

# Materials Performance and Characterization

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# Overview

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The paper prepared by Leszek A. Dobrzański and Anna D. Dobrzańska-Danikiewicz entitled “Why Are Carbon-Based Materials Important in Civilization Progress and Especially in the Industry 4.0 Stage of the Industrial Revolution” starts this Special Issue on Carbon Nanomaterials and Nanocomposites. The authors present in this paper a comprehensive literature study to show that since the emergence of the species of *homo sapiens*, the progress of human civilization is strongly dependent on the development of materials, over time mainly engineering materials and the accompanying increase in productive forces. Without the use of engineering materials and the development of manufacturing processes, it is impossible to manufacture any product and make it available to consumers. Currently, about 80% of work in the field of engineering materials development and material design is carried out following the Materials 2.0 protocol, but only the idea of Materials 4.0 overcomes human limitations in this area by using the cyber-physical systems. In manufacturing processes now there is an effective use of cyber-physical systems, which currently guarantees the production progress at the stage of the Industry 4.0 industrial revolution. The paper designates nine technologies that determine the change in industrial production at this stage, which lists required augmentation and includes manufacturing processes and engineering materials as well as living and bio-engineering machines. The importance of carbon-based nanomaterials is also presented along with several results of their own research of various such materials, with an indication of their application possibilities.

There are twelve contributed papers in the Special Issue on Carbon Nanomaterials and Nanocomposites indicating the applicability of different carbon materials. All submitted papers relate generally to composite materials reinforced by carbon-based materials. They can be divided into materials with a metal and polymer matrixes, in one case provided for catalytic purposes. Several papers relate to the concrete matrix, and some cases use so-called green raw materials originating from plant crops or waste from the production of cellulose pulp or paper. All papers will be generally discussed in the order in which they are published in the special issue.

Two of these papers are literature reviews. The Review Paper prepared by Thomas and Umasankar, “Review of Recent Progress in the Development and Properties of Aluminum Metal Matrix Composites Reinforced with Multiwalled Carbon Nanotube by Powder Metallurgy Route,” indicates that reinforcements such as graphene and carbon nanotubes (CNT) are the center of attention due to their contribution to mechanical, thermal, and electrical properties. The report takes into account the contribution of many scientists and tries to fill the gap in this area and determine the scope of future research. Among the available types of reinforcement, CNTs are distinguished by their beneficial effects on thermal conductivity and thermal expansion, as well as the strength properties of the composite materials produced.

Another review paper was developed by Addepally, Gandham, Palety, and Kanakaraju and is titled “Lignin-Based Carbon Nanomaterials—The Future Scope.” Coal can take various allotropic forms like fullerenes and related materials, carbon nanotubes, carbon nanofibers, and graphene, especially in carbon nanocomposites, which increases the chances of useful exploitation in various applications, showing better mechanical, thermal, electronic, and electrical properties in combination with chemical resistance. The different precursor materials used to produce carbon nanostructures include, for example, hydrocarbons, coal industrial waste, carbon blacks, and carbon nanotubes. The high cost of precursors is mainly because they are derivatives from crude oil. One alternative is discussed, which is bio-derived precursor materials

such as lignin, a polymeric aromatic compound with various side-chain substituents found in the walls of plant cells. Only the paper and pulp industry produces about  $50 \times 10^9$  kg of lignin per year, and also, when mixing biofuels, every ton of biomass produces 15–25% of lignin as a by-product. Besides, it can be also considered an animal fertilizer derived from herbivores, containing significant amounts of microbial, processed lignin. Therefore, material constraints can be avoided if lignin-based sources are used to generate nanomaterials. Lignin-based nanomaterials find different applications in many biocompatible applications.

All other papers are original research. In the first of these papers written by Tikale and Narayan Prabhu, “The Effect of Multi-Walled Carbon Nanotubes Reinforcement and Multiple Reflow Cycles on Shear Strength of SAC305 Lead-Free Solder Alloy,” the melting of these composite materials by differential scanning calorimetry, structure, and mechanical properties was investigated. The results of the research showed that with the participation of reinforcement in the range of 0.01–0.05% by weight MWCNTs improve both shear strength and wettability compared to SAC305 solder.

Authors Ramos-Galicia, Perez-Ramirez, Fuentes-Ramirez, Martinez-Hernandez, and Velasco-Santos prepared the paper “Carbon Nanotubes and Reduced Graphene Oxide’s Dimensionality Effect on Thermoset Matrix Performance.” They investigated mechanical, electrical, thermo-mechanical, and thermal properties of composite materials with epoxy resin as a thermosetting matrix reinforced with carbon nanotubes (1-D) and reduced graphene oxide (2-D), added in the concentration of 0.1, 0.3, 0.5, 0.7, 0.9, and 1.0 weight %. Carbon nanotubes are more suitable than reduced graphene oxide to improve certain properties. Measurements of electrical conductivity indicate that carbon nanotubes are better able to create conductive paths and give up to three orders of magnitude greater electrical conductivity than reduced graphene oxide, as well as contribute to improving thermo-mechanical stability.

In the paper “Effect of Graphene on Mechanical and Flowability Properties of Low-Density Polyethylene Composites,” the authors Sabet and Soleimani found out that the homogeneous graphene (Gr) spread in low-density polyethylene (LDPE) considerably increases the modulus of elasticity and elongation, but the tensile strength of LDPE/Gr composites does not change significantly. High specific surface area and good properties heat-treated graphene are decisive for these influences. The introduction of graphene leads to the limitation of the polymer chain, thereby reducing the maximum stress and increasing the melt flow index of the composite during processing.

The paper prepared by Sinha and Tyagi, “Vehicular Light Weighting by Finite Element Simulation of E Glass-Based Composite Automotive Seat,” refers to reducing the weight of front car seats, and thus the car’s fuel consumption, by replacing those previously produced using steel by a composite material with a polymer matrix reinforced with carbon, glass, or Kevlar fibers, respectively. The weight of the front seat is reduced by 79.76%, 57.27%, and 70.31%, respectively, and the allowable stresses calculated using the Finite Elements Method are respectively increased around 2.96, 1.95, and 2.40 times compared to the alloy steel.

The group of authors Meduri, Rahimian, Humbert, O’Brien Johnson, Tratnyek, and Jiao present the paper “A Comparative Study of Carbon Supports for Pd/Au Nanoparticle-Based Catalysts,” which concerns composite materials used in chemical catalysis. Carbon materials as carriers help to control the growth, aggregation and homogeneity of the catalytic nanoparticles (NP) hybridizing with them. Carbon composites from Palladium-gold (Pd/Au) were tested. Trichloroethylene (TCE) was used as a model contaminant to investigate the effect of four types of carbon media, i.e. granular activated carbon (GAC), carbon black, graphite, and graphite nanoplates for the formation of Pd/Au catalytic nanoparticles and their correlations with catalytic hydrodehalogenation (HDH) reactions organic compounds. Pd/Au-GAC composites generate the fastest degradation of TCE, providing a more increased rate in HDH than other types of carbon media, and because GAC is widely commercially available at relatively low cost, GAC is the preferred carbon carrier in mass production of Pd/Au NP catalysts.

Interesting is the paper on “Mechanical Properties of Multiwalled Carbon Nanotube-Reinforced Cement Composites” written by Sharma, Dubey, and Setia, which also concerns a particular group of composite materials with reinforcement of carbon-based materials. The article aims to find ways to improve the tensile and bending strength of cement after a shorter binding time to 14–21 days by adding 0.2% and 0.3% weight multiwalled carbon nanotubes (MWCNTs).

Another paper, presented by Pachideh, Gholhaki, Moshtagh, and Kafi Felaverjani under the title “An Investigation on the Effect of High Temperatures on the Mechanical Properties and Microstructure of Concrete Containing Multiwalled Carbon Nanotubes,” also applies to composite materials with the matrix of concrete reinforced by MWCNTs. This article presents the effect of multilayer carbon nanotubes in a proportion of 0.5, 1, and 1.5% by weight, respectively, on the properties of concrete investigated after heating to 25, 100, 250, 500, and 700 °C, respectively, and after the next cooling to room temperature. The increase in the proportion of MWCNTs in concrete increases the compressive and tensile strength of the composites by 138 and 88%, respectively.

Agarwal, Singh, Sharma, Sagdeo, and Csóka published the paper “In Situ Green Synthesis and Functionalization of Reduced Graphene Oxide on Cellulose Fibers by *Cannabis sativa* L. Extract.” Graphene oxide was synthesized using the modified Hummer method by a reduction in situ on a cellulose matrix using an aqueous extract of *Cannabis sativa* L. to functionalize the fiber with reduced graphene oxide (RGO). Different weight fractions of RGO, from 0.1 to 10%, were used to make RGO/cellulose composites by papermaking technique. RGO sheets uniformly covered the surface of cellulose fibers and dispersed well in the fibrous matrix. The surface resistivity and loading capacity of composite surfaces decrease with the increasing the concentration of RGOs. These composites exhibit high application potential as sustainable materials for portable energy storage devices, such as capacitors.

The final paper was included in the special issue despite the fact that it is outside the scope, but it was found to be interesting and we chose to include it in the special issue. The authors Gupta and Tyagi presented in the paper “An Experimental Evaluation of Mechanical Properties and Microstructure Change on Thin-Film-Coated AISI-1020 Steel” an experimental study of the effect of different types of coating processes on surface roughness, surface hardness and strength of low carbon steel AISI1020, coated with the technique of galvanizing and spraying. Chrome, zinc, nickel and tin were used as the coating material.

We hope that reading this special issue will bring both the cognitive benefits of PT Readers and the pleasure in learning about the issues raised there.

We wish you a pleasant reading.

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