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A REVIEW ON NANO COMPOSITES FOR SENSOR APPLICATIONS

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Abstract

Due to their significantly greater exposed surface area, conjugated polymer nanomaterials are proven to perform better than traditional materials. This work provides an overview of new synthetic methodologies that involve template-free and template-oriented procedures that are ideal for conjugated polymer nanomaterial growth, as well as their benefits and uses in the fabrication of nanodevices. This review covers the properties of conducting polymers with nanostructures and polymer nanocomposites, as well as their use in biosensors and sensors.

Introduction

Techniques for creating nanocomposites

There are other ways to create nanocomposites, however the three processes listed below are crucial. These three techniques are: (1) melt-mixing technique; (2) solution casting method; and (3) in situ reaction.

1. Reaction in situ

When producing nanocomposites using in situ polymer methods, appropriate initiators such as heat and radiation are typically present. This method involves mixing the nanoparticle in a monomer solution or liquid monomer.

2. Solution casting methodology

The foundation of the solution casting approach is Stokes' law. This process involves equally blending the polymer and prepolymer to make them soluble in the appropriate solution. While the nanoparticles dispersed within the same solution or in a different solution, the polymer, which was the matrix phase, dissolved easily soluble in the fluid. In the end, both were combined. For instance, the solution needs to swell to clay to suggest miscibility when creating clay-based nanocomposites [15]. Weak van der Waals force spreads the clay, causing layers to build up on top of one another in a multilayered pattern. After swelling, the solution is spread over the clay; in the solvent, a lengthy polymeric chain breaks, a process known as lysis. Adsorbed onto the silicate surface are the solvent particles. The desorption of solvent molecules from polymer/clay composites results in a decrease in entropy. The entropy lowers in this way to form an intercalated chain. The structure of the nanocomposite is established by the evaporation of solvent molecules [16].

3. Melt-mixing methodology

The melt-mixing approach involved the mixing of nanoparticles while they were still molten. This procedure involves combining modified clay with particles and letting them break down. Peeling of platelets is the term used to describe the long-term melting nanocomposite clay. A specific nanocompound, such as carbon nanotubes (CNTs), disperses the nanoparticles, indicating their breaking. The particle was scattered by the aggregation nanoscale during the melting process. The rate at which the polymer degrades determines the temperature and pressure.

Polymer-based nanocomposites

The linear or cross-linked combinations of their monomer units are known as polymers. Composites are materials composed of two or more constituent materials that have different phases and characteristics. Polymer composites are materials composed of polymers, consisting of two phases: the matrix phase, which has a low bulk modulus and high elastic properties, and the reinforcing phase, which has a very high load capacity. The characteristics of a polymer composite are wholly distinct from those of its constituent parts. Polymers are highly elastic and flexible materials that are often used as matrix components. The micro- and nanoscale region is where composite materials work best. Materials of two phases are equally combined in nanocomposites within a nanoscale range that does not exceed 100 nm. The polymeric composite determines the morphology of nanoparticles, such as spherical and platy. The increased mechanical, optical, and electrical capabilities of nanocomposites are based on polymers and nanoparticles in both their inorganic and organic states. Nanocomposites are used in a variety of scientific and technological domains, including biology, medicine, electronics, and chemistry, because of their exceptional and unmatched qualities in the past [1–8].

Sensor

It is an electronic device, module, or subsystem that, after detecting events in its surroundings or around it, transmits or delivers the information to other electronic devices, such as a computer processor. A sensor can be as simple as a light beam or as complicated as a computer system; it is never an isolated device and is always connected to other electrical equipment. A sensor's sensitivity quantifies the amount that a measured input change results in an output change in the form of a signal. Analog to digital or analog to analog conversion can be used for sensing. In general, there are two categories of sensors found in nature. (a) Biosensor: All living things contain biological sensors, which are comparable to mechanical devices when we think about the biological world. Certain specialized cells or tissues, which are responsive to light, temperature, gravity, sound, humidity, wetness, vibration, electric field, and magnetic field, perform the sensor functions. Aside from these, the cells are responsive to hormones, poisons, and nutrients. They are also responsive to metabolic markers such as osmotic pressure, glucose, and oxygen concentration. (b) A chemical sensor is an analytical instrument that operates independently and can offer data on its surroundings, including the concentration, reactivity, and states of matter (solid, liquid, or gas phase). Everyday objects like touch-sensitive lamps, escalators, and fingerprint-sensing buttons are examples of tactile sensors in use. Technological advancements have led to the use of MEMS technology in the robotics, aerospace, automotive, and medical sectors. Analog sensors like potentiometers and force-sensing resistors are employed alongside analog sensors like thermoregulators and microcontroller platforms, which are used to measure pressure and temperature flow.

Sensor development

Creation of the biosensor

PCN is employed as an electrode in the glucose biosensor detecting system. In order to immobilize biomolecules, the electrode surface is modified using clay. The electrode surface was immobilized using GOx, and the biosensor was stabilized by glutaraldehyde acting as a cross-linker [18]. Because of their aromatic conjugated units, clay nanocomposites and enzyme molecules adhere securely to the polymer matrix. The precise immobilization of the enzyme allows the designed biosensor to work exceptionally well. GOx operates within the range**.** The pH ranges 3.0 to 8.0; GOX, on the other hand, has an acidic pH of 4.2. Another study used a one-step noncovalent adsorption technique to biofunctionalize proteins onto SWNTs. In a biological application, this synthesized SWNT-protein was employed as a biosensor and added to PPy as a single negatively charged anionic dopant [19]. Several proteins, including cytochrome c, HRP, and bovine serum albumin (BSA), were sonicated in to increase the solubility of SWNTs in water. Additionally, it has a wide range of technological uses, including fuel cells and other types of electrochemical cells. When compared to film that is entrapped with an enzyme, the created nanocomposites were utilized for the detection of peroxides, such as hydrogen peroxide.

Using an equimolar ratio of clay laponite (L) to montmorillonite (MMT) in aqueous dispersion, the gelation method is used to generate nanocomposites (L/MMT¼1:1). The homogenous gel formed a clear nanocomposite film with good thermomechanical characteristics. ITO (indium tin oxide) was deposited on glass plates using the drop casting method to create the sensor electrodes. Ascorbic acid (AA), oxalic acid (OA), glucose (Glu), and cholesterol (ChO) in the concentration range of 1–20 mM were detected using the cyclic voltammetry method. The nanocomposites-prepared electrode was employed in this procedure. On the other hand, it was shown that the sensor was more sensitive in detecting cholesterol.

Development of the flexible pressure sensor

A pressure sensor based on aligned carbon nanotubes (A-CNTs) was created to measure blood pressure. Which of the following can be used in an endovascular aneurysm repair technique [20] and coupled to a stent graft? Using PDMS, an A-CNT flexible substrate was embodied to create capacitive sensors. Using silicon substrate with patterned Fe/Al2O3 catalyst, aligned CNTs were grown at air pressure and 750°C in a horizontal quartz tube furnace.

PNCs in sensor-related applications

Improved environmental monitoring, clinical diagnosis in biomedical applications, security surveillance across industries, and food safety are all greatly impacted by electrochemical sensors made from nanomaterials. Because of their high effective enzyme loading and greatest surface area per unit mass, nanoparticles can be used for the optimization of immobilized enzymes [21]. Organic substances including alcohols and volatile molecules like NH3, NO2, and CO were effectively detected by the conducting polymeric materials-based thin-film or composite sensors (VOCs).

Conducting polymers find application in electronics and nanoelectric devices; biochemical sensors benefit from their special qualities, which include low weight, high aspect ratio, large surface area, and flexible transport properties; they are also easily obtainable, inexpensive, simple to process, and scalable [22]. In Fig. 7.3, the creation of nanocomposites is demonstrated. Because of their chemical diversity, adjustable conductivity, and flexibility, conducting polymer nanowires are ultrasensitive, trace-level biological and chemical nanosensors [24, 25]. Compared to bulk materials, these materials have a larger surface area, a deeper gas molecular penetration depth, and are repeatable, which makes them extremely sensitive for biosensor applications.Using a variety of techniques, conducting polymer composites were created, including the polymerization of polypyrrol (PPy) and polyaniline (PANI) nanofibers [26, 27].

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