3. развитие силовой электроники и устройств на их основе, прежде всего различного рода сетевых управляемых устройств (гибкие системы передачи переменного тока – FACTS);
4. создание высокоинтегрированного информационно-управляющего комплекса оперативно-диспетчерского управления в режиме реального времени с экспертно-расчётными системами принятия решений;
5. создание и широкое внедрение централизованных систем противоаварийного управления, охватывающих все уровни Единой энергетической системы России;
6. создание автоматизированных систем управления спросом на электроэнергию;

Развитие будущих ЭЭС на технологической базе интеллектуальной энергосистемы позволит во многом нивелировать перечисленные выше потенциально негативные тенденции в изменении свойств ЭЭС.

ЛИТЕРАТУРА:

1. Воропай Н.И., Осак А.Б. Электроэнергетические системы будущего // Энергетическая политика.- 2014.- N 63.- С. 88.
2. Global and Russian energy outlook to 2040. ERI RAS, ACRF, 2014. -175 p.
3. Энергетическая стратегия России на период до 2030 года. Министерство энергетики Российской Федерации. Утверждена распоряжением Правительства Российской Федерации от 13 ноября 2009 г. № 1715-р.

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OBTAINING NANODISPERSED POWDER OF $ZNO+ BI_2O_3$ BY PLASMA DYNAMIC SYNTHESIS

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Zinc Oxide is an advanced material. Its application fields are very wide: diode manufacture for solar cells, LED manufacturing and other. Also ZnO powder is a part of powder lasers and constitutes interest for making materials and spintronic devices. In addition, Zinc Oxide is all-purpose in medicine and cosmetology. However, the most interesting field for researching is Zn-O based varistor ceramics. The main components of such ceramics are ZnO powder with Bismuth Oxide Bi_2O_3 additive.

There are many methods for obtaining nanodispersed powder of $ZnO+ Bi_2O_3$, which are written in [1-3]. It this work, ther powder of $ZnO+ Bi_2O_3$ was obtained by direct plasma dynamic synthesis, using a pulsed high-current coaxial magnetoplasma accelerator of erosion type (CMPA) [4].

In contradiction to difficult chemical methods [1-3], the plasma dynamic synthesis, which is offered at this article, provides obtaining nano-dispersed powder of $ZnO+Bi_2O_3$ in one short-time cycle of work (until 10^{-3} sec) [5]. For one cycle, it can be obtained up to 20 g of powder.

A sketch-map of the experimental setup is shown in fig. 1. The main part is a pulsed (until 10^{-3} sec) high-current (around 10^5 A) coaxial magnetoplasma accelerator of erosion type [4]. The central electrode 1 is made of latten. Accelerating channel (electrode-barrel) 2 is made of titanium Ti and contains inside closely packed Zinc disks. At initial condition parts 1 and 2 are electrically connected by Zinc tablet, placed in insulator-tip. In upper part of this tip the milled powdered Bismuth oxide Bi_2O_3 is put. Tip is placed inside a cylindrical channel and forms by itself the plasma formation zone 4. Cylindrical AC has the following geometry: diameter d_{AC} = 11 mm and length ℓ_{AC} = 150 mm. CMPA is entered into the working chamber, having a diameter of 300 mm, length of 700 mm, and space volume of 0,05 m^3, which is filled with oxygen to atmospheric at room temperature.

The CMPA is electrically supplied from a capacitive energy storage, having a capacitance of C = 4,8 mF and the value of a charge voltage of U_{chg} = 3,4 kV. It allows accumulating energy up to 27,7 kJ. Figure 2 shows oscillograms of current $I(t)$, voltage on accelerator electrodes $U(t)$, curves of discharge power $P(t)$ and released energy $W(t)$. The power supply begins, after closing the power keys (K) at the moment $t=0$, which is corresponded to the beginning of flowing the discharged current $I(t)$. During the time less ~20 μs, due to the electrical conductivity of Zinc tablet, the discharge is initiated with the further formation of plasma structure and arc stage is developed up to the moment, when the current is equal to I_m = 150 кA. The high-current arc discharge provides electroerosive accumulation of Zinc from AC surface and an acceleration of electoerosive plasma to supersonic speeds under the influence of electrodynamic forces in coaxial system.

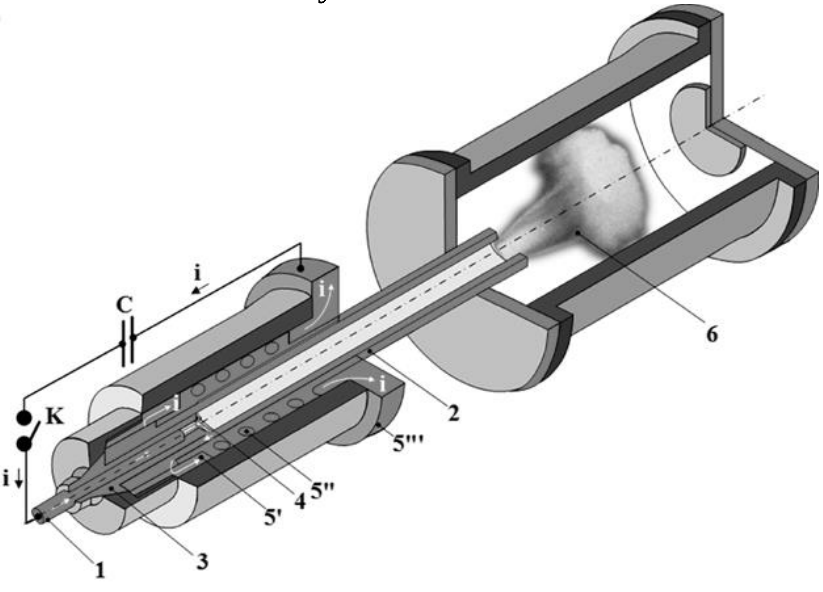

Fig. 1. System of plasma dynamic synthesis based on high-current coaxial magnetoplasma accelerator (CMPA) of erosion type. 1 – tip of central electrode; 2 – accelera-

tor channel (AC); 3 – fiberglass insulator; 4 – plasma formation zone; 5’- contact cylinder; 5” - powerfull solenoid; 5”’ – contact flange; 6 – plasma stream.

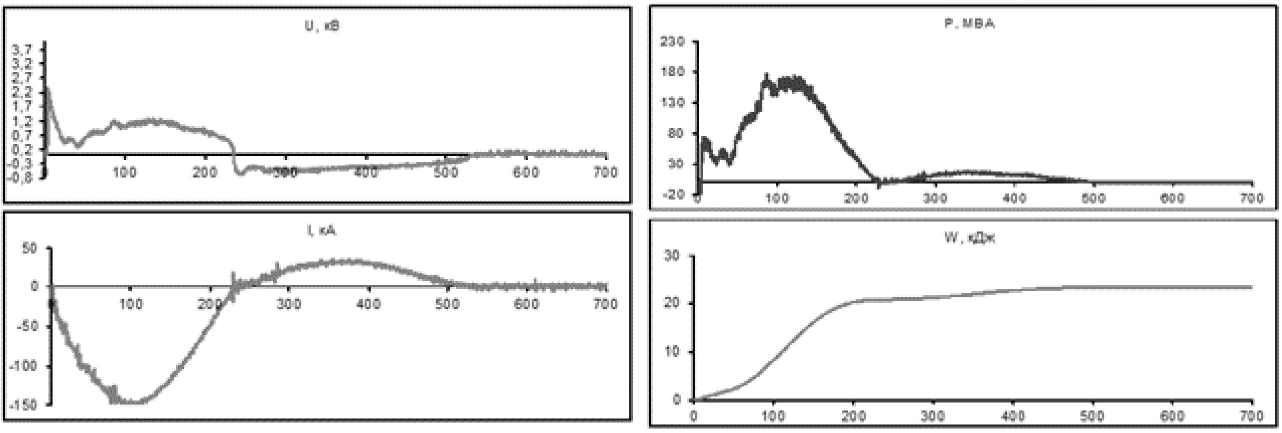

Fig .2. Oscillograms of current *I(t)*, voltage on accelerator electrodes of *U(t)*, curves of discharge power *P(t)* and released energy *W(t)*.

As a result of experiment, the nanodispersed powder of ZnO+Bi2O3 was obtained. It had a yellow color and a its mass was equal to m_{powder} = 9,265 g. The obtained product was investigated by X-Ray diffractometry method, using a Shimadzu XRD 7000S diffractometer with Cu-kα radiation. According to XRD pattern, it was found that the obtained powder did not have additional impurities and its cleanliness was about 99 percentThe XRD pattern of the product is shown in fig. 3.

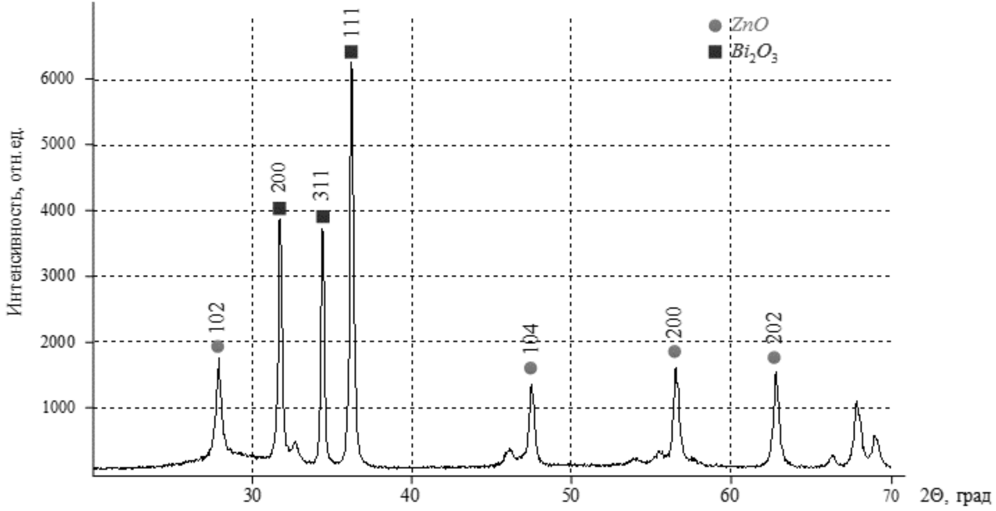

Fig. 3. XRD pattern of obtained powder *ZnO+*Bi_2O_3

The obtained powder was also investigated by a transmission electron microscopy method using a Philips CM12 microscope. A series of TEM-images was made (fig. 4). Analysis of images allows confirming the phase content. According to selected area electron diffraction (SAED), the obtained powder consists of only ZnO and Bi_2O_3. Yellow and green rings are for *ZnO* and Bi_2O_3, respectively. This analysis also gives an opportunity to investigate the form and sizes of particles. As it is seen from dark-field images ZnO particles have typical hexagonal form with sizes not more than 300 nm. These particles are covered by Bi2O3 that is clearly seen from insets 1a and 1b.

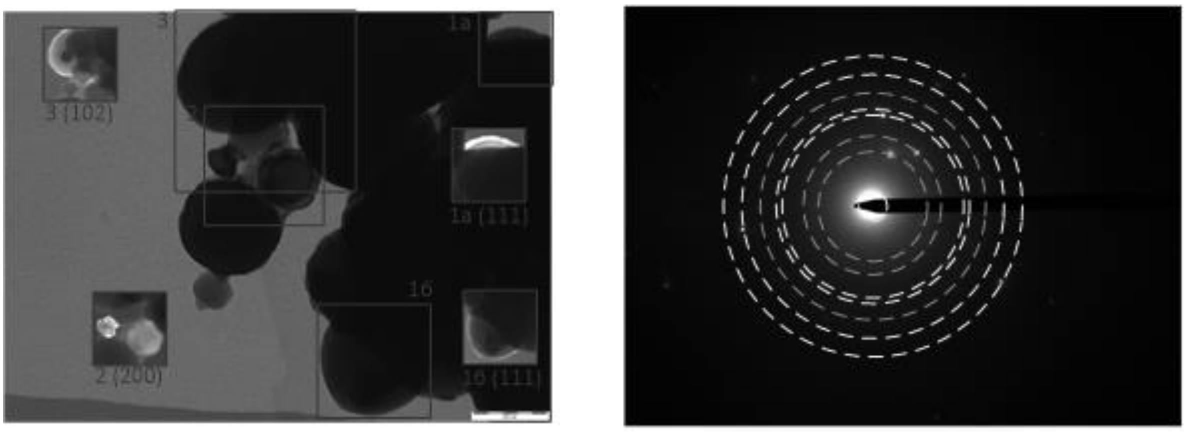

Fig. 4. Bright-field, dark-field and SAED images of the plasma dynamic synthesis product

After investigating the powder structure, it was sintered by SPS-method (spark plasma sintering) using a special setup "SPS 10-4" at following parameters: the pressure on punches was 200 MPa, a speed of sintering – 500 ˚C/min, maximal temperature – 550 ˚C. The sample cooling was natural to the room temperature.

In order to investigate the sample structure, the cross-section was made. After polishing this cross-section, it was investigated by scanning electron microscopy (SEM), using a Hitachi TM3000 microscope (Fig.5).

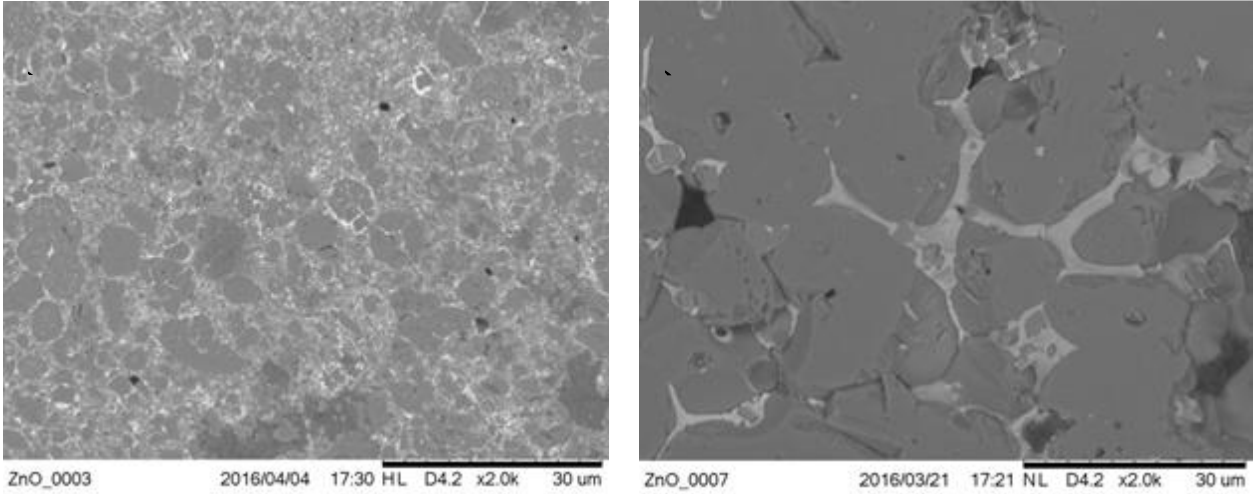

Fig. 5. a) SEM-image of sample from synthesized powder; б) SEM-image of industrial varistor

According to SEM data, it may be concluded that the structure of obtained ceramic presents by itself the close-grain phase of ZnO, which is surrounded by the matrix of Bi2O3. In comparison with industrial varistor sample, grain sizes in our product are much less that can give a positive effect, when electrical properties of the synthesized sample will be studied. However, there can be seen the polished big agglomerate of *ZnO*, as well as pore spaces. These problems can be solved by selecting the optimal mode of sintering and by changing the mass of Bi_2O_3, which is placed in plasma formation zone before experiment.

To sum up, this discussed method of plasma dynamic synthesis powder allows obtaining a mixture of $ZnO + Bi_2O_3$. The synthesized product has nanoscale structure and do not contain other impurities. This product can be used for sintering dense Zn-O-based ceramics, which is widely-used in electrical engineering as varistors. Particle sizes and product purities are the main advantages of the proposed method that can positively impact the final electrical properties of the obtained ceramics.

REFERENCES:

1. Sazonov R., Kholodnaya G., Ponomarev D., Remnev G., Razumeko O.. Plasma-chemical Synthesis of Composite Nanodispersed Oxides // Journal of the Korean Physical Society. – 2011. – Vol. 59. No. 6, pp. 3508-3512.
2. Nolan N. T. Sol-Gel Synthesis and Characterisation of Novel Metal Oxide Nanomaterials for Photocatalytic Applications // Unpublished doctoral dissertation, Dublin Institute of Technology, Dublin, Ireland. – 2010.
3. Aruna S.T., Mukasyan A.S. Combustion synthesis and nanomaterials // Current Opinion in Solid State and Materials Science. – 2008. – Vol. 12. – №. 3. – pp. 44-50.
4. Патент № 2150652 РФ. Коаксиальный ускоритель Сивкова. Сивков А.А. 7F41B 6/00. Опубл. 10.06.2000. Бюл. № 16.
5. Патент № 2183311 РФ. Коаксиальный ускоритель. Сивков А.А. 7F41B 6/00. Опубл. 10.06.2002. Бюл. № 16.

МОДЕЛИРОВАНИЕ АВТОНОМНОЙ СЭС НА ОСНОВЕ ЛИТИЙ-ЖЕЛЕЗО-ФОСФАТНЫХ (LIFEPO4) АККУМУЛЯТОРНЫХ БАТАРЕЙ

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Электрический аккумулятор – химический источник тока многоразового действия (вторичный химический источник тока), основная специфика которого заключается в обратимости внутренних химических процессов, что обеспечивает его многократное циклическое использование (через заряд-разряд) для накопления энергии и автономного электропитания различных электротехнических устройств и оборудования [1]. Химическими источниками тока называются устройства, в которых химическая энергия при разряде, за счет окислительно-восстановительных процессов превращается в электрическую энергию [2]. В настоящее время, возобновляемая энергетика не может обойтись без аккумуляторных батарей. Разные типы аккумуляторов имеют не только различную стоимость, но и отличаются по основным параметрам: количеству циклов перезарядки, максимальному сроку хранения, отдаваемой емкости, внутреннему сопротивлению, размерам, объему электролита, температурному диапазону работы, возможностям ускоренной зарядки. На сегодняшний день, литий-железо-фосфатные (lifepo4) аккумуляторные батареи являются наиболее совершенны эти аккумуляторы – малообслуживаемые, следовательно эксплуатационные затраты, связанные с их использованием, будут значительно ниже. Цикл заряда – разряда, в сравнении с другими типами аккумуляторов, может превышать несколько раз. В связи с этим, возникает необходимость проведения исследова-