# Formation of porous carbon nanosystems for application as electrodes of Li-ion batteries

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***Abstract*** Carbon nanomaterials, such as: 0D fullerene, 1D carbon nanotube, 2D graphene, 3D graphite, and nanodiamond, are increasingly used in a number of areas, ranging from probing to use as catalysts or materials in the energy industry. Along with this, the increasing demand for modern energy sources with high performance characteristics stimulates the development of technological approaches needed to create new storage materials and structures. In particular, carbon nanosystems are attracting increasing attention, as promising electrodes material for the lithium-ion batteries.

## *Methods*

The porous carbon nanosystem formation technology that is developed by us consist of magnetron sputtering and hollow cathode that allows us to produce carbon nanomaterials of various structures. During carbon deposition process, the condensates formation mechanism can be influenced by varying the diameter of the hollow cathode effecting in such a way the configuration of the internal electric field and the degree of plasma concentration.

By the above procedure, two-layer composites were also obtained. At the first stage, precursors were formed in the form of porous Ni or Zn nanosystems, and then carbon condensate was deposited by sputtering graphite.

Structural and morphological characteristics were studied using scanning electron microscopy (SEM) on an Inspect S50-B device using EDX analysis, and the phase state of condensates was studied using a DRON-4 device.

**Fig. 1 Sputtering system**

1 – the water-cooled anode;
2 – the section of permanent magnets;
3 – the magnet conductor;
4 – the graphite hollow cathode;
5 – the shield;
6 – the condensate;
7 – the substrate.

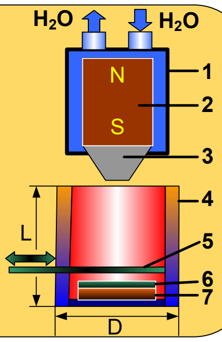
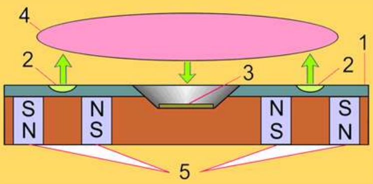



**Fig. 2 Schematic representation of the intersection of the magnetron atomizer with the substrate**

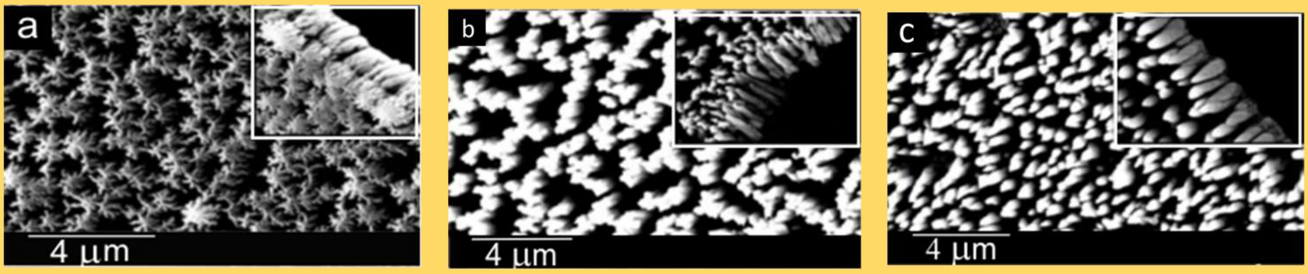



1 – target of the sprayed substance;
2 – erosion zone;
3 – substrate;
4 – zone of complete thermalization of sputtered atoms;
5 – magnetic system.

## *Results*

The usage of acetone vapors as the working gas, together with variations of the hollow cathode geometrical characteristics (Fig.1), has allowed us to obtain the porous graphite condensates (Fig. 3) in different morphological forms. In this case, the spatially distributed selectivity of the nucleation and growth of graphite columnar structures is determined by the fluctuations of the electric field strength over the growth surface.

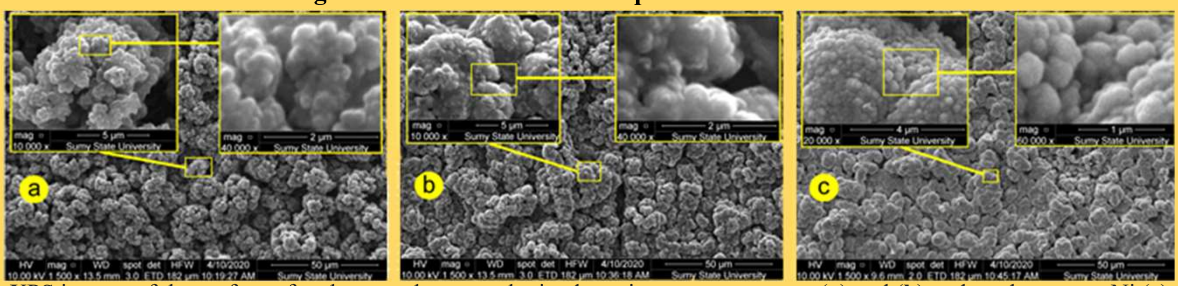
**Fig. 3 Carbon nanostructures with different morphologies**




The columnar graphite-like structure with openwork top layer (a) and structure of graphite layers at D = 0,6L (b) та D= 0,54L (c)

All carbon condensates were formed on the basic porous structures of Zn and Ni at the same technological parameters (PAr = 7 Pa and Pw = 80 W). From those presented in Fig. 4a and 4b RES images can be concluded that there is almost no effect on the structure formation of carbon condensates of the structure of zinc precursors.

**Fig. 4 Carbon condensates on porous substrates**




XPS images of the surface of carbon condensates obtained on zinc porous systems (**a**) and (**b**) and on the porous Ni (**c**).

## *Conclusions*

1. It has been shown that using hollow cathodes with different geometric characteristics it is possible to realize different degrees of field selectivity and as a result to form porous graphite condensates with different morphologies
2. The use of the described technology makes it possible to form carbon systems on porous substrates with various structural and morphological characteristics. It is shown that the different morphology of porous Zn precursors does not affect the further structure formation of cellular carbon nanosystems in the form of turbostrate graphite.

## *References*

1. V.I. Perekrestov, A.I. Olemskoi, Y.O. Kosminska, A.A. Mokrenko, Self-organization of quasi-equilibrium steady-state condensation in accumulative ion-plasma devices, Phys. Lett. A. 373 (2009) 3386–3391.

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