Extended Abstract Journal of Industrial and Environmental Chemistry 2021
Vol.5 No.2

Synthesis of Environmentally Friendly and Sustainable Multi-Functional Surfaces and Interfaces

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Abstract

The synthesis of environmentally friendly and sustainable multi-functional surfaces and materials is leading the research of innovative applications in energy, water and environmental remediation. The most important biological and physicochemical process occur at the surface or the interface between two or more materials. Hence, if a material's surface can be functionalized, it could perform different tasks simultaneously such as catalysis, selective separations, sorption and adhesion, and oxidation/reduction processes.

The development of new-generation materials that extend the industrial applications of reaction-separation processes is being addressed in some applications like water treatment or fuel cells. The development of functionalized surfaces in highly porous materials can led to stimuli responsiveness such as ionization, electron and ion transfer, swelling, hydrophobicity/hydrophilicity or sorption. These new combination of techniques and materials prove to be effective in selective separations in various environmental conditions, enhancing reactivity, durability and permeation. The main idea is how to increase the number of functional groups by unit of area on the material used in order to give and augment sensibility, reactivity, selectivity or sorptive characteristics and, at the same time not affecting or even improve the application performance. Polymers and biopolymers may display these different surface functionalities and due to their versatility, they can be applied in diverse research fields and simultaneously be sustainable technologies.

A bioinspired one-pot approach for the synthesis of ZnO - carbohydrate hierarchical architectures was developed. The synergy between a saccharide (mono, di- or polysaccharide) that contains D-glucose units and triethanolamine is the key parameter of the synthetic methodology. The morphology of the ZnO composites is dictated by the used saccharide, and rod, spindle, solid and hollow spherical-like ZnO structures are obtained varying the carbohydrate. The synthesized composites present good photocatalytical and antimicrobial activity.

Herein, we describe a phytosynthetic, additive-free, economically viable, environmentally sustainable and rapid methodology for the formation of sphere-shaped Ag-SnO2 nanocomposites of 9 nm average particle size employing the stem extracts of Saccharum officinarum. Employing various spectroscopic techniques, the morphology, size, crystallinity, elemental conformation, and functional groups liable for surface stabilization as well as capping were depicted. Considerably, the Ag-SnO2 nanocomposite in aqueous phase revealed excellent removal efficiency for the abatement of four industrially emerging pollutants (Methylene Blue, Rose Bengal, Methyl Violet 6B, and 4-nitrophenol) and probable mechanisms were also suggested. Nearly, 99.1, 99.6, 99.5, and 98.4% of Methylene Blue, Rose Bengal, Methyl Violet 6B, and 4-nitrophenol were eradicated respectively, within 60, 75, 75, and 58.3 min using the synthesized nanocomposite. Moreover, the spent nanocomposites were renewed and their photocatalytic proficiencies were assessed for three consecutive cycles. The spent nanocomposite and the degraded products were respectively analyzed using X-ray diffraction and liquid chromatography-mass spectrometry spectroscopic methods. Additionally, the nanocomposite displayed comparative antimicrobial action against Pseudomonas aeruginosa, Escherichia coli, and Bacillus subtilis and indicated fair activity on 2,2-diphenyl-1-picrylhydrazyl scavenging with IC50 values 0.73 mM depicting its efficient antimicrobial and antioxidant activity. Thus, the present article has disclosed a revolutionary way for fabricating Ag-SnO2 nanocomposites and depicted their multifunctional efficacy as photocatalysts and reducing and prospective antibacterial and antioxidant agents.

Contrary to conventional ATRP, aqueous A(R)GET-ATRP at ambient temperature without deoxygenating reaction solutions is an extremely facile method to create polymer brushes. Using these techniques, extremely thick poly[2-(dimethylamino)ethyl methacrylate] polymer brushes can be prepared (∼700 nm), or reaction solutions can be low chemical-content, consisting of 99% v/v water. Based on these techniques, we have also developed an easy and inexpensive method, referred to as "paint on"-ATRP, that directly pastes reaction solutions onto various large-scale real-life substrates open to the air. The resulting brush surfaces possess excellent oil-repellent properties, which can be activated or deactivated in response to solution pH.

Janus particles represent a unique group of patchy particles combining two or more different physical or chemical functionalities at their opposite sides. Especially, individual Janus particles (JPs) with both chemical and geometrical anisotropy as well as their assembled layers provide considerable advantages over the conventional monofunctional particles or surfactant molecules offering (a) a high surface-to-volume ratio; (b) high interfacial activity; (c) target controlling and manipulation of their interfacial activity by external signals

such as temperature, light, pH, or ionic strength and achieving switching between stable emulsions and macro-phase separation; (d) recovery and recycling; (e) controlling the mass transport across the interface between the two phases; and finally (f) tunable several functionalities in one particle allowing their use either as carrier materials for immobilized catalytically active substances or, alternatively, their site-selective attachment to substrates keeping another functionality active for further reactions. All these advantages of JPs make them exclusive materials for application in (bio-)catalysis and (bio-)sensing. Considering "green chemistry" aspects covering biogenic materials based on either natural or fully synthetic biocompatible and biodegradable polymers for the design of JPs may solve the problem of toxicity of some existing materials and open new paths for the development of more environmentally friendly and sustainable materials in the very near future. Considering the number of contributions published each year on the topic of Janus particles in general, the number of contributions regarding their environmentally friendly and sustainable applications is by far smaller. This certainly pinpoints an important challenge and is addressed in this review article. The first part of the review focuses on the synthesis of sustainable biogenic or biocompatible Janus particles, as well as strategies for their recovery, recycling, and reusability. The second part addresses recent advances in applications of biogenic/biocompatible and non-biocompatible JPs in environmental and biotechnological fields such as sensing of hazardous pollutants, water decontamination, and hydrogen production. Finally, we provide implications for the rational design of environmentally friendly and sustainable materials based on Janus particles.