12th Carbon Symposium

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Gliwice, Silesia, Poland

Welcome

The 12th Carbon Symposium is organized by the Polish Carbon Society. Previous editions of this event were known as the Toruń Carbon Symposia. The 2026 edition marks an important milestone, as it is the first time the conference will be held outside Toruń — this year in Gliwice, Poland. CS2026 is conceived as an interdisciplinary forum for researchers working in the fields of carbon science, carbon materials, and related technologies. The Symposium provides an excellent opportunity to present recent scientific results, exchange ideas, and discuss emerging research directions. Our aim is to inspire new generations of scientists from academia, research institutions, and industry, while fostering new collaborations and interdisciplinary approaches.

We hope that the Symposium will stimulate broad and constructive discussions on the current challenges, opportunities, and responsible development of carbon science and technology. The scope of the 12th Carbon Symposium covers carbon materials and technologies, including graphite, graphene, carbon nanotubes, fullerenes, carbon blacks, soot, nanodiamonds, carbon quantum dots, heterocarbons, hybrid materials, and sp^3-rich carbons; carbonization, graphitization, synthesis, processing, characterization, modelling, 3D printing, in situ and coupled techniques, and machine learning; as well as applications in electrochemistry, catalysis, electronics, medicine, environmental protection, composites, nanocomposites, and polymer materials.

We sincerely hope that you will enjoy the Symposium, attend the inspiring presentations, engage in fruitful discussions with fellow scientists, and find time to explore the Silesia region.

Mirosława Pawlyta
Chair

Pawlyta

Aneta Frączek-Szczypta
Vice Chair

Aneta Frączek - Szczypta

Sławoimir Boncel
Vice Chair

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ORAL PRESENTATIONS

A multiscale investigation of the thermomechanical properties of carbon/carbon composites

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An important feature of Cf/C composites is their very low heat expansion coefficient. Combined to their light weight and outstanding high-temperature capabilities, this property turns them into key materials for solid rocket motor nozzles and divergents, for extreme thermal protection systems and for high-energy braking systems. From a design point of view, it is highly desirable to control the relationship between the material's structure and its behavior. This talk will present a coupled experimental/modeling approach featuring (i) determination of the heat expansion coefficient of the components, and (ii) in-situ high-temperature tests performed in a CT scanner associated to Digital Volume Correlation and compared to image-based modeling. The developed tools and the main results obtained with them will be presented and discussed in this talk.

Design and Processing Effects on Degradation Mechanisms of Carbon–Carbon Rocket Nozzles under Operational Conditions

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Keywords: carbon-carbon composite, rocket nozzle

The durability of rocket nozzles made from carbon–carbon (C/C) composites is governed by complex interactions between material structure and high-temperature reactive environments. This work focuses on identifying how selected fabrication variables—fiber orientation, degree of densification, and post-processing temperature—control the resistance of C/C nozzles to oxidation and material loss during operation.

C/C composites were manufactured using carbon fiber reinforcements and a phenolic-derived carbon matrix. After initial carbonization at 1000 °C, the materials underwent repeated densification cycles to reduce porosity, followed in some cases by high-temperature treatment at 2000 °C. The resulting materials were evaluated using a combination of microstructural, structural, thermal, and mechanical characterization techniques, and subsequently tested under realistic conditions in hybrid rocket motor firing experiments.

The study reveals that nozzle performance is highly sensitive to fiber arrangement, which dictates both load-bearing capability and erosion behavior. Among the tested configurations, the 90/80° winding pattern demonstrated distinctly improved resistance to degradation compared to lower-angle architectures. A substantial decrease in throat erosion was achieved through densification, whereas further heat treatment produced only negligible gains despite clear evidence of increased carbon ordering and improved oxidation resistance in controlled environments. Moreover, attempts were made to modify the initial composite with a pyrolytic carbon phase using a pulsed chemical vapor infiltration (CVI) method.

Analysis of the operating conditions indicates that chemical erosion, driven primarily by reactions with H_2O and CO_2, is the dominant degradation pathway. In contrast, mechanical wear from particle impact was found to have minimal influence. These findings suggest that reducing porosity and optimizing fiber layout are far more effective strategies for improving nozzle lifespan than increasing the degree of graphitization alone.

Acknowledgements

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The mechanism of Ca-supported graphitization of banana biomass

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Keywords: biomass, graphite, catalytic graphitization, Ca-catalyst, structure

Biomass is a highly promising precursor for future graphite production due to its abundance, low cost, renewability, and ease of collection. The graphitization of biomass can be effectively enhanced through the use of catalytic additives, which facilitate the transformation of disordered carbon structures into turbostratic carbon and graphite. Compared to conventional graphite production from petroleum-derived cokes, where catalytic graphitization has also been widely employed for decades, biomass offers an additional advantage. It often contains intrinsic inorganic elements (such as alkali and alkaline earth metals) that can act as natural graphitization catalysts. Therefore, utilizing biomass not only reduces reliance on fossil-based precursors but also provides a cost-effective, and sustainable route to producing high-performance graphite materials [1,2].

In this work, progress in catalytic graphitization as an advanced synthesis route for converting biomass-derived precursors into structurally controlled graphitic materials will be presented. Our recent investigations demonstrated that graphitic and turbostratic structures can be obtained from traditionally non-graphitizing precursors, such as banana peel, through Ca-assisted catalytic graphitization [3]. Comprehensive structural and morphological characterization was performed using X-ray diffraction (XRD), Raman spectroscopy, scanning and transmission electron microscopy (SEM, TEM) combined with energy dispersive spectroscopy (EDS), and small-angle X-ray scattering (SAXS). XRD and Raman analyses confirm the development of enhanced graphitic ordering, providing detailed insight into the progressive structural transformation. TEM combined with EDS studies revealed the evolution of morphology and microstructure, as well as the influence of inherent mineral species present in the biomass precursor on the formation of graphite-like crystals (Fig. 1). SAXS analysis demonstrated the evolution of the pore structure during the catalytic graphitization. Based on results from multiple characterization techniques, a mechanism for Ca-assisted graphitization of banana biomass was proposed. Moreover, heat-treatment of the biomass-derived carbons at 3000°C allowed us to verify the potential of the Ca-catalyzed banana biomass for the production of graphite.

Acknowledgements

SAXS measurements were performed on APS beam time award (DOI: https://doi.org/10.46936/APS-190655/60014527) from the Advanced Photon Source, a U.S. Department of Energy (DOE) Office of Science user facility operated for the DOE Office of Science by Argonne National Laboratory under Contract No. DE-AC02-06CH11357. The research activities were co-financed by the funds granted under the jUŚT transition and the Research Excellence Initiative.

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Structural Evolution Of Carbon Catalyst For Autocatalytic Methane Decomposition under Induction Heating

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Keywords: Catalytic Methane Decomposition, Carbon Catalyst, Induction Heating, Autocatalytic Process, Carbon Materials

This work investigates the evolution of the structure of a carbon felt (CF) catalyst during catalytic methane decomposition (CMD) when heated by contactless induction heating (IH). The pristine CF consists of a network of carbon microfilaments with a high voidage volume of above 90% and a relatively low surface area of less than 4 $m^2 \cdot g^{-1}$, making it a promising metal-free catalytic substrate. Compared with conventional heating (CH) reported in the literature [1], IH gives higher methane conversion, even at much lower temperatures of 600 to 700 °C, as shown in Figure 1. This performance enhancement is associated with a distinct carbon growth pathway revealed by SEM, XRD, and Raman spectroscopy. Under IH, carbon forms conformal, graphene-like layers around individual filaments and creates conductive bridges across the felt network. These deposits contain many structural defects, as indicated by a strong Raman D-band signal, which acts as active sites [2] enabling sustained autocatalytic activity. In contrast, CH produces isolated, amorphous carbon nodules with limited structural integration. As a result, under IH, CF transformed into a reinforced C/C composite with significantly enhanced electrical conductivity (increasing from 400 to 1200 $S \cdot m^{-1}$) and improved mechanical integrity. The results highlight the decisive influence of the electromagnetic field in governing both the orientation and crystallinity of the deposited carbon. This positions IH as a powerful platform for the development of scalable, metal-free catalysts enabling CO_2-free hydrogen production.

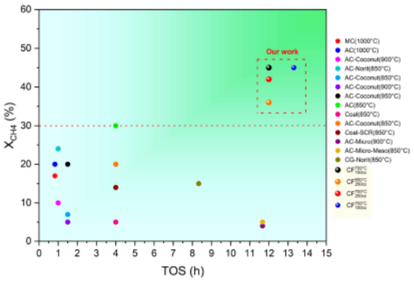

Figure 1. Comparison of CH4 conversion under CH (literature) and IH (our work)

Acknowledgements
This work was supported by French Government Scholarship, Ministry of Higher Education of Poland (0911/SBAD/2601), National Science Center (Preludium 2024/53/N/ST5/02202) and ANR-10-LABX-76-01, STORE-EX (France).

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Cytocompatible carbon nanotube nanocomposites for in vitro cell cultures

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Keywords: multiwalled carbon nanotubes, electrical stimulation in vitro, drug delivery

Careful selection of the physicochemical properties of carbon nanotubes (CNTs) and the optimization of their integration into a polymer matrix are essential for developing cytocompatible nanocomposites with desired functional characteristics. These may include electrical conductivity and/or drug eluting properties. In this study, multiwalled carbon nanotubes (MWCNTs) were used to grant elastomers with electrical conductivity (for fabricating elastic electrodes used in in vitro cell cultures) and to modify the collagen scaffolds. In the former application, electrodes allowed direct electrical stimulation, transmitted through the electrically conductive scaffold [1]. Elasticity of the cell well played part in cellular mechanotransduction. For the latter application, carefully tailored, oxidized MWCNTs allowed to bind drugs (dexamethasone and triiodothyronine) and release them in a controllable matter into the cell culture [2]. Electrically conductive nanoadditives were selected so as not to compromise native electrical conductivity of hydrogels.

The study proves that CNTs are effective tools for fabricating cytocompatible solutions for dynamic cell cultures in vitro.

Acknowledgements
The authors acknowledge financial support from the project: LIDER/7/0020/L-11/19/NCBR/2020

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Functionalised CNT-modified pyrocarbon composite electrodes: multifunctional performance under simulated conditions for deep brain stimulation application

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Keywords: Pyrolytic carbon, carbon nanotubes, carbon-carbon composites, electrochemical properties, deep brain stimulation

The design of multifunctional carbon-based electrode materials is a growing area of interest owing to the unique combination of electrochemical activity, chemical stability, and surface properties offered by the presence of carbon nanoforms. This work presents a comparative study of hybrid rod-like composites: carbon fibre/pyrolytic carbon (CF/PyC) with a CNT-modified surface (CF/PyC-CNT-OH) - evaluated for their electrochemical, mechanical, and biological performance under simulated conditions.

Electrodes were fabricated by directly heated fibers in chemical vapour deposition method (DHF-CVD) and subsequently surface-modified via airbrush deposition of highly-oxygen - functionalised multi-walled carbon nanotubes (CNT-OH). Characterisation involved cyclic voltammetry (CV), electrochemical impedance spectroscopy (EIS), scanning electron microscopy (SEM), X-ray photoelectron spectroscopy (XPS), and mechanical fatigue testing. Biological evaluation was conducted using primary mesencephalic cell cultures; cytotoxicity was assessed by lactate dehydrogenase (LDH) release, whilst immunostaining for dopaminergic (TH+) and neuronal (NeuN+) markers enabled detailed analysis of cell behaviour in material proximity.

The presence of CNT-OH coatings significantly enhanced the electrochemical characteristics of the composites: higher charge storage and injetion capacity, and improved resistance to degradation were recorded relative to unmodified- and Pt-ones and. Mechanical tests confirmed strong adhesion of the nanostructured surface layer and high tolerance to cyclic loading. Notably, biological assays demonstrated the absence of cytotoxic effects, alongside a pro-survival influence on neuronal cells in proximity to CF/PyC-CNT-OH electrodes. Accelerated ageing and durability tests further confirmed the structural and functional stability of the materials. These results demonstrate that hybrid CF/PyC-CNT-OH composites offer a compelling combination of electrochemical activity, mechanical robustness, and biosafety relevance as advanced carbon-based materials for demanding biomedical applications.

Acknowledgements

This study was financed by the National Science Centre, Poland, grant number: UMO-2020/39/B/ST5/02126. In particular, the functionalization of CNTs, mechanical and biological properties' tests were supported under this grant. The obtaining of CF/PyC composites, hydrogel brain phantom characterization and partly electrochemical tests and participation fee in the conference were financed under project: UMO-2025/57/N/ST11/03480. The research was conducted using equipment purchased within the framework from the subsidy of the Ministry of Education and Science for the AGH University of Kraków, grant no. 16.16.160.557.

Comparison of Pyrolytic Carbon Oxidation Techniques for Their Effect on the Electrochemical and Biological Properties of CF/PyC Composites Designed for Neural Cell Stimulation

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Keywords: carbon-carbon composites, deep brain stimulation, neural tissue stimulation, pyrolytic carbon, surface oxidation

This study investigates various surface oxidation techniques employed to functionalize the surface of carbon-carbon composites based on carbon fibers coated with pyrolytic carbon. The analyzed materials are intended for applications in neural tissue stimulation, particularly in deep brain stimulation (DBS), with potential use in peripheral nerve stimulation as well.

Currently, electrodes used in DBS are usually fabricated from metallic materials, most commonly platinum and its alloys. Although these materials are generally considered biocompatible, their relatively high stiffness and incomplete corrosion resistance may compromise long-term safety and functional efficiency [1]. Deep brain stimulation is an established method of treatment for neurodegenerative disorders such as Parkinson's disease, essential tremor, and dystonia, the prevalence of which has been increasing [2]. This trend underscores the need for the development of alternative electrode materials with improved properties.

The CF/PyC composites investigated in this study were synthesized using a directly heated fibers chemical vapor deposition method (DHF-CVD). Subsequently, surface oxidation was performed using three different methods: chemical acid oxidation, ozonation, and electrochemical oxidation. The modified materials were evaluated in terms of their electrochemical properties, biological response, and structural and chemistry of the surface characteristics. Additionally, their capability for dopamine detection was assessed.

The results enabled identification of the most effective oxidation method for enhancing the properties of carbon-carbon composites, especially synthesized pyrocarbon, intended for neural stimulation applications. The findings provide valuable insights that may contribute to the development of advanced materials for neural interfaces. Furthermore, the study allowed the exclusion of certain surface modification techniques as ineffective and helped define directions for future research aimed at optimizing carbon-based materials for use in the treatment of neurodegenerative diseases.

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Safety issues of Carbon Nanomaterials: a focus on Graphene Oxide and a Safer-by-design strategy to mitigate its potential impact on Health and the Environment

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Carbon nanomaterials, and especially Carbon Nanotubes (CNTs) and Graphene have been among the most studied nanomaterials due to their exceptional combination of physical properties which have led to applications in almost all fields. Unfortunately, in the case of graphene, the large-scale production of good quality samples (low number of layers (less than five, what is called "few-layer graphene", FLG), lateral dimensions exceeding one micrometer, good structural quality) still represents a challenge despite the regular advances described in the literature. A simpler alternative consists in preparing graphite oxide, easy to exfoliate into graphene oxide (GO), for example by simple ultrasonic treatment. GO is hydrophilic and much easier to disperse (solvent, matrix) than FLG, which is very hydrophobic. GO is an electrical insulator, while FLG is a good electronic conductor. When electrical conductivity is one of the desired properties, it is required to reduce GO (decrease its oxygen content) to obtain "reduced GO" (rGO), supposed to be equivalent to FLG, but still presenting many structural defects. As the oxygen content decreases, the electrical conductivity is progressively restored but as a counterpart the stability of the dispersion in a solvent or a matrix decreases.

Regarding safety issues, we have evidenced the toxicity and genotoxicity of GO both in vitro and in vivo [1, 2], but also the possibility to suppress these adverse effects by thermal reduction [3]. The aim is to find a compromise between the ease of use of GO on the one hand, and its negative impacts on humans and the environment on the other. This strategy, which aims to identify the most suitable experimental conditions allowing a compromise between the absence of (geno)toxicity and the preservation of its ease of use, is part of the "safer by design" approach.

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From 0D to 3D carbon nanomaterials: ecotoxicity across aquatic trophic levels

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Keywords: aquatic toxicity; carbon quantum dots; carbon nanotubes; graphene/graphite; nanodiamonds

The rapid expansion in the production and application of carbon nanomaterials (CNMs) raises increasing concerns regarding their environmental fate and ecological safety. Herein, we present a systematic cross-trophic assessment of fourteen well-characterized 0D–3D CNMs, including fullerene soot (FS), fullerene C60, amino-acid-derived carbon quantum dots (CQDs), single- and multi-walled carbon nanotubes (SWCNTs, MWCNTs), graphene (G1 and G3) materials, graphite (GR), and nanodiamonds (ND). Acute and chronic ecotoxicity was evaluated across three aquatic trophic levels representing producers (Lemna minor), consumers (Daphnia magna), and decomposers (Aliivibrio fischeri), following OECD and ISO guidelines.

Toxic responses were strongly dependent on both trophic level and physicochemical properties of CNMs. *D. magna* exhibited the highest sensitivity, particularly toward long, carboxylated (oxidized) MWCNTs (MWCNT-COOH) (EC50(48 h) = 5.8 mg L–1), where toxicity was associated with digestive tract accumulation and physical interference. In contrast, *L. minor* was most affected by leucine-derived CQDs (EC50 = 65.2 mg L–1), inducing chlorosis and growth inhibition. The bacterial model showed generally lower sensitivity, with toxicity modulated by dispersion behaviour and surface characteristics. Across CNMs, no single parameter governed hazard; rather, toxicity emerged from the interplay of dimensionality, aspect ratio, dispersibility, and surface chemistry with organism-specific exposure pathways.

These findings highlight the necessity of integrated, multi-trophic ecotoxicological evaluation for carbon nanomaterials and identify high-aspect-ratio, environmentally dispersible nanotubes as priority candidates for environmental risk assessment.

Synthesis and structural characterization of TiO_2-modified nanostructured activated carbons derived from agricultural wastes

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Keywords: activated carbons, modified, titanium dioxide, nanostructure

The development of sustainable carbon based materials from agricultural waste has gained increasing attention due to their potential applications in environmental remediation [1]. In this study, nanostructured activated carbons modified with titanium dioxide (TiO_2) were synthesized from different precusors, including peach stones, walnut shells, and apple wood. Four samples were obtained: AMPC – from peach stones via fludizied bed method, sorptive volume (V_s) about 0.8 cm^3/g; CAP – from peach stones via classical activation with water steam, V_s about 1.3 cm^3/g; AC-MR – activated carbon from apple wood, V_s 1.1 cm^3/g and AC1 – from walnut shells, V_s 0.71 cm^3/g.

The incorporation of titanium dioxide aimed to enchece surface functionality and introduce photocatalytic properties. The materials were characterized using BET surface area analysis, scanning electron microscopy (SEM), transmission electron microscopy (TEM) and Raman spectroscopy. Comprehensive characterization using BET, SEM, TEM and Raman spectroscopy confirmed the formation of porous carbon frameworks with dispersed TiO_2 nanoparticles and partially graphitized structures containing structural defects. The results highlight the strong influence of precursor type and synthesis method on the textural and morphological properties of the activated carbons.

Overall, the results demonstrate that TiO_2 modified activated carbons derived from agricultural wastes are promising multifunctional materials for adsorption and photocatalytic applications in water treatment [2].

Acknowledgements

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Application of Nanotechnology in Building Preservation: Innovative Nanocarbon-Enhanced Coatings

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Keywords: graphene, carbon nanotubes, water glass paints, protective coatings

Cultural heritage forms the backbone of human civilization and society, shaping national identity while also influencing emerging directions in modern architecture. This legacy underscores the importance of investing in its preservation. Around the world, numerous examples of tangible cultural heritage can be found in architectural structures constructed over centuries using a wide range of materials and styles. However, both historic and contemporary buildings gradually deteriorate due to environmental exposure. A commonly used method to protect surfaces from UV radiation and moisture involves coatings based on water glass, often modified with additives such as TiO_2 and mineral pigments. Ideally, such coatings should be durable, resistant to abrasion, and capable of withstanding radiation and moisture while also limiting the growth of microorganisms.

To further improve these characteristics, nanocarbon materials like graphene and carbon nanotubes (CNTs) can be incorporated. These additives enhance the mechanical strength and flexibility of coatings, and their antioxidant [1], hydrophobic [2], and UV-absorbing properties [3] make them particularly promising.

The proposed research aims to demonstrate the beneficial impact of incorporating nanocarbon materials into water glass (sodium silicate)-based paints used for building protection. It is assumed that the addition of these nanomaterials will improve hydrophobicity, antistatic behavior, and mechanical performance, leading to the formation of advanced nanocomposite coatings. The innovative aspect of the research lies in the application of novel carbon nanomaterials, both unmodified and functionalized, to achieve superhydrophobic properties. The resulting coatings are expected to have strong practical potential in construction applications. Importantly, the proportion of nanomaterials in the formulation will remain low, resulting in only a slight increase in cost while significantly enhancing performance. Preliminary studies have confirmed the successful preparation of short-term stable dispersions of carbon nanomaterials in sodium silicate solutions.

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Mechanochemical modification of single-walled carbon nanotubes

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Keywords: single-walled carbon nanotubes, mechanochemistry, functionalization, photoluminescence

Single-walled carbon nanotubes (SWCNTs) are a unique class of one-dimensional nanomaterials with the most significant feature being their electronic band structure. It depends on their chirality, which determines whether they behave as semiconductors or metals. This versatility makes them good candidates for future materials for electronics and photonics. In the field of light-based technologies, semiconducting SWCNTs are highly sought after because of their luminescence in the near-infrared region. When paired with their ability to emit single photons, they become ideal candidates for secure quantum communication and advanced optoelectronic devices. For biosensing applications, SWCNTs may serve as incredibly sensitive signal transducers. Their large surface area and the high sensitivity of their fluorescence to the local environment allow for non-invasive detection of various biological molecules. Importantly, SWCNTs emit light within the "biological window," a spectral range where living tissues do not absorb much light. This transparency allows for high-contrast imaging deep within the body, positioning nanotubes as powerful tools for real-time biosensing.

Despite this potential, it remains difficult to precisely modify their surface via conventional organic chemistry methods to improve brightness and tune their exact emission wavelength. To solve this, mechanochemistry provides a solvent-free alternative to traditional chemical methods. High-energy ball milling allows for the simultaneous introduction of optical defects capable of increasing fluorescence yields, tuning emission wavelengths and shortening the SWCNTs. The latter is crucial for biological applications due to easier cellular uptake and will likely increase the biocompatibility of the SWCNTs.

This work explores the potential for the application of mechanochemistry in SWCNTs functionalization using different radical sources (e.g., diazonium salts, benzoyl peroxide, phenylhydrazine). The process is optimized with consideration of multiple parameters in the reaction environment, such as time, reagent concentration, and the type of milling balls. The optical properties of the modified SWCNTs are determined using photoluminescence spectroscopy, their length is assessed with AFM imaging, and Raman spectroscopy allows for the determination of structural defect densities in SWCNTs.

Acknowledgements

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Carbon nanostructures growth on waste mineral powder grains for preparation of functional concrete

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Keywords: conductive concrete, carbon nanofibers, waste mineral powder, granite, limestone

Waste mineral powders, such as limestone and granite, are being repurposed as sustainable additives to reduce the CO2 footprint of commercial concrete [1,2]. In this work, metallic catalysts are impregnated onto these mineral grains to facilitate the direct synthesis of carbon nanomaterials by chemical vapor deposition (CVD). This approach creates hybrid additives where the mineral core is covered by a functional carbon layer, allowing for the modification of electrochemical properties and paste wettability.

The research demonstrates that the mineral substrate's elemental composition, porosity, and roughness are critical in determining the dispersion of catalytic nanoparticles. These variables directly influence whether the resulting carbon materials manifest as carbon nanofibers (CNFs) or carbon nanotubes (CNTs). Through characterization via scanning and transmission electron microscopy (SEM and TEM), Raman spectroscopy, and thermogravimetric analysis (TGA), the study shows that the specific morphology and structure of these fibrous carbon nanostructures are fundamental to the final composite's performance.

When integrated into cement mixtures, these mineral-carbon composites produce concrete with improved electrochemical properties. Unlike traditional additives, these engineered carbon-coated grains exhibit lower water demand, leading to enhanced mechanical properties and optimized settling times. By leveraging waste minerals as a foundation for tailored carbon growth, this work establishes a high-performance pathway for sustainable, "smart" conductive concrete.

Acknowledgements

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Targeted isolation and modification of single-walled carbon nanotubes

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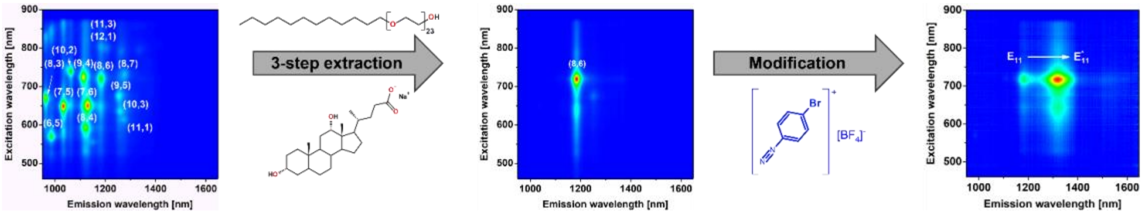
Keywords: single-walled carbon nanotubes, photoluminescence, aqueous two-phase extraction.

Single-walled carbon nanotubes (SWCNTs) exhibit extraordinary electrical and optical properties dependent on their carbon lattice arrangement. The order of carbon atoms in each SWCNT species can be described using a chiral vector denoted by a pair of numbers *(n,m)* which denotes how graphene sheet should be imaginary rolled in order to obtain certain SWCNT structure. Unfortunately, all routine synthesis techniques result in a complex mixture of different SWCNT species which significantly hinders the high-tech applications of this nanomaterial.

To overcome this problem, different separation techniques have been developed, such as conjugated polymer extraction, density gradient ultracentrifugation or aqueous two-phase extraction (ATPE)[1]. ATPE uses phase-forming compounds, especially polymers (e.g. dextran (DEX) and polyethylene glycol (PEG)), which form two-immiscible phases at certain concentration. When a surfactant suspension of SWCNTs is introduced to such system, each SWCNT type shows a different affinity towards top or bottom phase. The migration of SWCNTs can be influenced by the addition of modulators such as other surfactants or salts[2].

In this work, we present a universal procedure for extraction of (8,6) SWCNT using ATPE from various starting materials differing in species distribution[3]. We utilized a system composed of DEX-PEG to which SWCNT suspension in sodium deoxycholate (DOC) was introduced. In order to tune the SWCNT migration, Brij35, a non-ionic surfactant with an opposite effect to DOC, was utilized. This approach allowed for isolation of specific SWCNT by a simple three step extraction. The obtained fraction was then subjected to chemical modification using 4-bromobenzenediazonium tetrafluoroborate to enhance the optical properties of the material. Modified (8,6) SWCNT showed a response to the addition of vitamin C, revealing their potential utility for ratiometric sensing applications.



Acknowledgements
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Carbon materials for energy storage systems working in aqueous and organic medium

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Keywords: carbon material, graphite, activated carbon, electrochemical capacitor, Li-ion cells

This presentation will be devoted to general overview of carbon materials applied for various energy storage systems such as electrochemical capacitors (EC) and Li-ion cells. The unique properties of carbon, i.e., electrical conductivity, tunable porosity, electrochemical stability are indispensable for wide electrochemical applications. Carbon materials are highly effective for ion sorption, insertion, intercalation processes due to their diverse porosity from ultramicropores to mesopores.

Capacitance values of EC are proportional to the surface of electrodes where ions are sorbed in the available pores. Hence, electrodes of symmetric electrochemical capacitors are based on activated carbons with a highly developed specific surface area (SSA), typically from 1000 m^2/g to 2 500 m^2/g. The charge accumulated at electrode/electrolyte can reach ca. 100 F/g. Though, too high SSA would be responsible for low capacitance expressed per volume unit (F/cm3). For optimal EC performance, porosity of carbons should match ions sizes which depend on type of electrolyte (aqueous, organic), solvation, permittivity. However, for quick charge propagation mesopores are useful. Additionally, for long lifespan of EC, carbon disorder and structural defects should be controlled. The higher number of defects limits operational voltage range and cyclability.

For hybrid lithium-ion capacitor (LiC) or Li-ion cells, organic electrolyte in the form of two carbonates mixture is used and the graphitic carbon with a very limited porosity serve as an electrode material. In this case, surface of carbon is covered by solid electrolyte interphase during first cycles, then reversible intercalation of desolvated Li+ into graphite domains takes place. Such process allows long term cycling and supply energy for various portable devices and/or electric vehicles.

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Uncovering the Charge Storage Mechanism of Carbon Electrode in Sodium-Ion Capacitors via Operando Techniques

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Keywords: electrochemical capacitor, sodium-ion cell, activated carbon, dilatometry, Raman spectroscopy.

Sodium-ion capacitors (NICs) are hybrid electrochemical energy storage systems which have emerged owing to their high power density, the natural abundance of sodium resources, and their ability to deliver up to ca. 4 times higher specific energy than conventional electrical double-layer (EDL) capacitors [1]. By combining faradaic and capacitive charge storage mechanisms, NICs offer an attractive balance between energy and power performance. In this work, we investigate the electrochemical behavior of a carbon electrode material for NIC applications using a sodium-based electrolyte.

To elucidate the effects of ion fluxes in the EDL positive electrode made of nanoporous carbon, complementary electrochemical and operando methods were employed. The point of zero charge and the electrochemical stability window were determined, while the carbon electrode dimensional changes during cycling were quantified by *operando* electrochemical dilatometry. Afterwards, the strain was correlated with the ionic resistance variations obtained from in situ impedance spectroscopy and further supported by *operando* Raman spectroscopy analysis.

This combined methodology provides detailed insight into the ion fluxes occurring at the carbon electrode/electrolyte interface and highlights the influence of electrolyte selection on the properties of sodium-ion capacitors.

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Waste valorization for synthesizing carbon/graphene composites for supercapacitors

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Keywords: waste, carbon, graphene, composite, supercapacitor.

The global demand for sustainable and efficient energy storage devices has led the scientific community to rely majorly on carbon-based materials. In this regard, the present work targets the synthesis of waste-derived activated carbon/graphene composites for supercapacitor applications. Initially, biomass waste has been valorized for obtaining large-surface area activated carbon via thermochemical treatment using KOH [1]. Further, activated carbon/graphene composites were synthesized using few/multi-layer graphene with different morphologies, obtained from commercial graphite and a waste source. These materials were tested as supercapacitor electrodes in 1 M KOH using three-electrode setups, along with cyclic stability tests. The composites showed a 50-70% increase in specific capacitance, with a very small decrease even at higher scan rates and current densities, compared to the initial activated carbon. The preliminary tests of the best-performing composite in a coin cell assembly exhibited a specific capacitance of 125 F/g at 1 A/g with 98% retention. The energy density for this device was calculated to be in a range of 3.4-4.6 Wh/kg with a power density range of 260-4237 W/kg. This work demonstrates the concept of circular economy by valorizing the solid wastes for building sustainable and economical supercapacitors.

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Effect of N-Carbon Quantum Dots on Charge Storage in Electrochemical Capacitors

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Keywords: carbon quantum dots, surface functionalities, electrochemical capacitor, aqueous electrolyte, lifespan

Carbon quantum dots (CQDs), with a Csp^2 core and plentiful functional groups in the shell, demonstrate the potential to improve the performance of electrochemical capacitors (ECs). Nonetheless, their application and understanding of their effect on the EC performance remain unclear. An adjusted bottom-up approach[1] was utilized to obtain different disorder, functional groups content, and fluorescence of CQDs. Various pairs of citric acid and amines (EDA, HMTA, TEDA, oPDA) were used to prepare aqueous solutions of CQDs by hydrothermal carbonization. In-detail purification using centrifugation, dialysis, and filtration was realized to remove unreacted products and larger particles.

Several techniques were employed for physicochemical (TEM, SEM-EDX, UV, spectrofluorometry, FTIR, XPS, TGA) and electrochemical (CV, GCD, EIS) characterization. The N-CQDs with a size of approximately 6 nm exhibited a blue emission at λ=365 nm, which is attributed to the recombination of electron-hole pairs located within the Csp^2. As-synthesized N-CQDs possessed a high abundance of hydrophilic groups, with oxygen content reaching up to 23 at.% and nitrogen content up to 20 at.%. A facile impregnation of carbon cloth (CC) with N-CQDs was performed, and the even distribution of C, N, and O elements within the CC was validated through chemical mapping. CC impregnated with the N-CQDs served as electrode material in aqueous-based ECs (1M Li_2SO_4.) The N-CQDs improved the capacitance, reaching 146 F g^{-1} (CC-TEDA-CQDs) in contrast to 116 F g^{-1} (CC). Importantly, the N-CQDs enhanced the EC lifespan, extending the floating time to 200 hours for CC-TEDA-CQDs, whereas CC only reached 74 hours. The high content of O-, N-groups, quantum effects due to nanoscale size/modification of electron density as well as the improved electrolyte conductivity promoted by partial release of N-CQDs during the electrochemical testing are at the origin of the better EC performance. Importantly, these findings provide a strong basis for the subsequent design of electrode/electrolyte interface utilizing N-CQDs for EC as well other energy storage systems.

Acknowledgements
This work was supported by French Government Scholarship, Ministry of Higher Education of Poland (0911/SBAD/2601), National Science Center (Preludium 2024/53/N/ST5/02202) and ANR-10-LABX-76-01, STORE-EX (France).

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State of the art and future perspectives of traditional carbon materials and new carbon forms

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Keywords: precursors, processing, carbon materials, materials applications

Carbon materials cover a wide range of structures and may exhibit very different properties. Traditional carbon materials such as carbon fibers, activated carbons or carbon-based composites, mainly prepared from petroleum or coal derivatives, served from decades as a vanguard in several industrial applications and are still nowadays the worldwide leaders in carbon material´s production. The discovery of new carbon forms such as graphene produced a revolution in the field at a scientific level which is being nowadays consolidated in specific applications. A detailed discussion of the evolution at an industrial and scientific level of traditional carbon materials and the new carbon forms will be the focus of the presentation. In this regard, some relevant results obtained by our group (Composites Group) in both traditional carbon materials (carbon fibers, activated carbons and activated carbon fibers, composites) and graphene materials are also presented. These include some recent advances and new perspectives on the technologies used for the preparation of graphene based materials according to their subsequent application. Information about their use in different applications such as structural and environmental ones (air/water purification, desalination, water splitting, etc.), catalysis, health or energy storage, will be also discussed.

Three-in-one, integrated, inkjet-printed electrode for electrochemical sensing applications

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Keywords: flexible electrodes, graphene inks, integrated electrode system, electrochemical applications, water pollutants

Miniaturized electrodes have emerged as a key technology for sensitive and rapid detection in modern analytical systems. Their reduced dimensions provide significant advantages, including lower sample volume requirements and portability of the setup. These features make them particularly attractive for applications in electrochemical sensing and real-time environmental samples analysis [1]. Recent advances in fabrication techniques (inkjet printing, screen printing, 3D printing) have increased the development of miniaturized electrode platforms, allowing precise control over electrode geometry, surface properties, and functionalization. As a result, these systems can achieve high selectivity and sensitivity toward a wide range of target analytes, including water pollutants and contaminants of emerging concern [2]. Nevertheless, there is still a high need to develop low-cost fabrication systems, as commercially accessible technologies are cost-ineffective [3].

In this work, we propose a fully printed, integrated, flexible electrode containing a working electrode (WE), a counter electrode (CE), and a pseudoreference electrode (pRE) on a Kapton®, printed with an EPSON printer. Different ink formulations were tested. The final ink, being the base for all electrodes, was composed of graphene oxide (GO), Milli-Q water, Triton X-100, and glycerol. The glycerol contribution in the ink was optimized considering the quality of printed films and the time of drying. After printing, the setup was thermally treated at 400 °C, and the main active compound in the electrode system was thermally reduced graphene oxide (TRGOs). To obtain a fully integrated electrode, the pRE and CE were prepared by functionalization of as-obtained TRGOs by several techniques, such as electrodeposition of active compound, drop-casting, and ink deposition. The morphology and homogeneity of deposited layers were characterized by atomic force microscopy (AFM) and field emission scanning electron microscopy (FESEM). The electrodes were applied in an electrochemical detection of diclofenac (DCF), and the obtained results were compared to the results recorded on a conventional glassy carbon electrode (GCE) modified with TRGOs, and previously reported in which WE printed on Kapton® was applied [3,4]. The printed layers exibited homogeneity and a high degree of substrate coverage, which led to promising results in DCF testing.

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Oscillating structural transformations in the electrochemical synthesis of graphene oxide from graphite

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Keywords: graphite, graphite oxide, anodic oxidation, oscillating reaction, synchrotron radiation

Electrochemical synthesis of graphene oxide (GO) in aqueous inorganic acids is known to occur with potential oscillations [1-3], but the structural changes underlying these oscillations have remained unclear. In situ time-resolved X-ray diffraction studies of electrochemical graphite oxidation in aqueous sulfuric acid reveal periodic structural changes of a graphite intercalation compound (GIC) into pristine graphite oxide [4]. The potential oscillations of graphite electrode correlate with the appearance and disappearance of a solid phase identified as stage-1 GIC. The observed phenomenon can be considered as a new type of oscillating reaction.

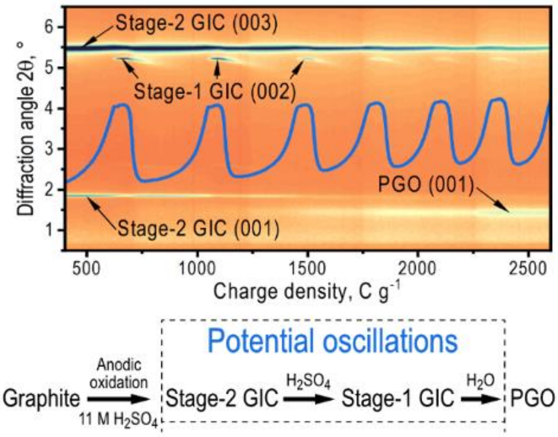

Fig. 1 Heat map constructed using XRD patterns (λ=0.35435 Å) recorded during the electrochemical graphite oxidation combined with the galvanostatic curve showing voltage oscillations.

Acknowledgements

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Characterization of electrically conductive copolyester hot-melt adhesive containing carbon nanotubes and carbon black

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Keywords: hot melt adhesives; carbon nanotubes; carbon black; extrusion; electrical conductivity

Functional conductive filaments used in additive manufacturing are predominantly based on conventional thermoplastic polymers such as PLA, ABS, or PETG, which are modified with conductive fillers to achieve electrical conductivity. These commercial materials are widely studied with respect to applications in sensors, electromagnetic shielding, and flexible electronics. Hot-melt adhesives represent a promising alternative matrix due to their low processing temperatures, strong adhesion properties, and potential for rapid processing without solvents.

In this study, conductive composites based on a low-temperature copolyester hot-melt adhesive were produced using two types of carbon fillers: multi-walled carbon nanotubes and highly conductive carbon black. In comparison to metallic fillers, carbon-based conductive particles offer several advantages, including lower density, improved chemical stability, and better resistance to oxidation and corrosion. The materials were processed using a twin-screw extruder to ensure effective dispersion and homogenization of the fillers within the polymer matrix. The obtained pellets were analyzed in terms of their thermal (TGA, DSC) and rheological (rheometry) properties to optimize the FDM (Fused Deposition Modeling) 3D printing process parameters. Electrical conductivity measurements were performed for the initial granules, extruded filaments, and printed structures obtained under varying printing parameters. The influence of processing conditions on electrical performance was analyzed and correlated with filler dispersion and microstructural changes induced during extrusion and 3D printing.

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Atomistic Investigation of Nitrogen-Doped Carbon Nanotube Growth and Structural Evolution from Pyridine and Pyrazine Precursors

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Keywords: Nitrogen doped carbon nanotube, bamboo shaped CNT, Molecular dynamics, reactive force field.

Nitrogen-doped carbon nanotubes (N-CNTs) have attracted considerable attention due to their enhanced electronic, catalytic, and mechanical properties compared with pristine carbon nanotubes [1]. In this work, molecular dynamics simulations were performed to investigate the growth mechanism and structural evolution of nitrogen-doped CNTs under catalytic conditions. The simulations focus on the interaction between catalyst nanoparticles and carbon–nitrogen precursor species at elevated temperatures, enabling the formation of CNT structures with nitrogen incorporation using pyridine and pyrazine as precursors. Cluster evolution, atomic diffusion, and bonding configurations were analyzed to understand the role of nitrogen in modifying catalyst stability and nanotube nucleation.

The results reveal that nitrogen incorporation significantly influences catalyst–carbon interactions, promotes defect formation, and alters the local bonding environment, which can affect the diameter and morphology of the resulting nanotubes. Additionally, the formation and reconstruction of catalyst clusters during growth suggest that catalyst particle size and structure play a crucial role in determining CNT characteristics. As shown in Figure 1, the Fc30TAr system consisting of ferrocene and toluene in the presence of argon forms a stable Fe cluster containing 19 atoms. In comparison, the nitrogen containing precursor systems show different cluster sizes, where the pyrazine case Fc30Pz10TAr forms a 16 atom Fe cluster, while the pyridine system Fc30Pd10TAr results in a 17-atom cluster. The analysis of the radius of gyration indicates that the pyrazine system exhibits the lowest value, suggesting the formation of the most compact catalyst cluster. The Fc30TAr and Fc30Pd10TAr systems show slightly larger radius of gyration values, with the pyridine case being marginally lower than the Fc30TAr system.

These observations indicate that precursor chemistry and nitrogen incorporation significantly influence catalyst cluster size, compactness, and stability, which in turn affect carbon chain formation and the early stages of nanotube nucleation. Overall, these findings provide atomic scale insights into the growth dynamics of nitrogen-doped CNTs and highlight the critical role of precursor selection in controlling catalyst behavior and nanotube structure, contributing to the rational design of doped carbon nanostructures for applications in energy storage, catalysis, and nanoelectronics.

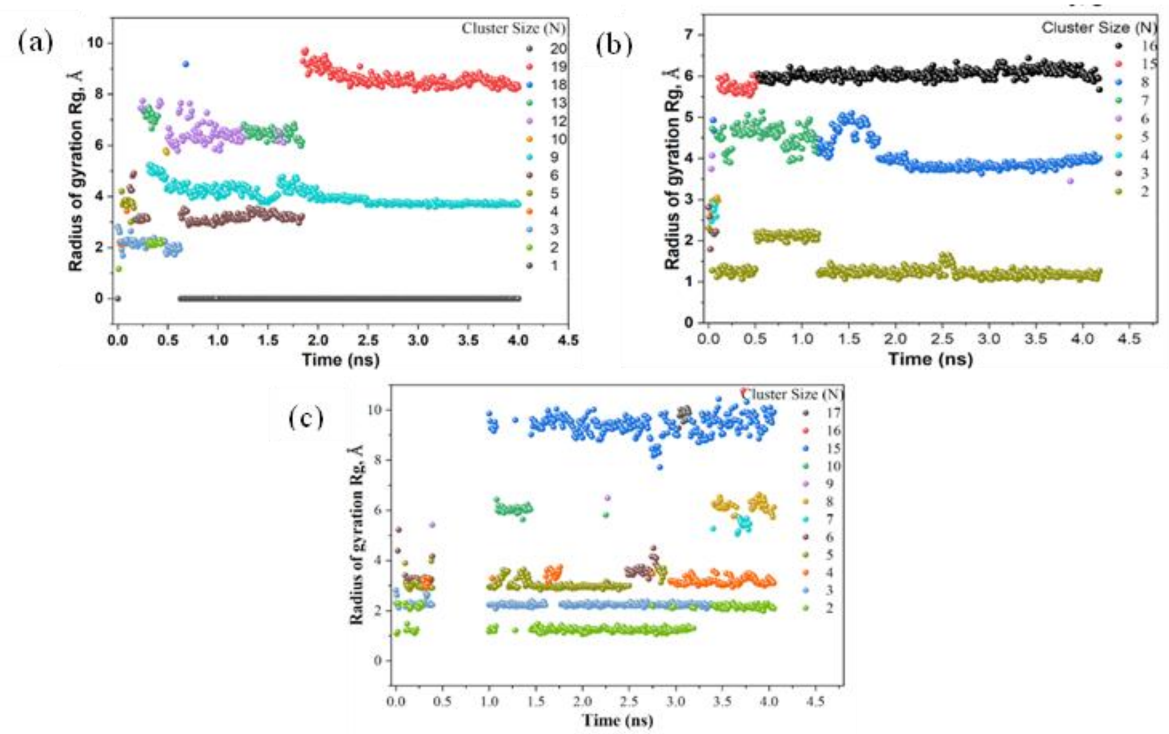

Figure 1: Molecular dynamics post-processing results obtained after 5 ps from a 4 ns simulation at 760 °C (1033 K), a cluster analysis for a) Fc30Tar b) Fc30Pz10TAR and c) Fc30Pd10Tar respectively.

Acknowledgements

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An overview of “Not-to-nanotube-itself” functionalization strategies

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Keywords: covalent functionalization, carbon nanotubes.

Multiple functionalization strategies are widely explored to harvest the potential of carbon nanotubes (CNTs) for their applications ranging from targeted drug delivery to nanocomposites to miniaturized electronics [1]. As one of the most important strategies, covalent functionalization enables formation of the operation- and condition-stable bonds between CNTs and the newly incoming moiety. Several functional groups, mainly such as COOH, OH, and NH_2, also born via molecular-level designed linkers, have been reported [2] to enhance dispersibility and physicochemical compatibility of CNTs with a variety of liquid and solid matrices[3]. The -COOH and -OH chemistry further facilitates modifications of CNTs via numerous organic chemistry-inspired routes[1].

General functionalization schemes, so-far reported to effectively affect morphological and electronic properties of CNTs – based on the organic chemistry classification – include: (a) all-type addition, i.e., radical, nucleophilic and electrophilic, as well as cycloaddition reactions[4]. 1,3-dipolar cycloaddition (1,3-DCA) is efficient but difficult to control. For instance, 1,3-DCA of azomethine ylides to CNTs leads to incorporation of pyrrolidine rings onto nanotube walls [1].

To achieve efficiency and controllability, a convenient anchoring point to facilitate subsequent functionalization is mildly explored but promising functionalization strategy. This is an overview of to-date “not-to-nanotube-itself” functionalization strategies as well as our findings. This approach represents a step forward in the CNT chemistry as leaving behind the non-controllable ‘to-nanotube’ strategy. Importantly, the strategy enables both initial and the further extension of π-conjugation between the nanotube and the novel fragment.

Acknowledgements
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Differences in Morphology of Carbon Nanotubes for Tribological Application

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Keywords: Tribology, MWCNTs, COF, IoNanoFluids, nanomaterials

Carbon nanotubes (CNTs) are studied as additives to various lubricants such as polyalphaolefins or ionic liquids. The introduction of CNTs can improve their properties such as reduction in wear and friction thus improving rheological properties [1]. Therefore, their efficiency depends on the morphology of their structure such as aspect ratio, metallic residue, no. of walls, and overall carbon purity. Within those parameters, one can tailor CNTs for targeted applications.

The existing literature shows significant differences between CNTs in the case of tribological properties [2]. In this work, we focus on describing the morphology influence of CNTs on their impact on the tribological and rheological properties of IoNanoFluids (INFs). Analysis of rheological and tribological parameters of in-house synthesized high-purity MWCNTs can lead to a more reliable description of such systems. As was proven in the latest work, even a small addition of CNTs can lead to drastic changes in the rheological parameters of INFs [3].

To parametrize CNTs, we apply thermogravimetric analysis (TGA), scanning and transmission electron microscopy with energy-dispersive X-ray spectroscopy (TEM, SEM/EDX), Raman spectroscopy, and X-ray photoelectron spectroscopy (XPS). At the same time, to quantify functional characteristics IoNanoFluids we implement rheological (viscosity, shear rate and shear stress) and tribological measurements on polymer-steel (UHMWPE/steel AISI 4130) tribo-pairs, including coefficient of friction (COF).

Relation between partitioning process of single-walled carbon nanotubes and hydrophobic-hydrophilic interactions in aqueous two-phase systems

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Keywords: SWCNTs, ATPS, ATPE, surfactants

Since discovery of carbon nanotubes in 1991, they have got great attention from scientific community, thanks to their unique structure and properties. Among those materials, single-walled carbon nanotubes (SWCNTs), became the most prominent candidate for material of the future, mainly owing to their optical [1] properties. However, SWCNTs exhibit different properties depending on arrangement of carbon atoms along nanotube wall [2], what we call their chiralities. To fully utilize potential of SWCNTs, we need to separate desired ones form the mixtures.

To achieve this goal, we apply variety of separations techniques, among which aqueous two-phase extraction is very appealing. In this technique, chiralities partition between two immiscible phases, created by polymers dissolved in water. Depending on properties of combined polymers, their concentration and addition of modifiers [3] such as surface acting agents, we can change partitioning results. However, to precisely tune ATPE process, we need to better understand the complexity of phenomena happening in aqueous two-phase systems. As for now, we are aware that, one of the driving forces in partitioning process is hydrophobic-hydrophilic interactions between water, polymer and surfactant. Those are strongly related to functional groups present in their structures.

In this study, we investigated how different polymers and surfactants affect partitioning of SWCNTs during ATPE. Then, we correlated those results with hydrophilic/hydrophobic characteristics of solutions obtained for pure compounds, which were characterised by measuring wetting properties on surface of Teflon. Consequently, we revealed strong relationship between the character of these liquid media and their capacity for SWCNT partitioning.

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Carbon nanofiber nonwoven as potential back electrode contact for perovskite solar cells: Effect of heat treatment temperature on structure and electrical conductivity

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Keywords: Carbon electrodes; Electrical conductivity; Electrospinning; Flexible electronics; Graphitization;

Electrospun carbon nanofibers (eCNFs) represent a promising class of electrode materials owing to their intrinsic electrical conductivity, high surface area, tunable morphology, and versatility across a broad range of applications. However, their full potential remains limited by insufficient mechanical strength and electrical performance that still fall short of the requirements for certain advanced technologies, such as solar cells, EMI shielding, and flexible electronics. At the same time, perovskite solar cells (PSCs) continue to face critical stability challenges associated with environmental stressors and the migration of ionic and metallic species at the electrode/perovskite interface. One promising strategy to mitigate these degradation pathways is the replacement of conventional metallic back contacts with carbon-based electrodes, which can suppress metal-induced instability and improve chemical compatibility with the perovskite absorber [1]. Nevertheless, currently employed carbon electrodes are not without limitations, as their conductivity often remains suboptimal, while wet deposition methods may mechanically disturb the underlying highly crystalline perovskite layer and induce microstructural damage.

In this work, we present preliminary results on electrospun carbon nanofiber nonwovens as potential back electrodes for perovskite solar cells focusing on the effect of heat treatment over broad temperature range (750-3200 °C) on the structure, surface chemistry, and electrical properties of carbon nanofiber nonwovens. The materials were comprehensively characterized by high-resolution scanning and transmission electron microscopy (SEM, TEM), X-ray diffraction (XRD), Raman spectroscopy, X-ray photoelectron spectroscopy (XPS), and ultraviolet photoelectron spectroscopy (UPS). By correlating the structural and microstructural evolution of the nanofibers with their electrical conductivity and work function, we identify the key parameters governing charge transport and electronic alignment in nanofibrous carbon architectures.

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Adsorption of Volatile Organic Compounds on Graphene-Containing Carbons

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Keywords: mechanochemistry, graphene nanostructures, volatile organic compounds, adsorption

The concentrations of volatile organic compounds (VOCs) in the air have been increasing over recent years. They are mainly released from industrial processes, chemical manufacturing, transportation, and petroleum product refining, among others. The need for cost-effective, efficient technologies to remove harmful and toxic compounds from the environment is becoming increasingly urgent. Advanced porous carbon materials represent a promising solution to this challenge.

In this study, we present a simple and versatile mechanochemical approach combined with a one-step activation process to produce porous graphene-containing materials with high yields and substantial porosity. The synthesis process is based on the conversion of graphite powder using a ball milling machine [1][2]. This method is particularly attractive because it significantly reduces processing time, energy consumption, and the need for chemical reagents while avoiding labour-intensive procedures.

High porosity and graphene domains in the prepared sorbents assured high adsorption capacities for benzene and hexane, especially at high vapor pressures. Benzene was used as a model compound to evaluate the adsorption behavior of these carbons toward BTX (benzene, toluene, xylene) compounds because they represent widespread and important VOCs that pose a direct threat to human health. The presented mechanochemical method appears to be facile and feasible for fabricating porous carbon materials from graphite for VOC adsorption.

Acknowledgements

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The Influence of Iron Nanoparticles Distribution on The Magnetic Properties of Carbonaceous Adsorbents Obtained from Mixtures of Different Iron Salts and Polymers

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Keywords: carbonaceous adsorbents, magnetic activated carbon, adsorption, iron species

The increasing demand for sustainable materials in water treatment technologies has highlighted the need for innovative strategies to develop improved adsorbent materials. During the last few decades, activated carbon (AC) has remained one of the most efficient adsorbents for water purification; however, its separation, recovery, and control of pore development remain challenging.

Integrating magnetic particles into activated carbon structures offers an alternative to address the weaknesses seen with traditional activated carbon. Nevertheless, the effect these particles have on the adsorbent performance is not fully understood. Additionally, the most common method to synthesize MAC is impregnation, which requires organic solvents to disperse the AC and then attach magnetic particles to its surface. This method is effective but often results in poor particle dispersion and limited penetration of magnetic particles into the carbon structure.

To target these drawbacks, we present a simple one-step methodology for synthesizing PFA-magnetic activated carbon that avoids the use of organic solvents. Different iron salts ($NH_4Fe(SO_4)_2$, $FeCl_3$, $(NH_4)_2Fe(SO_4)_2$, $FeCl_2$, $C_{10}H_{10}Fe$) were used to study the influence of the iron species on the pyrolysis and physical activation performance. The resulting MACs showed a homogeneous particle distribution and strong magnetic behavior, especially when iron chlorides were used. Surface area and structural features were investigated using N_2 and CO_2 adsorption, and SEM/EDS, demonstrating that porosity is dependent on the iron compound used. TGA and XRD analyses were performed to assess thermal stability, evaluate the presence of surface oxygen-containing groups, and identify the iron species formed after pyrolysis. Finally, the adsorbents were tested for adsorption on a variety of organic water pollutants, like phenols, dyes, and pharmaceuticals.

The results reveal a clear correlation between the nature of the iron precursor, the development of the pore structure, and the adsorption performance of the resulting materials. These findings highlight the critical role of the iron source in controlling the structure and functionality of magnetic activated carbons, providing new insights for the rational design of magnetic carbon adsorbents for water treatment applications.

The influence of diamond doping and nanomodification on the sensory properties of electrodes

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Keywords: diamond as dopant, nanostructured electrodes, electrochemical detection, surface modification, sensing properties.

Diamond is a material with exceptional physicochemical properties, making it highly attractive for sensor applications [1]. In this approach, diamond is introduced as a dopant into the electrode structure, enabling modification of its electrical and surface properties. The combination of diamond doping and nanomodification allows for improved sensitivity, selectivity, and stability of electrodes.

Sensors are widely used in industry, environmental monitoring, and medical diagnostics, creating a demand for advanced materials capable of operating in both gaseous and liquid environments [2]. Electrodes modified with diamond exhibit significant potential for the development of versatile sensing systems [3].

The aim of this study is to investigate the influence of diamond doping and nanomodification on the sensory properties of electrodes. The novelty lies in the use of diamond as an active dopant combined with nanoscale surface engineering to optimize electrode performance.

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POSTER PRESENTATIONS

UV light-controlled Graphene oxide modification using photoswitchable molecules

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Keywords: Graphene, Photoswitching, Azobenzene, 2D Materials

Graphene oxide (GO) has piqued the interest of scientists worldwide due to its superb characteristics, atomic thickness, and numerous uses [1]. The exceptional properties include low toxicity, large specific surface area, high thermal conductivity, one atom thickness, quantum hall effect, high Young's modulus, carrier mobility, and long-range ballistic transport [2]. Physicochemical modification, which involves adding a range of organic or inorganic molecules to graphene's surface, is the primary technique used to increase graphene's applicability. However, these modifications are rarely adjustable or changeable after synthesis.

Use of photo switchable molecules to synthesize a controllable structure of graphene-based materials is highly appealing. Azobenzene which can undergo cis → trans isomerization is a well-known photo-switchable molecule that has been extensively researched and utilized in the synthesis of organic functional materials. The trans-isomer has a bent configuration (non planar, dihedral angle of approximately 56°) with higher polarity (dipole moment $\mu = 3.1$ D), whereas the cis-isomer is nearly planar (dipole moment $\mu = 0.5$ D). A few studies on carbon nanomaterials and azobenzene-based composites for various applications have been published, taking advantage of azobenzene's photo switchable characteristics [3]. There hasn't been much study done in this field up to this point. GO has hydroxyl and epoxy groups on its basal plane and carbonyl, hydroxyl, and carboxylic groups at its edges [4]. Azobenzene, which is covalently linked to a carbon atom in the aromatic ring, can functionalize GO since its edges and surfaces are covered in -OH groups. Because of the isomerization of Azo, the photocurrent responds quickly to ultraviolet (UV) light irradiation, and the covalent bond can help transfer charges or energy from Azo molecules to graphene sheets through a strong electronic contact [5]. In this view, functionalized graphene oxide with controllable and switchable structural parameters might be more beneficial in multiple applications, e.g., in energy storage, filtration, controlled drug delivery, and sensing.

In our work we examine various functionalization routes to obtaining a UV-switchable system with changing distance between GO planes (pore-size), for controlled adsorption and electronic properties, as a base for future applications.

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Electrochemical deposition of poly[ethylene-dioxythiophene] (PEDOT) films on graphene nanopletelet films

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Keywords: carbon nanotubes, graphene nanoplatelets, electrochemical deposition.

Electrochemical deposition of EDOT monomer on graphene nanoplatelet (GNP) films was carried out in aqueous solution of $LiClO_4$ (dopant) and EDOT. The aim of the work was to evaluate the influence of number of cycles of EDOT deposition on the morphology, electrical resistance and electrocatalytic properties of the films.

The deposition process was carried out by cyclic voltammetry (CV) in three electrode configuration, in which GNP films were used as working electrodes. The CV potential changed in the range of -0.3 V and +1.4 V vs. Ag/AgCl with scan rate of 50 mV/s. The morphology of PEDOT changes with the number of polymerization cycles (Figure 1). Fifty electro-polymerization cycles resulted in PEDOT layers 60 µm thick. Raman spectra of PEDOT layers show strong Raman features at 1430 cm^{-1} ($C_{\alpha}=C_{\beta}$), 1365 cm^{-1} ($C_{\beta}=C_{\beta}$) and 1500 cm^{-1} ($C_{\alpha}=C_{\alpha}$), which are characteristic to PEDOT [1]. Surface resistance of PEDOT layers electrodeposited during 10 CV cycles was 1.8 Ω per square and increases slightly for layers electro-polymerized over 50 cycles. It should be noted that the surface conductivity of the bare GNP substrate was 2.3 Ω per square. The PEDOT deposition leads to an increase in the capacitance of the electrochemical double layer. The measurements of electrochemical behavior toward ferri/ferrocyanide and ruthenium hexamine redox probe show significant changes in electrocatalytic activity of PEDOT.

The obtained results demonstrate that both GNP constitute effective scaffolds for PEDOT growth making these hybrid materials promising candidates for electrochemical sensing platforms and flexible conductive electronic applications.

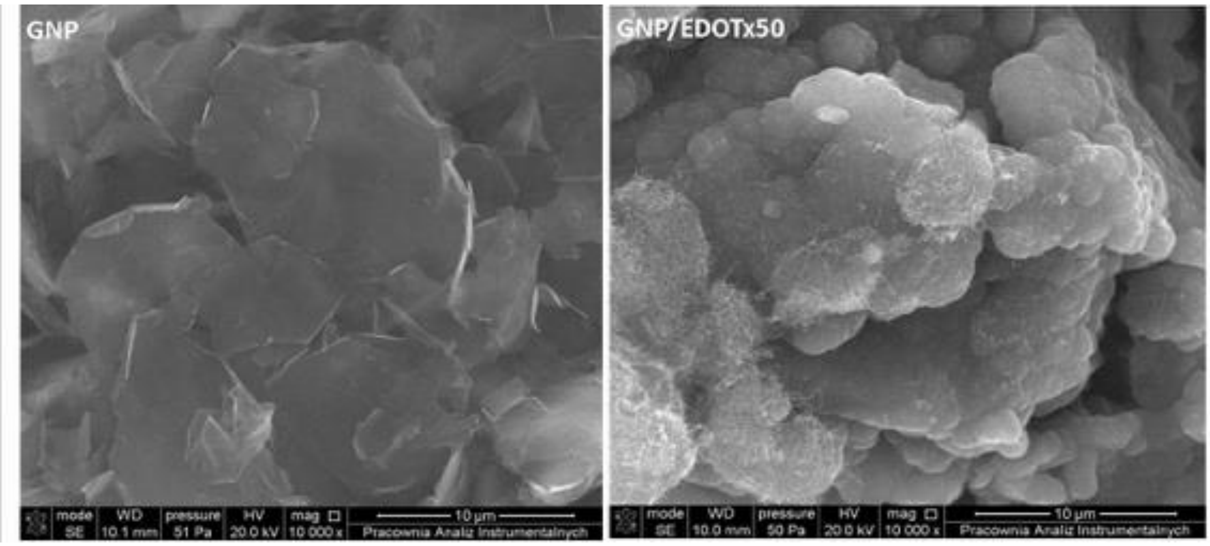

Fig.1. SEM images of PEDOT films obtained with a varying number of electrochemical polymerization cycles 50.

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Characterisation of biochar after interaction with products of biomass thermochemical conversion

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Keywords: biochar, tar, syngas, pyrolysis

Biochar is long-known carbonaceous material, derived from organic biomass; its successful application in agriculture is dated back to ancient times. Both then and nowadays, it is produced via thermochemical processes, such as pyrolysis. During pyrolysis (a process conducted at elevated temperatures, in an oxygen-free environment), apart from biochar, gaseous and liquid products are generated. Both of them interact with biochar already at the production stage but also later, in additional reformers.

The aim of this research is to establish how the interactions between biochar and tar, as well as between biochar and syngas, affect the properties of biochar. For this purpose, samples of biochar and biochar activated by oxidising process gases (H_2O, CO_2) were subjected to interactions with selected tar components (toluene, eugenol) and, to model the real-life conditions, with the full range of degassing products (obtained from degassing wood chips), which contain process gases in addition to tars.

The physiochemical properties of the biochar were investigated by a variety of analyical methods, including gas adsorption measurements (N2 and CO2), TGA, and TEM.

It was observed that the interaction of biochar with selected tar components resulted in pores clogging, whereas interaction with degassing products did not. An interesting observation was that biochar, after interacting with degassing products, did not undergo further pore filling by toluene/eugenol, despite retaining its porosity.

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Covalent Network Formation in Carbon Nanotubes Using S-Tetrazine Chemistry

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Keywords: carbon nanotubes, s-tetrazine, electrical properties, functional nanocomposites

Carbon nanotubes (CNTs), owing to their quasi-aromatic structure, cylindrical morphology, and nanoscale dimensions, exhibit outstanding electrical, thermal, mechanical, and optical properties. Since their discovery, they have attracted significant scientific interest and have found applications across various fields, including electronics, materials science, and medicine. Functionalization of these materials enhances their dispersibility in solvents and improves their physicochemical compatibility with polymer matrices, typically through the introduction of anchored functional groups. Consequently, there is a continuous demand for the development of modified nanomaterials, where controlled functionalization enables CNTs to be tailored for specific applications.

At the same time, assembling CNTs into defined structures and geometries with superior electrical, thermal, and mechanical performance would ideally require infinitely long nanotubes. This limitation can be addressed through strategies such as cross-linking. In this work, we present an approach for the covalent cross-linking of CNTs using s-tetrazine derivatives. Several designed s-tetrazine compounds, incorporating both aromatic and aliphatic substituents, were selected for this purpose.

The resulting functionalized CNTs (f-CNTs) were characterized using a range of analytical techniques, including thermogravimetric analysis (TGA), scanning electron microscopy (SEM), transmission electron microscopy (TEM), Raman spectroscopy, and Fourier-transform infrared spectroscopy (FTIR). Subsequently, novel nanocomposites and electrically conductive pastes were prepared from the f-CNTs, and their electrical and thermal properties were evaluated for potential applications.

Fluorine-Modified Carbon Nanotubes for Superhydrophobic and Anti-Icing Coating Applications

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Keywords: Fluorinated carbon nanotubes, superhydrophobic surfaces, anti-icing coatings

Ice accumulation remains a significant challenge in many sectors, including aviation, energy transmission, transportation infrastructure, telecommunications, and wind energy systems [1]. This drives the need for durable and efficient passive anti-icing solutions. Carbon nanotubes (CNTs), due to their unique physicochemical properties, are promising nanofillers for advanced coatings. In particular, fluorinated CNTs combine chemical stability with extremely low surface energy, making them suitable for the fabrication of superhydrophobic and icephobic surfaces [2].

In this work, pristine and hydroxylated single-walled carbon nanotubes (SWCNTs) and multi-walled carbon nanotubes (MWCNTs) were modified using commercially available perfluorocarbon emulsions. The modification approach was designed to tailor the surface chemistry by introducing fluorinated functionalities, leading to reduced surface free energy and enhanced hydrophobicity.

The obtained materials were characterized using X-ray photoelectron spectroscopy (XPS) and thermogravimetric analysis (TGA) to evaluate their surface composition and thermal behavior. Wettability was assessed by water contact angle (WCA) measurements, revealing superhydrophobic properties with contact angles up to 165°. The influence of fluorine and oxygen surface concentrations on water repellency was systematically analyzed.

Selected materials exhibiting the highest hydrophobicity were further evaluated for anti-icing performance by measuring the freezing delay of water droplets. The results confirm that fluorinated CNTs can effectively retard ice formation, demonstrating their potential as functional components of passive anti-icing coatings.

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DFT study of [AC-PAH] complex

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Keywords: activated carbon surface, PAH (poly-allylamine hydrochloride), DFT method

Complexes formed between poly-allylamine hydrochloride (PAH) and activated carbon (AC) represent a class of hybrid materials with advanced interfacial properties, determined by the combination of the polycationic character of the polymer and the electron-rich aromatic structure of the carbon surface. Due to this interfacial architecture, the PAH–AC complex has uses in applications where selective adsorption, strong electrostatic interactions and stability at the interface are needed.

In this work, the data of the DFT study of the PAH–AC complex are presented, with the aim of elucidating the electrostatic, electronic and charge transfer processes that lead to the formation of a stable complex at the interface.

Thus, two PAH-CA complexes in which AC is unoxidized (without functional groups) (Fig. 1. a) and oxidized (contains carboxylic, ketone and phenolic groups) (Fig. 1. b) were optimized using the DFT/WB97XD method and the 6-31+G(d,p) basis set in the Gaussian09 program [1].

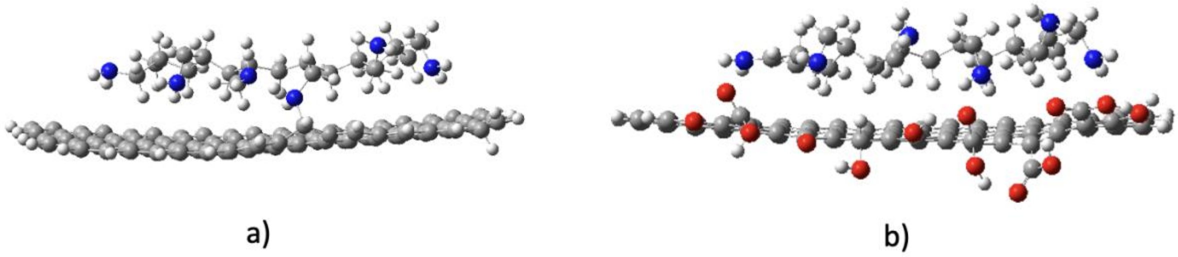

Fig. 1. Optimized structure of PAH-AC complexes.

The estimated binding energy calculated by the formula:

$$E_{bind} = E_{complex} - (E_{PAH} + E_{AC})$$

is 95.38 kcal/mol (in case a) and ~200.0 kcal/mol (in case b). The charge analysis (Mulliken) reveals a net charge transfer of 0.75 e^- from the carbon cluster to the PAH oligomer upon adsorption.

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TiO_2-carbon composites derived from peach stones activated carbons: synthesis, characterization and application

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Keywords: activated carbon, composite, surface chemistry, porosity, titanium dioxide

Activated carbon derived from biomass waste represents a promising approach due to its wide availability, cost-effectiveness, and intrinsic physicochemical properties that make it an efficient adsorbent. The production of activated carbon (AC) from such precursors constitutes a viable strategy for enhancing sustainability, offering multiple functionalities, including environmental remediation, resource recovery, and energy storage. AC composites made up of two or more components exhibit novel physicochemical properties integrated into a single system that can be used in a variety of engineering applications [1–3].

This work focuses on the development and characterization of novel carbon-based composite materials, based on AC functionalized with titanium dioxide (TiO_2), with photocatalytic properties. A series of AC derived from peach stones with different surface chemistry (CAP-25 - initial sample, pH ≈ 6; CAPO-25 - oxidized sample, pH ≈ 2.5, rich in carboxylic groups) and different porosity (Vs 0.3 ÷ 1.1 cm3/g) were used for the synthesis of the carbon composite materials. The AC-TiO_2 composites were assembled from two individual components (AC and TiO_2 in a weight ratio of 1:1) by using polyallylamine hydrochloride (PAH) as a linking polymer.

The structural and morphological characteristics of the obtained composites were investigated using XRD, BET, FTIR, EPR, TEM/SEM and XPS. The photocatalytic activity of the samples was tested against model pollutants (RhB, OTC) under visible light irradiation. The photodegradation mechanisms were identified based on the detection of reactive oxygen species (ROS) and density functional theory (DFT) calculations.

Acknowledgements
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‘Nanotubium-Nanotubate’: From Van der Waals bundles to ‘Io-NanoHybrids’

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Keywords: Carbon nanotubes (CNTs), Ionic functionalization, Electrostatic self-assembly, Io-Nano hybrids, Ion-conductive materials

Carbon nanotubes (CNTs) present a rich and complex scientific landscape, requiring precise control to unlock their vast functional potential. Although CNTs exhibit outstanding mechanical, electrical, and thermal properties, translating these intrinsic attributes into macroscopic, free-standing architectures remains challenging due to poor dispersibility and Van der Waals interactions [1]. To address this, we offer a self-assembly strategy that utilizes complementary chemical functionalization to promote inter-tube interactions.

In this study, multi-walled carbon nanotubes (MWCNTs) were functionalized with specific, oppositely charged moieties to create cationic (‘nanotubium’) and anionic (‘nanotubate’) modifications. These were then combined to form ‘Io-Nano hybrids’ through electrostatic-driven assembly [2].

Successful functionalization and ionic self-assembly is confirmed by optical microscopy, dynamic Light Scattering (DLS), raman spectroscopy, thermogravimetric analysis (TGA) and X-ray photoelectron spectroscopy (XPS) etc. Further analysis of the conductive and mechanical properties of the free-standing bucky papers prepared from ‘Io-Nano hybrids’ is in progress [3]. The resulting ‘Io-Nano hybrids’ can serve as versatile precursors for ion-conductive membranes, nanocomposites, and electrochemical devices, where synergistic ionic interactions enhance functionality and performance.

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Direct electron transfer between sp^2-bonded carbons and adsorbed aromatic molecules

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Keywords: carbon nanotubes, graphene, doping, heterogeneous electron transfer.

Non-covalent π-π stacking, which occurs between aromatic molecules and sp^2-bonded carbon layers, leads to direct electron transfer [1]. As a result, the Fermi level shifts within the electron structure of graphene or a carbon nanotube, leading to p-type or n-type doping. The key point about this type of interaction is that it does not alter the structure of the π-electron bands.

Here, we focus on the influence of benzoic acid, limonene and polyvinylpyrrolidone (PVP), which are commonly used as water dispersants for carbon nanotubes and graphene. We show that direct electron transfer between permanently adsorbed aromatic molecules or pyrrolidone rings and sp^2-bonded carbon host results in changes of both the electrical and electrocatalytic properties of graphene and carbon nanotubes. Direct electron transfer carbon host and guest molecules was assessed based on the shifts in the Raman G and 2D bands [2]. Doping induced by adsorbed aromatic molecules has an effect on heterogeneous electron transfer kinetics, which has been investigated by cyclic voltammetry using ferro/ferricyanide and hexaammineruthenium(II)/(III) as redox probes. The impact of adsorbed aromatic molecules on the course of the oxygen reduction reaction was studied using the linear sweep voltammetr. Based on the Gerischer-Marcus model, we explain the effect of carbon nanotube and graphene doping on the rates of cathodic and anodic reactions [3].

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Sponge carbon electrode - the impact of the carbonisation process

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Keywords: electrode, carbonisation, melamine sponge, carbon

3D electrodes are a new type of electrode which, unlike conventional electrodes, are not flat and have a porous structure [1]. These electrodes can take various forms, such as felts, foams, meshes or sponges. The main objective in designing 3D electrodes is to maximise the electrochemically active surface area whilst minimising the space occupied by the electrode itself [2]. The three-dimensional structure of the electrodes provides an interconnected network of electron and ion channels, enabling efficient exchange of charges and mass during the Faraday process, which has a positive impact on high-performance electrochemical energy storage systems, flow batteries and electrocatalysis [2].

Of the various methods for producing 3D electrodes, those made using commercial melamine (MS) foams appear to be the most attractive and desirable. MS is a good starting material due to its porous structure, high nitrogen content and the simplicity of its production via pyrolysis [3]. As a result, we obtain a highly porous, self-supporting 3D electrode containing nitrogen atoms in its structure and having a low weight [1]. An additional advantage of electrodes derived from melamine foams is their distinct mechanical properties, such as flexibility and compressive strength, which are not found in other carbon electrodes [1,2].

A key consideration in the manufacture of 3D electrodes from melamine foams is understanding the impact of the carbonisation process on the properties of the final product, such as porosity, surface area, heteroatom content and electrical conductivity.

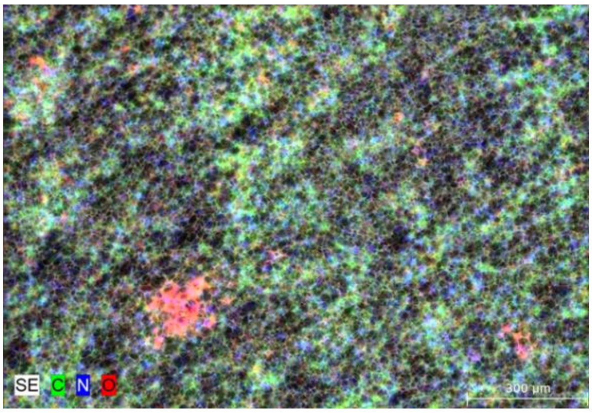

Fig1. SEM image for carbonised melamine sponge.

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Backbone Engineering and Post-Synthetic Modulation of Fluorene-Based Copolymers for Monochiral SWCNT Isolation

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Keywords: Single-walled carbon nanotubes, conjugated polymers, conjugated polymer extraction, irradiation

The isolation of semiconducting single-walled carbon nanotubes (s-SWCNTs) with high chirality and enantiomeric purity is a cornerstone of next-generation carbon photonics. Conjugated polymer extraction (CPE) has proven to be an efficient sorting method, capable of achieving monochiral purity through the optimization of conventional polymer characteristics [1]. However, most current research remains focused on a limited set of established structures, such as PFO, PFDD, PFTD, F8BT or PFO-BPy, leaving the vast chemical space of copolymer backbones under-explored.

While early systematic studies by Mayor and Kappes established foundational libraries of fluorene and carbazole copolymers [2,3], recent advancements have primarily pivoted towards degradable backbones for polymer-free SWCNT recovery [4] or specialized enantiomeric resolution. Despite these developments, a comprehensive re-evaluation of how core backbone modifications dictate monochiral selectivity is missing in the literature.

In this work, we return to the systematic screening of fluorene-based copolymer architectures to fill this knowledge gap. We introduce a series of unique copolymers incorporating naphthalene, anthracene, and other polycyclic aromatic hydrocarbons (PAHs) or heteroaromatic rings coupled with a fluorene moiety. This structural diversity allows us to finely modulate the conformational rigidity and electronic interaction with the SWCNT lattice. This approach builds upon our group's previous success in the high-purity isolation of the rare (7,3) chirality through mixed-solvent engineering [5].

Furthermore, we demonstrate that achieving high selectivity is not only a matter of chemical composition but is critically dependent on macromolecular parameters. Building upon foundational studies [6] and our recent findings that "size matters" in CPE [7], we investigate the influence of molecular weight and dispersity on sorting efficiency. Finally, we present synthetic and post-synthetic techniques to precisely tune the polymer properties in situ. These findings provide a robust framework for the rational design of the next generation of sorting agents, enabling tailored electronic properties of SWCNT-based materials

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Tuning Fluorene-Based Polymers for Chirality-Selective Extraction of Large-Diameter SWCNTs

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Keywords: carbon nanotubes, conjugated polymers, interactions, photoluminescence.

The heterogeneity in diameters of commercially produced single-walled carbon nanotubes (SWCNTs) has undermined their electronic and optical properties, constraining their integration into high-performance technological applications due to broad distribution of their band gap energies[1]. Conjugated polymer extraction (CPE) has emerged as one of the promising techniques for harnessing the potential of SWCNTs by enabling their sorting into distinct chiralities with specific diameters and band gap energies[2].

We have recently shown that fluorene based conjugated polymers, including poly(9,9'-dioctylfluorenyl-2,7-diyl-alt-6,6'-(2,2'-bipyridine)) (PFO-BPy6,6')[3], poly(9,9-dioctylfluorene-alt-benzothiadiazole) (PFO-BT)[4], and poly(9,9-dioctylfluorene-2,7-diyl) (PFO), exhibit excellent performance when applied to sort SWCNT materials with narrow chirality and diameter distributions, enabling the selective sorting of small diameter SWCNTs. However, their selectivity declines significantly when applied to materials with broader chirality and diameter distributions, such as CoMoCAT SG76i, HiPco, and Tuball. Despite the progress achieved in conjugated polymer extraction (CPE), the selective sorting of large-diameter SWCNTs with uniform electronic character from such heterogeneous materials remains a significant challenge.

To address this limitation, we propose the use of a novel fluorene-based conjugated polymer. This approach enables the selective sorting of (8,7) and (9,5) SWCNTs across a range of starting materials, including CoMoCAT SG65i, CoMoCAT SG76i, HiPco, and Tuball. The universal nature of the reported polymer makes it particularly attractive for bringing SWCNTs closer to their long-anticipated application.

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Iron Nanoparticle-Functionalized Magnetic Biochar for Isoproturon and Cr(VI) Adsorption Kinetics

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Keywords: isoproturon, biochar, magnetic carbon adsorbent.

This study presents the development of magnetic biomass-derived carbon adsorbents doped with iron nanoparticles for the removal of organic and inorganic pollutants from aqueous solutions. Magnetic activated carbons were synthesized via pyrolysis and steam activation of walnut shell impregnated with an aqueous FeCl3, FeCl2 and (NH4)2Fe(SO4)2, NH4 Fe2(SO4)2 solution, producing materials with integrated magnetic functionality.

The presence of iron nanoparticles imparted magnetic properties, enabling easy separation of the adsorbents after treatment. Textural properties were determined using nitrogen adsorption isotherms at 77 K, while SEM, XRD, and thermogravimetric analyses were applied to evaluate morphology, structure, and metal distribution. Magnetic behaviour was confirmed by magnet tests and hysteresis measurements.

The adsorption performance of selected magnetic carbons was evaluated for isoproturon and Cr(VI) under batch conditions at ambient temperature. Cr(VI) adsorption was favored at pH 2 and was best described by Langmuir and Langmuir–Freundlich isotherm models. Kinetic data followed a pseudo-second-order model, with adsorption controlled mainly by intraparticle diffusion and partially by film diffusion.

Magnetic adsorbents showed significantly higher adsorption capacity for Cr(VI) compared to non-magnetic materials derived from the same precursor, highlighting the positive effect of iron incorporation. However, iron did not improve the development of porous structure. In contrast, isoproturon adsorption depended primarily on the textural properties of the carbon matrix. These results demonstrate that magnetic biomass-derived carbons.

These results demonstrate that magnetic biomass-derived carbons are promising adsorbents, combining high efficiency with the practical advantage of magnetic separability.

Influence of Nitrogen Sources on N-Doped Reduced Graphene Oxide Aerogels for Efficient Neutral Aqueous Symmetric Supercapacitors

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Keywords: graphene aerogels, supercapacitors, energy storage, hydrothermal synthesis, nitrogen precursors

Graphene-based aerogels recently emerged as promising 3D architectures for next-generation electrochemical energy storage devices, especially supercapacitors, owing to their ultrahigh specific surface area, exceptional electrical conductivity, interconnected porous network facilitating rapid ion transport, and mechanical robustness for flexible applications. The intrinsic characteristics of graphene-based aerogels enable high energy and power densities in electrochemical devices while ensuring excellent stability, thanks to the robust two-dimensional planar structure arranged within a three-dimensional framework. Furthermore, nitrogen doping of carbon and graphene materials is a powerful strategy to improve their electrochemical performance by introducing pseudocapacitive active sites, improving surface wettability, modulating the electronic structure, and increasing electrical conductivity, which results in a synergistic effect of boosting charge storage capacity and rate capability in supercapacitors.

In this study, we investigate the influence of various nitrogen precursors during hydrothermal synthesis—namely ammonia, a mixture of ammonia with citric acid, and ammonium oxalate—on the physicochemical and electrochemical properties of nitrogen-doped reduced graphene oxide (NrGO) aerogels. The morphological features, surface chemistry, and porosity of the synthesized NrGO aerogels were analyzed using FESEM, XPS, and nitrogen sorption analysis. The electrochemical performance of the materials was evaluated in symmetric supercapacitor configurations with a safe and environmentally friendly neutral aqueous electrolyte (1 M Na2SO4). Assembled devices achieved the maximum operational voltage up to 1.7 V. The electrochemical testing demonstrated promising energy storage capabilities, with energy densities reaching ~17–23 Wh kg–1 and high cycling stability. The obtained results demonstrate that selection of a nitrogen source determines the aerogel electrode properties, which is later translated to differences in the symmetric cell electrochemical performance, including charge storage capabilities, ionic diffusion, and stability of the electrode/electrolyte interface.

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Balancing Sun Protection and Environmental Safety: A Carbon-Based Approach to UV Filter Removal

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Keywords: UV filters, Carbon-based materials, UV–Vis spectroscopy

UV filters play a crucial role in protecting human health from the harmful effects of solar radiation, preventing sunburn, premature skin aging, and skin cancer. Their effectiveness has been confirmed in numerous studies, and their use is widely recommended. As consumer awareness grows, the number of products containing UV-protective substances is increasing, leading to their rising presence in the environment. It is estimated that thousands of tons of UV filters enter aquatic ecosystems annually, both during bathing and through the daily removal of cosmetics, resulting in their detection in surface waters worldwide.

Substances such as oxybenzone, octinoxate, octocrylene, and avobenzone can negatively impact aquatic organisms, affecting the hormonal balance of fish, contributing to coral bleaching, and disrupting plankton growth. Additionally, these compounds may undergo transformations under UV radiation or react with other substances, while their persistence and lipophilic nature promote bioaccumulation. Therefore, intensive research is underway to reduce their emissions into the environment.

The aim of this study was to evaluate the effectiveness of a novel carbon-based filter material designed to capture UV filter molecules during their removal from the skin surface. The analysis was performed using UV–Vis spectroscopy in ethanol solutions. The proposed approach represents an alternative strategy for reducing aquatic pollution at the source, without the need to eliminate UV filters from cosmetic formulations.

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3D-printing wastes derived TPU/GO membranes: toward compact real-time water quality monitoring devices

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Keywords: COMSOL, graphene oxide, recycling of3D printing wastes, TPU, real-time water quality monitoring system

Drinking water is a critical resource essential for the survival of civilian populations as well as for the effective functioning of armed forces in crisis situations. In the face of contemporary threats such as armed conflicts, terrorist attacks involving weapons of mass destruction, industrial accidents, and natural disasters, water quality may deteriorate rapidly due to the presence of chemical substances, biological pathogens, and radioactive isotopes. These contaminants, often of deliberate origin, pose a significant challenge to water treatment systems, particularly those operating under field conditions or in situations with limited access to infrastructure [1]. Therefore, it is crucial to develop devices that enable real-time water quality monitoring. Several approaches exist to address this challenge; however, electrochemical techniques are particularly promising due to their compact instrumentation and rapid analytical response [2].

In this study, we propose a flexible membrane made of 3D printing filament (thermoplastic polyurethane -TPU) and graphene oxide (GO). The membrane has been tested in terms of crucial properties (mechanical strength, stability) to its potential use as a real-time water quality monitoring device for water filtration systems. GO being an active part of the membrane can be further reduced to reduced graphene oxide (RGO) to improve electrical conductivity which is crucial from the point of view of monitoring of water pollutants using electrochemical techniques. The impact of the addition of GO into TPU was evaluated, taking into account the mechanical strength of the membrane up to the operational pressure of 10 bars. Moreover, the model that enables the determination of the pressure drop and fouling of the perforated membrane has been built using COMSOL Multiphysics software. The preliminary results of the optimization of the membrane composition and mechanical strength tests provides a promising pathaway for further application of the proposed solution in electrochemical tests.

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Metal-Functionalized CNTs for Enhanced Lithium Grease Lubricity

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Keywords: carbon nanotubes, nanohybrids, friction, lubrication, wear

Carbon nanotubes (CNTs) are widely recognized as a promising class of nanomaterials with potential applications in numerous advanced and smart technologies, including tribological systems.[1–2] Friction-related energy losses account for nearly 23% of global energy consumption, emphasizing the growing demand for efficient, durable, and scalable lubrication technologies.

In this work, high-performance nanolubricants were developed by incorporating small amounts (0.01 wt%) of gold-, copper-, and nickel-functionalized multi-walled carbon nanotubes (MWCNTs) into a commercial lithium grease. Tribological investigations performed using a four-ball tribometer demonstrated a substantial improvement in lubrication performance. In particular, Cu-MWCNT additives reduced the wear scar diameter by approximately 75% — from 2.96 mm to 0.73 mm under a 1 kN load — while simultaneously increasing the maximum non-seizure load from 1.2 kN to over 1.4 kN. Increasing the nanoparticle concentration to 0.1 wt% resulted in a slight deterioration of performance, indicating a non-linear dependence between additive concentration and tribological effectiveness.

The durability of the developed lubricants was further confirmed through long-term bearing tests exceeding 1,150 hours, corresponding to approximately 152 million revolutions. Raman spectroscopy analysis revealed that MWCNTs remained structurally stable under rolling contact conditions, whereas under sliding conditions they transformed into amorphous carbon, functioning as a sacrificial protective layer. Energy-dispersive X-ray spectroscopy (EDS) analysis detected no residual copper species on the wear tracks, suggesting that the observed lubrication enhancement originates primarily from catalytic tribochemical interactions rather than direct material deposition.

Moreover, Cu-MWCNT additives promoted the formation of protective tribofilms derived from zinc dialkyldithiophosphate (ZDDP) and reduced oxidation of steel surfaces under high-load conditions. Overall, the results demonstrate that trace amounts of surface-engineered carbon nanomaterials can significantly enhance lubrication performance through complex mechanochemical mechanisms. The proposed nanolubricants are scalable, energy-efficient, and fully compatible with existing industrial grease formulations.

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Synthesis and Physicochemical Properties of Biochar@Graphene Oxide Carbon Composites

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Carbon-based hybrid materials combining disordered carbon matrices with graphene-derived nanostructures have recently attracted significant attention due to their tunable surface chemistry, hierarchical structure, and multifunctional physicochemical properties. In this work, a series of hybrid carbon composites based on graphene oxide (GO) and carbonaceous materials with different structural organization were synthesized and investigated.

Three model systems were prepared and comparatively analyzed: pristine GO, GO combined with commercial activated carbon (Norit-80), and GO integrated with nanostructured carbon materials. The composites were synthesized using a solution-assisted assembly approach, followed by controlled drying and stabilization. The obtained materials were characterized using complementary physicochemical techniques, including X-ray diffraction (XRD), Fourier-transform infrared spectroscopy (FTIR), Raman spectroscopy (RS), scanning electron microscopy (SEM), and selected adsorption/surface analyses.

The results demonstrate that the type and structural ordering of the carbon phase strongly influence the organization of GO sheets, interfacial interactions, and the distribution of surface functional groups. Significant differences were observed in the degree of structural heterogeneity, aggregation behavior, and oxygen-containing functionalities between composites containing commercial activated carbon and nanostructured carbon materials. The hybridization process led to the formation of complex interfacial carbon architectures combining graphitic domains with highly defected and oxygen-rich regions.

The obtained results indicate that biochar@GO composites constitute a promising platform for the design of advanced carbon materials with tunable adsorption, interfacial, and transport properties. The presented approach may be relevant for future applications in environmental engineering, energy conversion, catalysis, and functional carbon interfaces.

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