Efficient and ecological production of advanced conductive and non-toxic (bio)materials and composites based on polypyrrole

Development status

Phase 2

Feasibility study. There is a realistic design of the technology and the initial tests in the laboratory are leading to the specification of the technology requirements and its capabilities.

IP protection status

Patent CZ 310455 https://isdv.upv.gov.cz/doc/FullFiles/Patents/FullDocuments/310/310455.pdf PCT https://cz.espacenet.com/publicationDetails/originalDocument?CC=WO&NR=2025002490A1&KC=A1&FT=D&ND=3&date=20250102&DB=EPODOC&locale=cz_CZ#

Partnering strategy

Co-development, Collaboration, investment, licensing, spin-off

Institution

Univerzita Tomáše Bati ve Zlíně
Tomas Bata University in Zlín

Challenge

The conductive polymer polypyrrole (PPy) shows good conductivity, stability, and biocompatibility, making it suitable for both electronics (batteries, supercapacitors) and biomedical applications. However, standard PPy synthesis methods often use strong oxidizing agents and toxic substances. Additionally, PPy is relatively brittle and difficult to process. Therefore, PPy is mainly used in composites, usually blended into the matrix. Because PPy isn't anchored, the composites prematurely degrade under stress, releasing PPy and losing their properties, hindering industrial application. The motivation for the present invention was to develop a new, simpler, and "greener" method for preparing PPy-based conductive materials that would overcome the above-described drawbacks. This method allows firm binding of PPy to the matrix, increasing the composites' stability, safety, and lifespan, decreasing the fabrication costs while eliminating toxic oxidants or complex modification steps.

Description

The technology relates to a method for preparing conductive copolymers and composites based on polypyrrole (PPy). Composites have low toxicity and enhanced stability and are particularly suitable for biomedical and environmental applications. The method can be used to prepare conductive composite (nano)particles, (nano)fibers, membranes, hydrogels, or 3D porous structures. The method is based on the use of polysaccharides from renewable sources (cellulose, alginate, hyaluronic acid, dextran...). In the first step, polysaccharides are selectively oxidized to dialdehyde polysaccharides (DAP), while the oxidizing agent used can be regenerated even on an industrial scale. A key step of the method involves the utilization of a spontaneous condensation reaction between the aldehyde groups of DAP and pyrrole, leading to the formation of stable covalent bonds. This reaction occurs in an aqueous medium under mild conditions and is highly efficient. Subsequently, spontaneous chaining of attached pyrrole rings into (co)polymers (DAP-PPy) occurs. This process is highly accelerated by slightly elevated temperatures. Other polymerization methods are thus not required. DAP also acts as a template for the formation of (co)polymers with PPy. Various materials thus can be prepared, ranging from nano/microparticles, through (nano)fibers, yarns, and textiles, to conductive hydrogels that accelerate wound healing. Resulting (co)polymers exhibit strong anti-inflammatory properties and very low toxicity compared to other PPy-based materials, making them particularly suitable for biomedical applications. In addition to polysaccharides, various other hydrophilic polymers (e.g., polyamide), which can be impregnated with a DAP solution, can also be used as templates. Prepared (co)polymer templates can be further utilized as matrices for the preparation of conductive composites in combination with traditional PPy preparation. When polymerization of pyrrole is initiated in the presence of the (co)polymer matrix, PPy chains preferentially grow on its surface, incorporating bound pyrrole cycles, thereby bonding the matrix and the conductive polymer layer. This enhances the durability and stability of the PPy composites and reduces the required amount of reactants.

Commercial opportunity

The technology offers a more efficient and environmentally friendly route for producing advanced conductive and non-toxic (bio)materials and composites containing the conductive polymer PPy, with significant potential in sectors such as biomedicine, wearable electronics, sensors, and energy storage. The technology is highly versatile, allowing for the use of various substrates, particularly from renewable sources, and the preparation of a wide array of different materials (particles, fibers, hydrogels...). Due to the spontaneous formation of covalent bonds with DAP, PPy is firmly anchored within the materials, preventing its release from the matrix. Composites prepared using this method therefore exhibit enhanced durability and a longer lifespan. The simplification of the manufacturing process, utilization of renewable resources, and elimination of toxic substances can lead to cost reduction and improved production safety. Biological testing of these materials indicates very low toxicity, the ability to suppress inflammation, and accelerated healing. Furthermore, the conductivity of the composites is comparable to those prepared using traditional methods. Currently, efforts are being made to prepare clinical testing of hydrogel-based products for chronic wound healing, and the development of membrane (bio)sensors, conductive fabrics, and highly porous 3D sponges for electrocatalysis.