Proceedings of the 5th International Conference on Nanotechnology: Fundamentals and Applications
Prague, Czech Republic, August 11-13, 2014
Paper No. 191

Functionalized Carbon Nanotubes for Catalysis of Oxygen Reduction

Kamila Żelechowska
Gdansk University of Technology, Faculty of Applied Physics and Mathematics
Narutowicza St. 11/12, Gdansk, Poland
kzelechowska@mif.pg.gda.pl

Krzysztof Stolarczyk, Dominika Majdecka, Renata Bilewicz
University of Warsaw, Faculty of Chemistry,
Pasteura St. 1, Warsaw, Poland

Jan F. Biernat
Gdansk University of Technology, Faculty of Chemistry
Narutowicza St. 11/12, Gdansk, Poland

Extended Abstract

Biofuel cells employ biocatalysts (such as microbes, organelles or enzymes) to convert chemical energy into electrical energy. Important features of biofuel cells are the selectivity of processes occurring at the enzymatically modified electrodes and the ability to operate at room temperature and at pH close to neutral. Moreover, open construction of the device, allows the utilization of dioxygen and glucose (fuel) from the surrounding environment, such as blood tissue and makes biofuel cells the potential source of power for implantable devices such as pacemakers, sensors or micropumps (Falk et al. 2013).
Electrochemical reduction of oxygen to water with high current efficiency and the smallest overpotential is one of the main goals in modern fuel cells technology. The enzymes used to construct biocathode are billirubin oxidase or laccases. Laccases are different multicopper oxidases catalyzing four electron dioxygen reduction directly to water. In recent years, carbon nanotubes (CNTs) were shown to provide an attractive, versatile and simple route for the development of the bioelectrical devices, because of their significant mechanical strength, excellent electrical conductivity, large surface area and good chemical stability. As was shown earlier, chemical functionalization of carbon nanotubes may increase the stability and efficiency of the biofuel cell (Stolarczyk et al. 2013, Żelechowska K. et al. 2013). Due to the presence of hydrophobic pocket laccase exhibits affinity to aromatic groups attached to the carbon nanotubes. It is directed onto the carbon nanotubes covered electrode in favorable orientation to achieve an efficient biocathode. Considering the above, it was expected that conducting electrode nanostructured with the properly chemically modified nanotubes would be beneficial for electron transfer properties of bioelectrodes and the whole biofuel cell. The series of various aryl residues linked chemically to single walled carbon nanotubes by different spacers were prepared. The chemical pathway was optimized in order to obtain more uniform and highly functionalized nanotubes. The functionalized CNTs under study cover phenyl, naphthyl, anthryl, biphenyl, terphenyl and other groups attached chemically to CNTs by direct carbon to carbon bond. The same residues were attached also by amide bonds. The synthesized materials were characterized by Raman, FTIR and UV-Vis spectroscopy and thermogravimetric analysis. These insoluble materials of high electrical conductivity were used to connect electrically the redox center of the enzyme molecule and conducting electrode. The aryl residues were selected considering efficiency of the catalytic reduction of dioxygen in the presence of laccase, the easiness of CNTs derivatization and effectiveness of final purification of the modified carbonaceous materials. To establish the effect of different groups attached to CNTs on the electrochemical behavior of biobattery catalytic properties of the functionalized CNTs were studied measuring the effectiveness of oxygen reduction using as zinc/hopeite

counter electrode showing stable potential. In all experiments laccase (enzyme catalyzing reduction of oxygen to water) adsorbed on functionalized CNTs was used. The pH was maintained around 6 using McIlvaine buffer. It was found out, that naphthyl is the most efficient residue in case of side functionalized and end *N*-arylamides as well.

References

Falk M., Villarrubia C., Babanova S., Atanassov P., Shleev S. (2013). Biofuel Cells for Biomedical Applications: Colonizing the Animal Kingdom. Chem. Phys. Chem. 14, 2045-2058

Stolarczyk K., Kizling M., Majdecka D., Żelechowska K., Biernat J.F, Rogalski J, Bilewicz R. (2014). Biobatteries and Biofuel Cells with Biphenylated Carbon Nanotubes, J. Power Sources 249, 263–269

Żelechowska K., Stolarczyk K., Łyp D., Rogalski J., Roberts K.P., Bilewicz R., Biernat J.F. (2013). Aryl and N-arylamide carbon nanotubes for electrical coupling of laccase to electrodes in biofuel cells and biobatteries. Biocyb. Biomed. Eng., 33, 235-245