Project title: **A novel carbon nanopearls based electrode for supercapacitor applications**

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To create sustainable energy systems one needs to develop affordable, environment-friendly and low/large scale energy storage devices with high energy density and high power density. Among electrical energy storage systems, supercapacitors possess effective advantages to become a viable alternative to batteries. They provide higher power density than batteries, fast charge–discharge characteristics, and long lifetimes. The main shortcoming of supercapacitors is their low energy density meaning that supercapacitors provide several times less energy density than batteries [1-4].

Supercapacitors are divided in electric double-layer capacitors (EDLCs) of nanostructured carbon materials (activated carbon, carbon nanotubes, graphene, carbon nano onions, etc.) and pseudocapacitors of redox-active materials (transition metal oxides such as RuO_2, MnO_2, NiO, Fe_2O_3, etc. and conducting polymers such as polypyrrole, polyaniline, poly(3,4-ethylenedioxythiophene, etc.), [1-4]. Due to their specific properties such as high electric conductance and thermal resistance, exceptional strength and chemical stability, low mass density and resistivity and large surface area, carbon nanotubes (CNTs) are the most common studied carbon material for EDLCs electrodes. However, there are few drawbacks in using CNTs as electrode material. First, the fabrication cost of CNTs is still high and second the fabrication method is very complex meaning that in order to separate the CNTs from the catalyst and the growth substrate a purification method must be applied [1-4]. Moreover, due to their geometry it is difficult to obtain uniform, homogenous, and reproducible dispersion of the nanotubes in polymers mainly at high concentration. Thus, the reduced number of emitting nanotubes is a serious drawback. In order to obtain high-performance (specific capacitance, energy density, and rate capability) supercapacitors a reasonable balance between the specific surface area and the pore size distribution of the electrode material of EDLCs is crucial to achieve. Therefore, there is a need to design and develop more suitable carbon materials electrodes that provide both high-energy and power density [1-4].

Carbon nanopearls (CNPs) is a novel cost-effective carbon material obtained with a mass production process which unlike CNTs exhibit a stable and uniform field emission independent of their orientation. Carbon nanopearls are monodisperse solid nanospheres (Φ~100nm) connected into linear strings that form a volumetric 3D foam-like structure. Thus, carbon nanopearls have the potential to replace successfully the CNTs as material for supercapacitor electrodes [5, 6].

The main goal of this project is to develop a novel carbon nanopearls based electrode for supercapacitors applications. In this project, we will address the following issues:

Specific aim 1: Preparation of electrode material

The first goal of this project is to develop a reliable recipe for uniform, homogeneous and reproducible carbon nanopearls based thin film. We will use two raw materials carbon nanopearls that basically, should provide higher specific surface area than CNTs and microcellulose that provide both flexibility and porosity to the system. Despite the fact that the carbon nanopearls CNPs have been around for a while (10 years, [5, 6]) there are no publications reporting on electrodes containing carbon nanopearls such we can claim this is the first study performed in this direction. Unlike carbon nanopearls cellulose have been more intensively studied as spacer or binders in EDLCs applications. As the major issue in fabricating carbon materials - integrated cellulose composites is the insolubility of cellulose in most common solvents [7] the starting point is to establish the most appropriate solvents and their optimum concentration. Thus, a suspension of microcellulose (> 4%) into the deionized water and ethanol will be first obtained. Secondly, a small concentration (<5%) of CNPs will be added into this suspension to produce a smooth paste. The thin films will be obtained by immersing an ITO glass into the CNPs-based paste using a dip-coating apparatus. The fine-tuning of the dip-coating parameters (pull-up speed and immersion time) can determine the quality of the thin film. The quality of the thin film depends also on the CNPs-based paste viscosity, drying process, quality of the substrate surface, etc [8]. To improve the quality (uniformity, homogeneity and reproducibility) of the CNP-based films the ITO glass slides will be modified with polianyline (PANI) – silane-coupling agent [9].

Specific aim 2: Preparation and characterization of the CNPs-based electrodes

Once the homogenous thin films obtained the electrodes will be prepared and the physical, structural and electrochemical characterization of the CNPs-based electrodes will be performed. In the second part of the project we will utilize methods such as scanning electron microscopy, Raman spectroscopy measurement and x-ray spectroscopy measurement in order to prove the preservation of the physical integrity of the nanopearls into dispersion, the presence of nanocrystalline and disordred graphite and the composition of the product. The N_2 adsorption/desorption based on Brauner-Emmett-Teller (BET) method will be used to determine the specific surface area, and the pore size distribution. This part involves also the utilization of CHI instrumets potentiostat to perform cyclic voltametry, galvanostatic charge/discharge measurements, cycling life test stability and electrical conductivity measurements.

Development of production processes for CNPs-based electrodes and devices is an integral part of the project. The long-term goal of this project is to demonstrate the performance of materials and components on the functional model of supercapacitors.

References

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