SILESIAN UNIVERSITY OF TECHNOLOGY

FACULTY OF CHEMISTRY

DEPARTMENT OF ORGANIC CHEMISTRY, BIOORGANIC CHEMISTRY AND BIOTECHNOLOGY

GRZEGORZ STANDO, MSc

Doctoral dissertation

Development of high-performance composites based on non-functionalized carbon nanostructures

Supervisor: Dawid Janas, Ph.D. DSc

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Abstract in English

Carbon nanostructures were discovered at the end of the last century, and despite the passage of time, they are still a hot topic. Especially carbon nanotubes and graphene are the objects of both basic research and R&D. A single carbon nanotube or graphene flake has magnificent mechanical, electrical, and thermal properties compared to conventional materials such as copper and steel. However, macroscopic objects from carbon nanomaterials do not retain these unique properties. The connection of carbon nanomaterials with polymers, metals, or ceramics is one of the solutions to keep some of the nanostructure properties presented by individual building blocks by facilitating stress or charge transfer. It is commonly believed that the surface of nanotubes, graphene, and fullerenes is hydrophobic, which unfortunately limits their application in composites. The most popular answer to this problem is destructive chemical functionalization by inserting hydrophilic functional groups. Obtaining a hydrophilic surface of carbon nanomaterial increases its compatibility with other materials, such as polymers or metals. However, this functionalization often deteriorates the primary structure of carbon nanomaterials and changes their properties.

The scientific goal of this dissertation was to test the hypothesis that carbon nanostructures (fullerene C_{60}, carbon nanotubes, graphene) may, under certain conditions, exhibit hydrophilic character and the reason for their hydrophobic surface in the ambient is the adsorption of aromatic hydrocarbons present in the air. In parallel, the aim was to produce high-performance composites based on non-functionalized carbon nanostructures and to investigate their potential applications.

The first part of this work proved that to make the surface of nanocarbon hydrophilic, and it is enough to subject them to annealing that desorbs surface contaminations. Secondly, a general mechanism of the observed phenomenon – changing the surface character of carbon nanostructures from hydrophilic to hydrophobic, was developed using spectroscopic studies and selected theoretical models. Lastly, to prove that non-functionalized carbon nanostructures can be interfaced well with polymers and metals, such composites were made and characterized. Their electrical, mechanical, thermal, and thermoelectric properties were determined, and their potential application areas were indicated.