, with the temperature of 150 ° C and with the exposure time 120 minutes.

The dependence of the voltage of the chemo electronic converter, with the working layer in the form of YSZ, from the concentration of the PVA content is presented in Fig. 3.

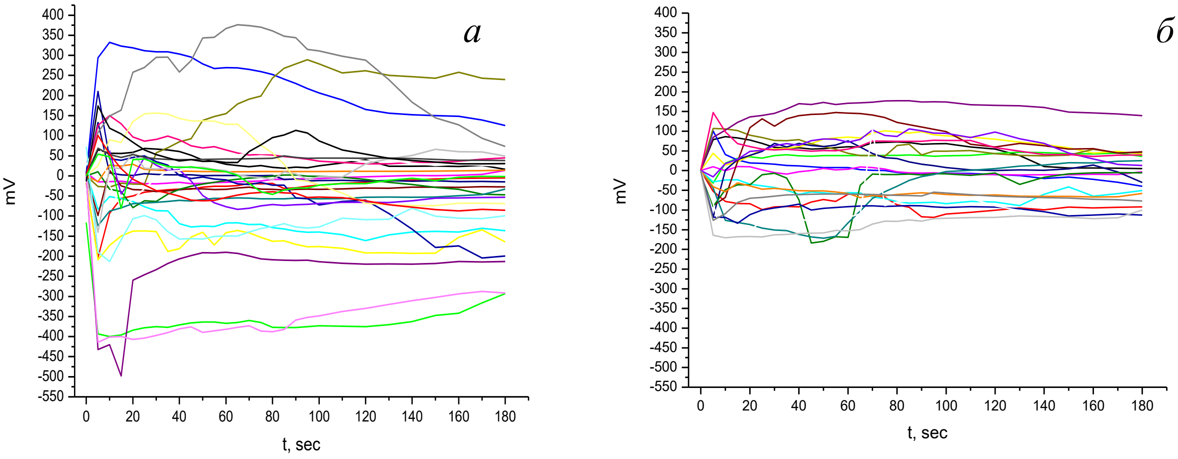
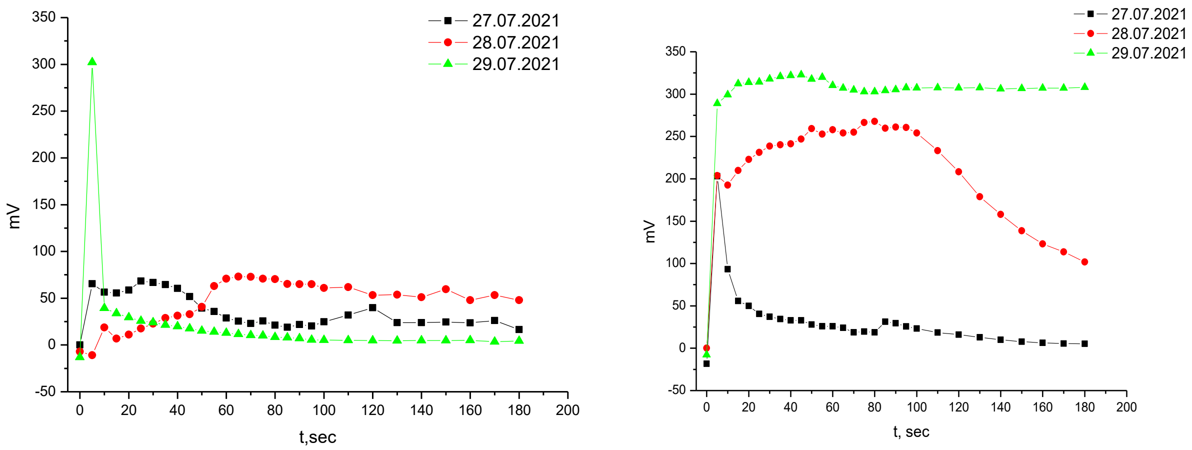


Figure 3. Time dependences of the voltage of the chemo converter at maximum humidity and different concentrations of YSZ with a polymer binder PVA: *a* - composition No. 1, *b* - composition No. 2

As can be seen from the following graphs, the working layer containing less PVA provides greater voltage than an element containing a large proportion of a polymer binder. The maximum voltage of 500 mV was achieved in composition No. 1, The maximum voltage reached in composition No. 2 was 200 mV (Fig. 3).

The resulting samples were studied on repeatability depending on the number of working cycles of the chemo converter.



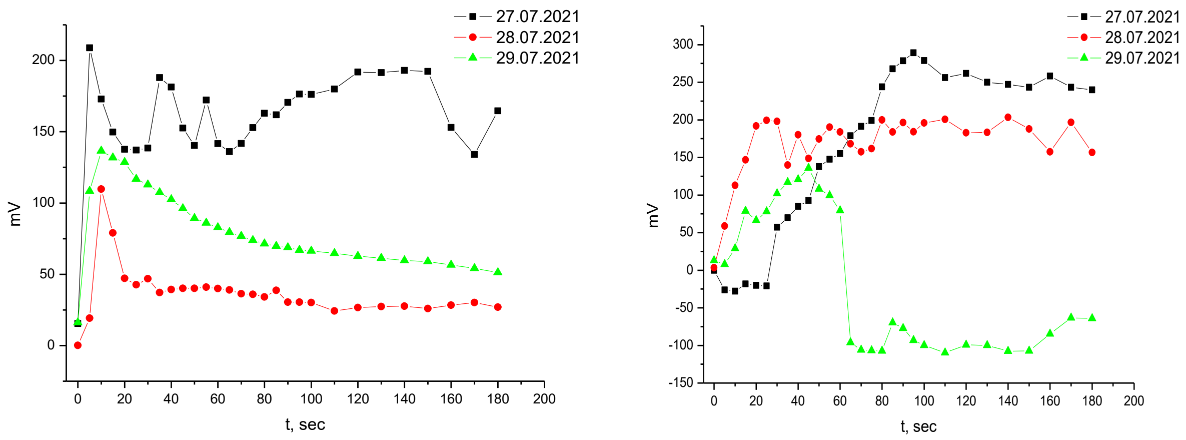


Figure 4. Research of the repeatability of the properties of the chemo converter with the working layer of YSZ composition No. 1

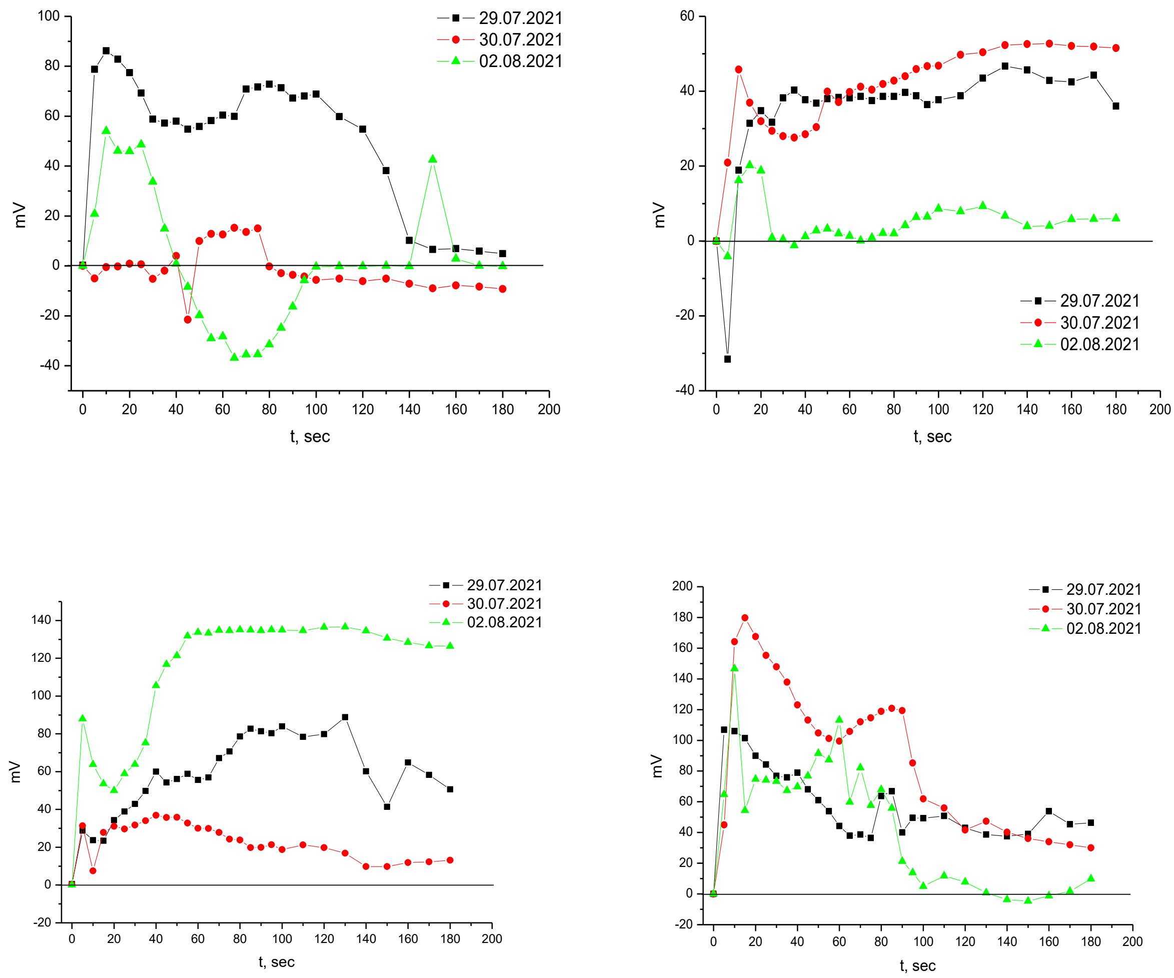


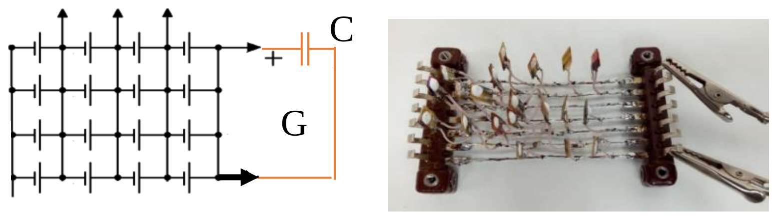
Figure 5. Research of the repeatability of the properties of the chemo converter with the working layer of YSZ composition No. 2

From the data obtained, it can be concluded that the workspace changes its properties depending on the number of working cycles. Such behavior of the system is due to various factors, including atmospheric humidity, air temperature, etc.

An important factor is that at the concentration of YSZ and the polymer 0.5g to 20mg, there is a significant deformation of the working layer, which leads to the appearance of cracks and peeling the workspace. The solution of this problem can be the variation of the concentrations of YSZ and the polymer binder, because the degradation of the workspace leads to redusing of life time of the chemo converter. Based on the above data, it can be concluded that the working layer with concentrations of 0.5 g to 40 mg has worse characteristics, but it is able to withstand significantly more working cycles.

When using YSZ + 50 wt.% $CaSiO_4$ as the basis for the working layer, the same chemo converter parameters are observed as when using YSZ powders. Increasing the properties of the chemo converter was not observed which indicating the advantage of using YSZ as a working area, since less reagents are used during the creation of YSZ powders.

The resulting chemo converters G (Fig. 6) consists of sequentially - parallel connected working cell, which made it possible to obtain a voltage of 0,6V. The energy generated by the chemo converter was accumulated in the electrical capacitor.



a b

Figure 6. Connection diagram (a) and assembled chemoconverter (b),

The above data suggest that the use of a polymer electret as a substrate for the working layer of the chemo converter is a promising method for producing moisture-adsorption sources of electricity, however, to improve this system, it is necessary to improve the technology of obtaining workers cells. Currently, preparations for obtaining more advanced designs based on electret materials are being prepared.

Conclusion

As a result of the work, the chemo electronic converter based on electret substrate were obtained, the optimal composition it's functional layer were selected. The temporal dependences of the voltage of the chemo converter cells were studied and the number of working cycles of elements was determined. A collected working chemo-converter cell is able to accumulate the charge on the condenser, which indicates the prospects of new moisture-adsorption sources of electricity.

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