Nano-Silica and Biopolymer Hybrid Composites for Sustainable (Bio)Organic Sensing Applications

Amar Yasser Jassim[1], Wesam R. Kadhum[2] and Ehsan kianfar[3,*]

[1]Department of Marine Vertebrate, Marine Science Center, University of Basrah, Basrah 61001, Iraq

[2]Department of Pharmacy, Kut University College, Kut, Wasit 52001, Iraq

[3]Young Researchers and Elite Club, Gachsaran Branch, Islamic Azad University, Gachsaran, Iran

Abstract: In the chemical industry, the development of sustainable economic strategies for accessing products with high added value from substitutes and cheaper sources is now more of a challenge. Silica is one of the most frequently used chemicals and is often used in many industrial applications, such as in toothpaste as a cleaning agent, in the rubber industry, and as a reinforcing material. This essay summarizes alternative approaches for the synthesis of salt and hybrid geocide materials. So far, these phases have been synthesized from molecular silane precursors via water-splitting sol-gel chemistry or chlorinated silane incineration processes, and thus indirectly from quartz sand. However, quartz sand is a non-renewable resource, and the scarcity of actual sand is becoming increasingly problematic for various processes in the chemical industry. In fact, quartz sand is the second most common raw material in the world, and its availability has a major impact on many production processes. B. Healthcare or electronic devices. In the actual context of sand shortage, the drafting of silica-based materials is increasingly attracting interest from alternative sources. This summary article discusses the new possibilities for access to bio sourcing and material-based sources such as renewable starting materials, electrical and electronic equipment in waste equipment, or fluorosilicic acid, a by-product of the phosphate industry. Silica must be considered a valuable raw material, and it demonstrates that alternative production processes from renewable resources, as well as cyclical lifetime assessments and valuable recycling strategies for these materials should be considered in consideration of the creation of sustainable and periodic production processes. The exciting science of organic devices has brought about a completely new stage of feasible bio detecting innovation, which offers a prospective horizon for applications in therapeutic diagnostics and organic checking. This audit report provides a thorough analysis of the remarkable advancements in organic electronic devices and their potential for bio detection applications. The need for more accurate, more affordable, and more capable sensors was felt as a result of global scientific advancements, the development of electronic equipment, and the enormous changes that occurred over the last several decades. In order to be sensitive to minute amounts of gas, heat, or radiation, sensors with high affectability are used nowadays. It is necessary to disclose underused materials and devices in order to increase the affectability, capability, and accuracy of these sensors. Due to their small and nanoscale estimates, Nano sensors—sensors that are nanometers in size—have exceptionally high precision and responsiveness, allowing them to react without a doubt to the proximity of many gas particles. Compared to conventional sensors, Nano sensors are inherently more delicate and smaller.

Keyword: Sustainable bio-sensor, Chemical sensor, Pharmacia sensor, Efficiency, Nano sensors, environmental, Nano-Silica, Hybrid Composites.

1. INTRODUCTION

The use of chemical, nano, and biosensors is one of the most fascinating topics in chemistry [1-5]. The number of variables and the categorization of techniques and methods used in this topic can be used to resolve this issue [6-10]. More often than not, this is especially because of the unmet demands that have arisen in useful analysis, routine examination, nutritional analysis, and timing of many things. Sensors, for instance, may be used to identify dangerous chemicals, illegal narcotics, and persons engaged in conflict. Another practical use of biosensors that has received some attention recently is the control of drug action inside the body [11-16]. The structure of a sensor displays examiners of several disciplines, including normal chemistry, science, devices, and the unique branches of chemistry (common, examination, texture science, and surface) and texture science (mechanics, light, and thermodynamics) [17-22]. The identifying element is a sincere endeavor to identify and formally inform the target analyte (species of inquisitive) about a complicated test [23-27]. At that point, the pioneer converts the chemical signals sent to the analyte by the official of the recognizing component into a measurable yield accost [28-33]. Biosensors rely on commonplace elements like antibodies. Additionally, sensors can be made of chemicals, receptors, or cells [34-38]. It is possible to find a recognizing component for analytes for which there are no common receptors with a short time, later cues, and a focus on and correct union of particles (and macromolecules) in normal chemistry [39-44]. This shown particle is somewhat linked to the topic of debilitating and may be used as a sensor component in a chemical sensor (Chemo sensor) [45-50].

2. (BIO)ORGANIC SENSING

A chemical device or species that can converse with an analyte in reverse is called a sensor. A change in a

*Address correspondence to this author at the Young Researchers and Elite Club, Gachsaran Branch, Islamic Azad University, Gachsaran, Iran; E-mail: ehsan_kianfar2010@yahoo.com; ehsankianfar775@gmail.com

Received on 05-09-2025 Accepted on 13-10-2025 Published on 15-10-2025

E-ISSN: 2311-8717/25

quantifiable quantity, such a change in color or fluorescence, is associated with this connection [51-55].

2.1. Detection Methods in Chemo Sensors

In recent decades, the fabrication of nanoscale materials has proven to be a promising avenue for use in chemical sensing and biomedical and biological analysis [56-59]. Nanomaterials have proven promising in such chemical and biological analyses primarily due to their highly customizable size- and shape-dependent chemical and physical properties. Additionally, they have unique surface chemistry, thermal stability, high surface area, and large pore volume per unit mass, which can be exploited for sensor fabrication [60-64]. This review discusses the chemical and physical properties of nanomaterials required for use as chemical and biosensors. We also highlight some notable recent approaches using nanoscale materials as scaffolds for chemical and biosensor monitoring [65-70]. As described herein, nanomaterials that have proven useful in sensor fabrication have compositions that include metals, metal oxides, chalcogenides, and polymers. Their structures range from nanoparticles, nanorods, and nanowires to nanopores and nuclear shells [71-74].

- Fluorescence Detection
- Colorimetric Detection
- Electrochemical Detection

Every one of these tactics has advantages and disadvantages. Fluorescence is a widely used method that may have very high affectability. Although it contains a lesser affectability, the colorimetric approach is equivalent to fluorescence. Although the electrochemical approach is used for some species, its affectability is high and the hardware needed is simple [75-80].

2.2. Fluorescence-Based Sustainable Bio-Sensor Principles

The two essential parts of chemical sensors are the collector of this salute and the fluorophore, which is the allocate that generates the accost. The fluorophore shows up a change in salutation within the form of a color adjustment or fluorescence, and the receptor binds to the analyte within its proximity [81-85]. Figure **1** shows the elements that make up a chemical sensor. The excitation of an electron from the atom's highest elevated orbital (HOMO) to its smallest had orbital (LUMO) causes a photon or fluorescence spike in a coordinate arrangement. As you can see in Figure **1**(**b**), a combination of non-bonded electrons is positioned inside the fluorophore particle's area. This orbital is crucial because it is between the fluorophore's HOMO and LUMO orbitals [86-90]. In the absence of light, one of the non-bonded electrons is traded to the HOMO orbital fissure of the fluorophore, which is created after the electron excitation, energizing the electron from the HOMO orbital to the LUMO [91-95]. The excited electron is transferred to a non-bonding orbital, which stops the fluorescence instead of going back to the ground state. Photoinduced Electron Transfer (PET), is the name of such a device [96-100]. The essentiality of this orbital will decrease and the exchange of the electron to the homo orbital's crevice will be expected if the same non-bonding electron combination becomes interested in a holding interaction, as shown in Figure

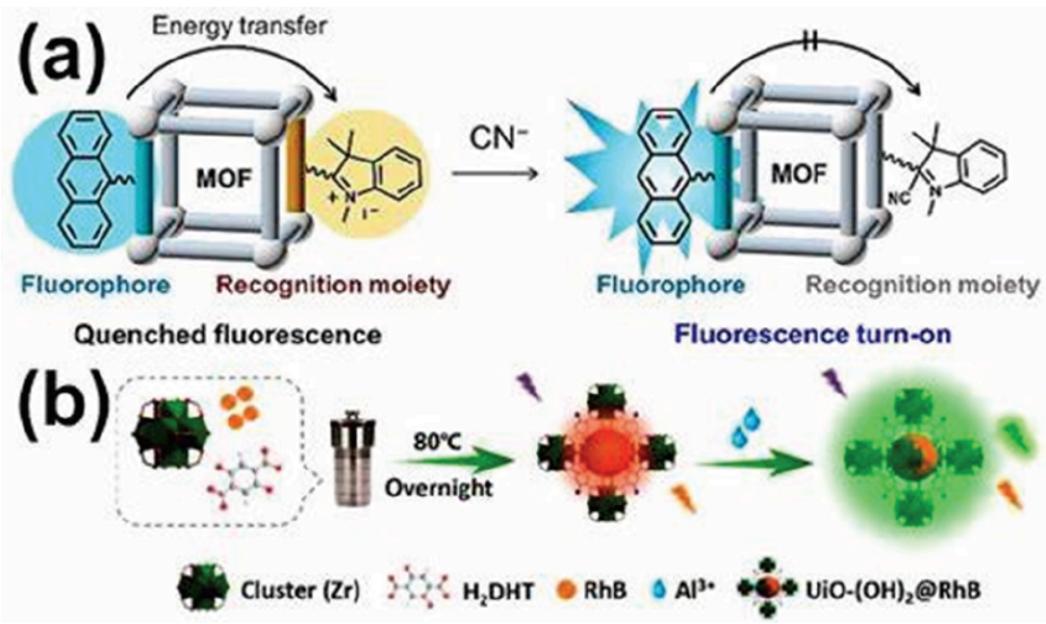

Figure 1: Components of an organic chemical sensor [1-2].

1(**b**). With the emission of radiation, the energetic electron from the LUMO orbital returns to the ground state; this phenomenon is known as Chelation-Enhanced Fluorescence (CHEF) [101-106].

3. ANION SUSTAINABLE BIO-SENSOR

Numerous anions, including fluoride, cyanide, phosphate, nitrate, pyrophosphate, and others, can be detected using a variety of bioorganic sensors. Some of these are listed below [40].

3.1. Fluoride Ion Detection via Fluorescence using an Ion-Sustainable Biosensor

Functionalization of nano silica by a distinctive particle Fluorescence change inside the vicinity of the fluoride anion during watery action, as seen in Figure **2**(**b**). The fluorescence does not change the proximity of other anions such bromide, iodine, and sulfate, as seen in Figure **2**(**a**). In the interim, a change in fluorescence occurs due to the proximity of the fluoride anion and the formation of hydrogen bonds with nitrogen hydrogens [107-111]. Here, the fluorescence is stopped because nitrogen exchanges non-bonded electrons with the sensor's fluorophore allocate.

3.2. Sensor for Detection of Phosphate Anion Through Colorimetry

This sensor uses fluorescein reinforcement to identify phosphate anion. Its fluorescein allocation takes on a certain hue. As seen in Figure **3**, this sensor is made up of crossover materials with nanoscale anion authoritative acceptor targets. The opacity of mesoporous nano-silica is caused by the absence of the phosphate anion, the anionic subordinate of fluorescein. This reinforcement is released into the environment because to the proximity of the phosphate anion, as seen in Figure **3** and is the cause of the color change [112-117]. Consequently, the fluorescein reinforcement's release into the environment is actually what led to the development of the salute.

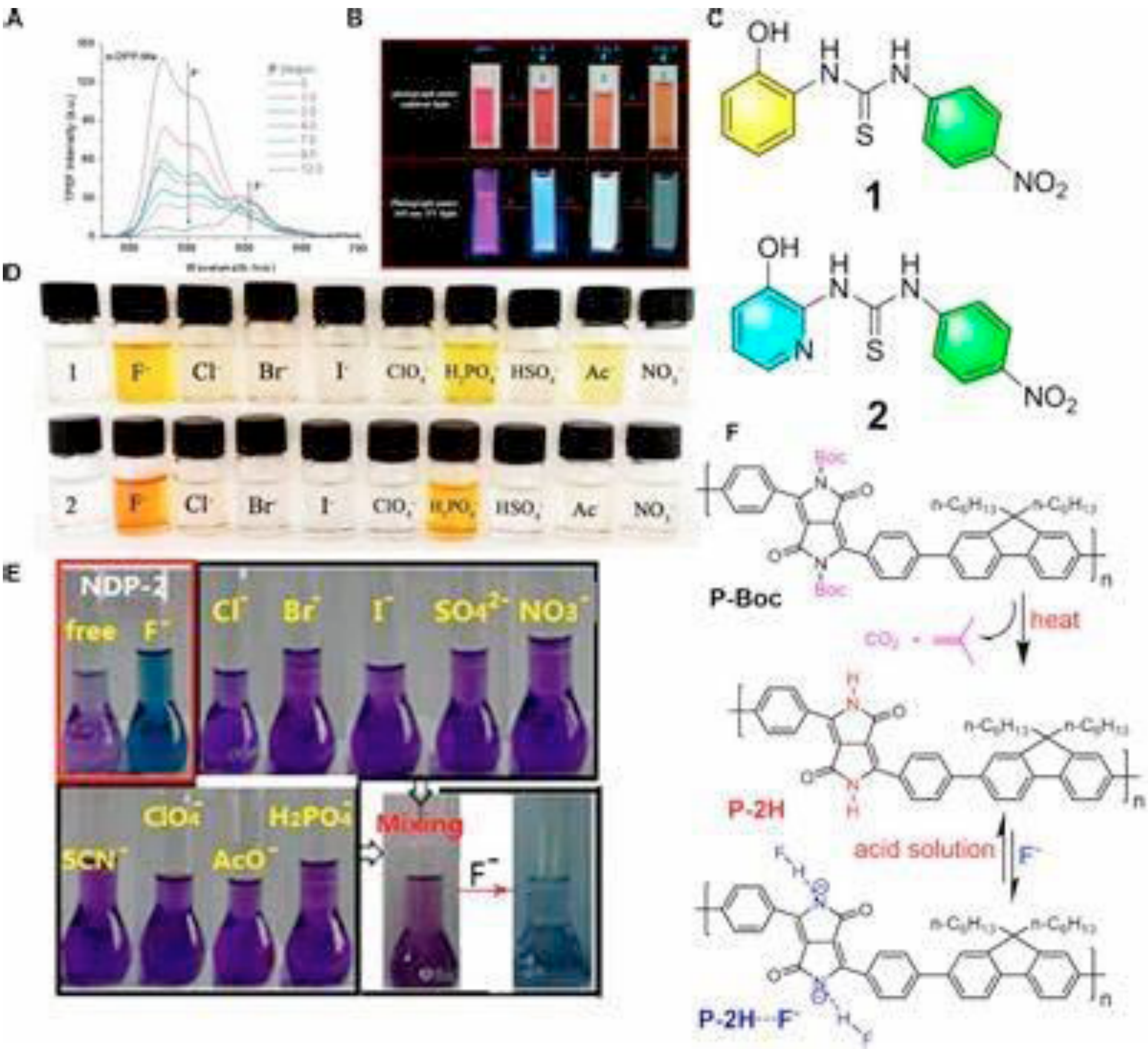

Figure 2: An ion sensor that uses fluorescence to detect fluoride ions [3].

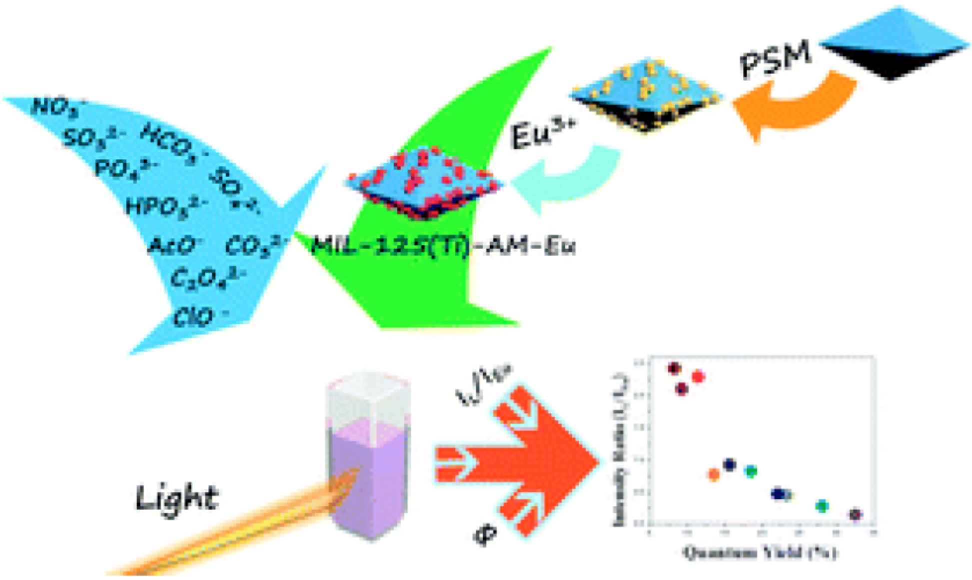

Figure 3: Phosphate anion detection sensor [3].

4. CATION SENSORS

4.1. Sensor to Identify Copper Cation Through Colorimetry

The purpose of this sensor is to differentiate between copper cations. By functionalizing silica nanotubes with organic particles, this sensor is created [118-123]. The color of functionalized silica nanotubes is shown in Figure **4**(**a**) when no cations are nearby, in Figure **4**(**b**) when copper cations are nearby, and in Figure **4**(**c**) when additional cations are nearby. Additionally, the interaction between copper and the acceptor position on the silica nanotube is shown in Figure **4**(**d**).

4.2. SENSOR for the Detection of Mercury Cations Through fluorescence

Research presents a cationic chemical sensor for lead particles that is built on core-shell silica nanoparticles on press oxide. In this study, an organic chemical is used to functionalize the core-shell nanostructure [124-127]. Figure **5** shows how this sensor's fluorescent changes. When an organic atom is close to a cation, it emits radiation.

5. CHEMO DOSIMETER IRREVERSIBLE CHEMICAL SENSORS

These sensors are indicative of sensors that undergo irreversible reactions with the analyte; the alteration within the normal species' structure is what

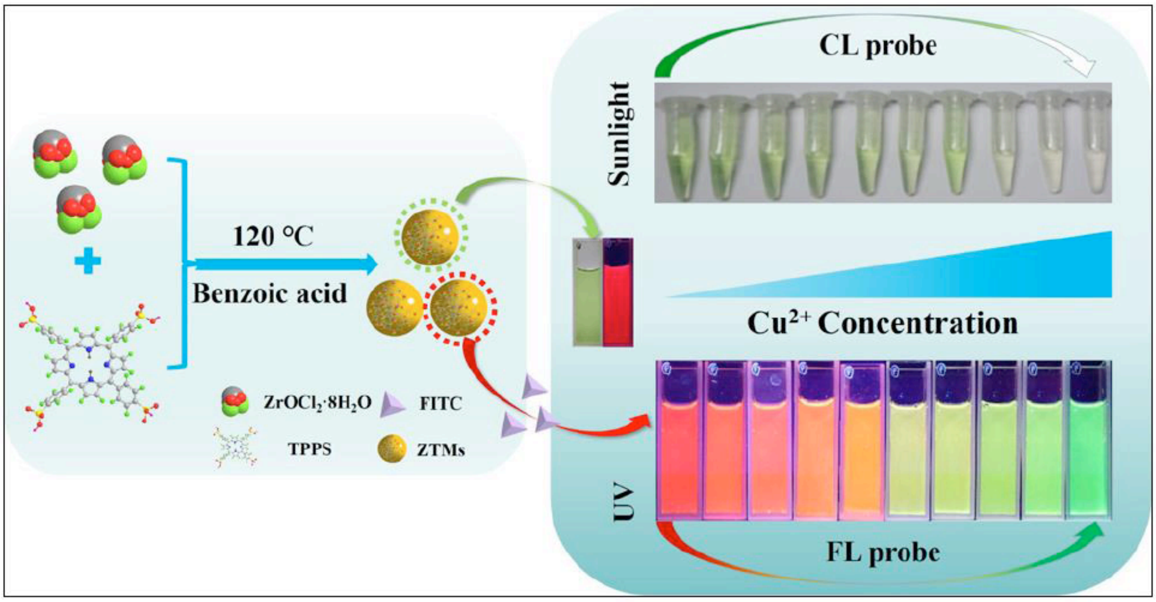

Figure 4: Colorimetric sensor for copper cation identification [3].

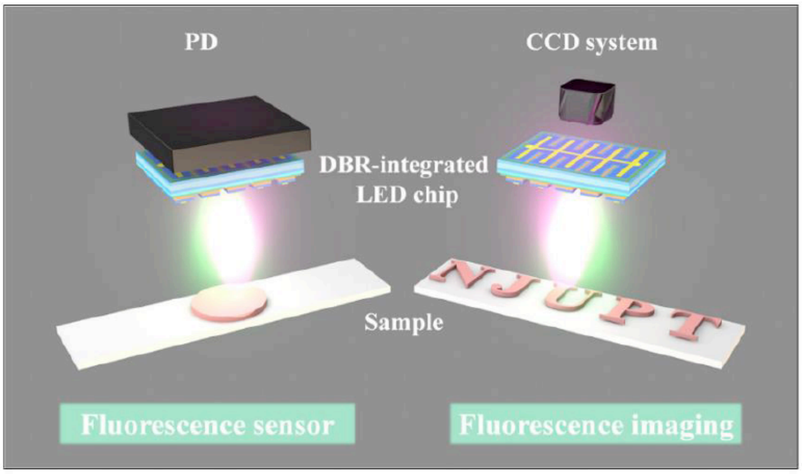

Figure 5: Fluorescence-based sensor for lead cation detection [4].

causes the color shift or fluorescence modification in these sensors. These sensors have undergone an irreparable alteration. Examples of this type of sensor are provided below to help with memorization [128-131].

5.1. CHEMO Dosimeter Based on Gold Nanoparticles for Detection of Nitrate Anion Through Colorimetry

To identify unique structures including DNA, proteins, tiny particles, metal cations, and cancer cells, functionalized gold nanoparticles that exhibit specific optical characteristics are used. Figure **6** shows the nitrate anion zone's chemo dosimeter. Two functionalized gold nanoparticles in this chemical situation undergo a bimolecular reaction inside the proximity of the nitrate anion, which results in the coupling of these two particles and color adjustment [132-137]. Figure **6**(**b**) illustrates this color change within the proximity of different nitrate anion concentrations.

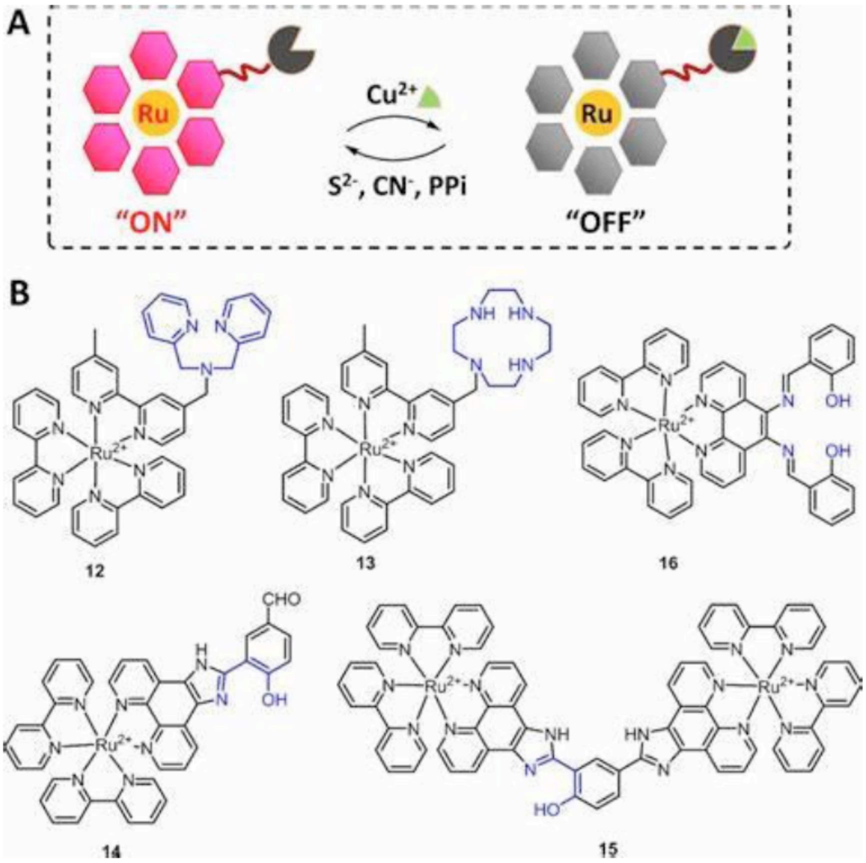

Figure 6: Chemo dosimeter for anion [4].

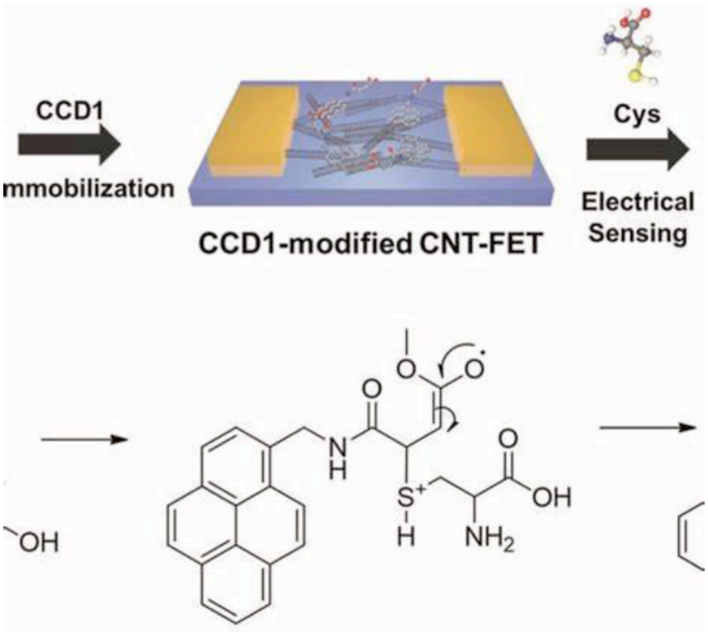

Figure 7: Nano-silica-based chemo-dosimeter for copper cation detection [3].

5.2. Chemo Dosimeter Based on Nano Silica to Identify Copper Cation Through Fluorescence and Colorimetry

Copper cations are intended to be recognized by this chemo dosimeter. The structure may function as a chemo dosimeter with the dual characteristics of color change and fluorescence when the copper cation is nearby. It does not exhibit any change in fluorescence when it is in close proximity to other distinguishing cations, as you can observe [138-142]. A change in the particle's structure, as seen in Figure **7**, results in a change in color and fluorescence when the copper cation is close by.

6. MOLECULAR SENSORS

6.1. Sensor for Glucose Detection

A composite of nano-silica and organic molecule was engineered, which functioned as an effective sensor for X due to its specific interfacial properties (Figure **8**). However, boron acquires a negative charge when saccharide is present and interacts with it. In this instance, nitrogen experiences an increase in the production of positive charge [143-146]. When a hydrogen bond forms, nitrogen acquires a positive charge that stops electrons from moving and causes a shift in fluorescence.

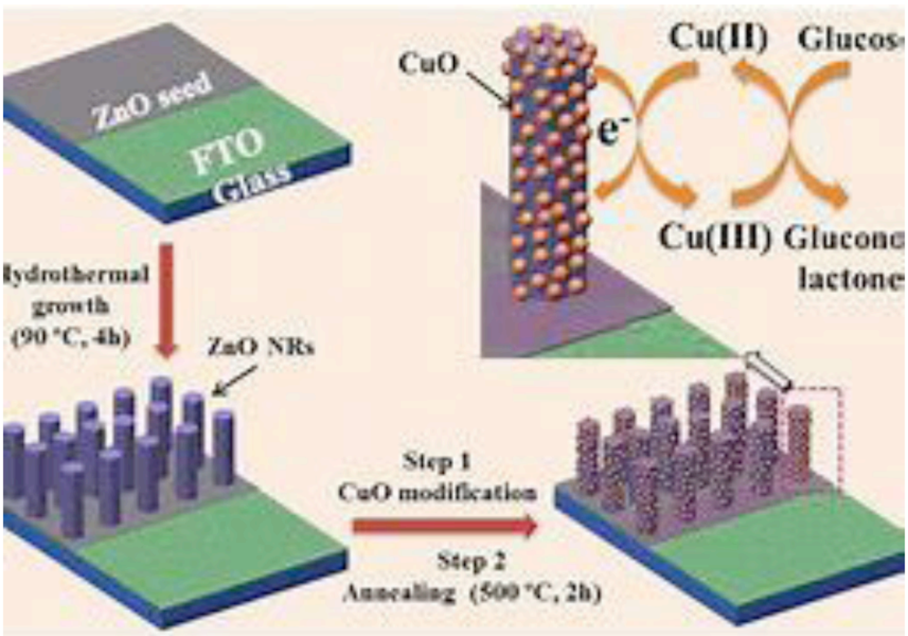

Figure 8: Glucose detecting sensor [4].

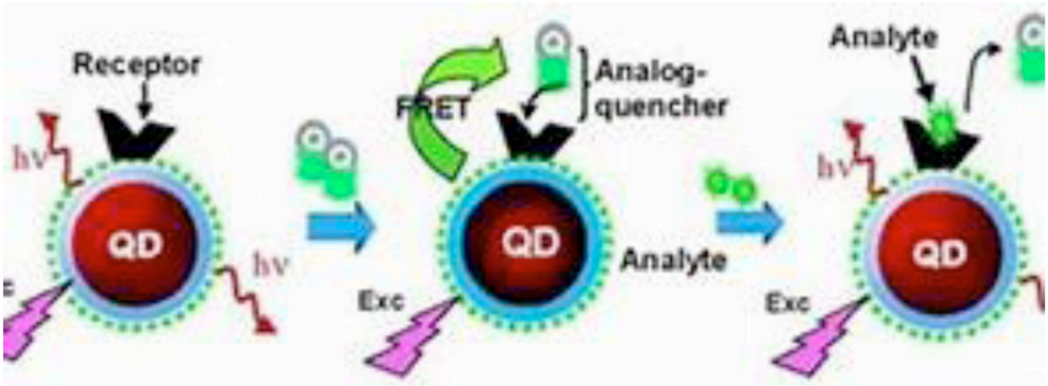

Figure 9: A trinitrotoluene detection sensor [5].

6.2. Nanoparticle-Based Molecular Sensor used for the Detection of Trinitrotoluene

In Figure **9**(**a**), a sensor for detecting TNT (trinitrotoluene) was depicted. A small number of conjugate-bonded polymer strands make up this sensor [147-151]. This polymer string's units are shown in Figure **9**(**b**). Based on the change in the fluorescence of the pyrene species deposited on the nanoparticle in the vicinity of TNT, the functionalized ruthenium metal nanoparticle has been used to differentiate trinitrotoluene (Figure **9**(**c**)).

6.3. Biological and Environmental Applications of Sensors Based on Magnetic Nanoparticles

Engaging nanoparticles with organic-mineral crossovers are particularly capable of identifying and allocating particles in routine and standard testing. Various clinics have thought about limiting the initial figure of the disease from blood. Typically, layers are used to specifically hold small particles that are restricted to small particles, such serotonin, potassium, and urea. These films cannot be used to limit normal materials because they are too broad [152-157]. In a study, lead was separated from human blood using nickel nanoparticles tagged with molecule 1. As seen in Figure **10**, the acceptor objectives' absorption of lead causes a change in fluorescence. Because to this nanoparticle's interest, all of the lead is retained inside the blood after 30 minutes and can be separated using a magnet. It is possible that uranium is a naturally occurring radioactive metal [158-162]. This species is growing and is occasionally observed in public waterways, which is dangerous for human survival. Thus, the coordination of sensors capable of identifying and separating this species has been highly esteemed. By using charming press nanoparticles enhanced with bisphosphonates, they were able to adequately identify and retain these particles in their investigation [163-168]. Figure **11** shows how to distribute effectively.

6. COMPOSITE" AND "BIODEGRADABLE"

6.1. Composite Structure

Due to the synergetic or complementary results among organic and inorganic components, which could bring about stepped forward houses or performances,

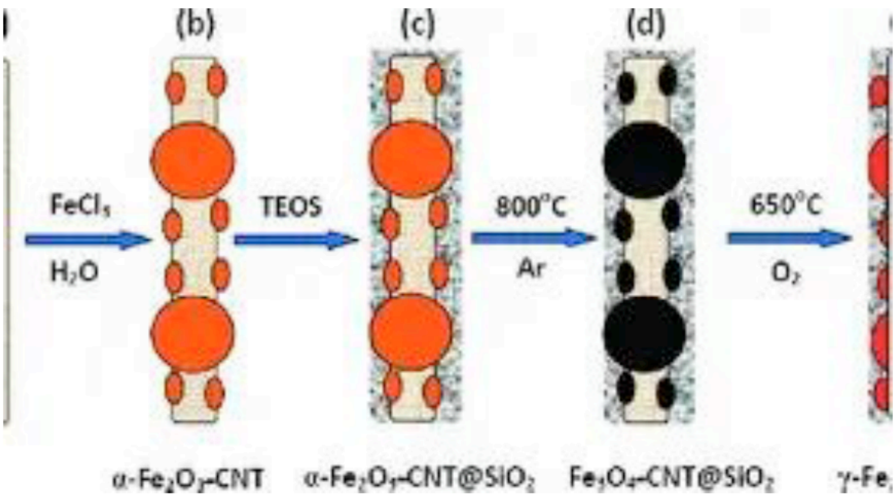

Figure 10: Magnetic Nano silica synthesis for blood-lead separation [6].

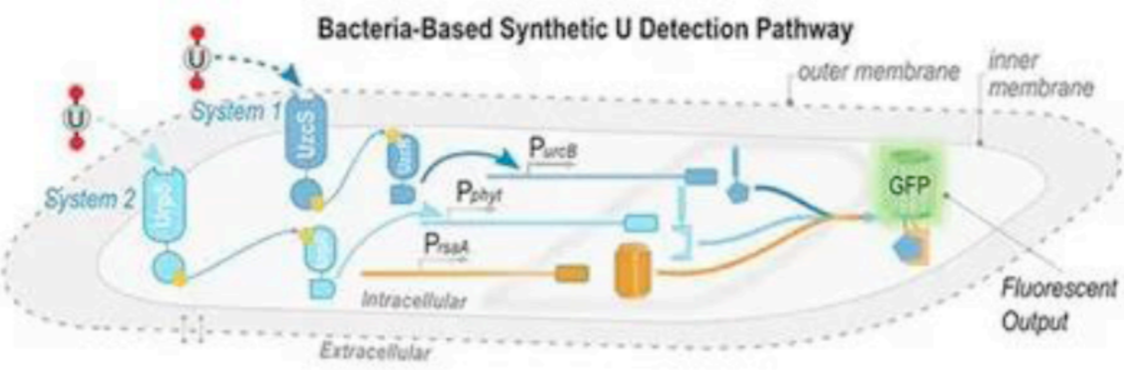

Figure 11: Uranium detection sensor [6].

the organic/inorganic hybrid substances have currently won a sizeable hobby in lots of fields [169-172]. Up to date, many reviews have been posted primarily based on the organic/inorganic hybrid substances for the sensor applications. The paper furnished a complete assessment of the latest development of the organic/inorganic hybrid sensors. The organic/inorganic hybrid sensing substances will be fabricated in numerous configuration kinds which include intercalating kind, core–shell kind, coating kind and blended kind [173-176]. The sensing shape of the hybrid sensors will be supplied in thin-movie, thick-movie or pellet shape, and the sensing performances may want to be measured within the flowing or static-kingdom system. The hybrid sensing substances have been implemented in fuel Oline sensors, humidity sensors, ultraviolet sensors, stress sensors, electrochemical immunosensors and fluorescent chemo sensors [177-182].

Growing concerns about environmental protection have led to the continued expansion of sensor development. A sensor is a converter that converts energy foam into another suitable shape suitable for further processing. While many types of sensors are well established in industrial, agriculture, medicine and many other fields, the development of sensor materials with high sensor skills is still underway at an unprecedented pace. Inorganic and organic compounds have been proposed as sensory materials and are becoming increasingly popular due to several special benefits [183-186]. In general, inorganic compounds generally have high chemical and thermal stability, allowing for applications under a variety of operating conditions. It can be obtained through cost-effective procedures and can be easily separated into thin or thick film formats with a variety of techniques. Organic compounds are characterized by their synthetic versatility and reactivity. This allows modulation of the molecular structure of the detection material to improve selectivity for target analytes. Furthermore, in the field of sensors, organic detection materials such as conductive polymers (polyaniline (PANI), polypyrrole (PPY), and polyhyophen (PTP) can show the disadvantages of individual inorganic or individual organic detection materials, namely high operating temperatures and low operating temperatures for inhibitory systems of muscular, muscular, emergency materials. This study shows that mechanical strength and chemical stability can be improved by adding inorganic particles to organic materials for the formation of hybrids [188-190]. According to this idea, the most common approach was that inorganic connections are exploitation as protective matrix, and organic units, which are detection components, are distributed by various techniques. On the other hand, another more attractive approach is that hybrid materials work together both components of the detection mechanism, leading to improved services. Thus, in recent decades, organic/inorganic hybrid materials with different combinations of two components expected to receive new art composites with synergistic or complementary behaviors have attracted the attention of many electronic, optical, magnetic, or catalytic applications. country. Regarding sensor applications, many reports have been published based on organic/inorganic hybrid recording materials for alleyways, moisture sensors, UV sensors, stretch sensors and other sensor applications. However, there is still no special review of the recent development of inorganic/organic hybrid materials for sensors. Research over the past decade prepared various/inorganic hybrids including PTP/SNO2, PPY/SNO2, PPY/WO3, PTP/WO3, PPY/ZNO, PANI/ZNO/ZNO and PPY/d ex-fe2O [191-193]. Gases such as NH_3, H_2S, NO_2, methanol, ethanol, and acetone. Gas barriers showed that the hybrids exceeded each alleyway in the alley compared to individual components in space or cold temperatures [194-196]. Experimental data also showed that the hybrids had higher thermal stability than pure polymers. This was advantageous for potential applications as chemical sensors. Based on research and detailed reference tests, we present a comprehensive study on the development of sensors based on the latest inorganic/organic hybrid recording materials. Researchers looking for new material for advanced features are expected to receive valuable information from the overview [197-203].

MS Saveleva *et al*. [69] Hybrid substances, or hybrids incorporating each organic and inorganic constituents, are rising as a completely amazing and promising elegance of substances because of the diverse, however complementary nature of the houses inherent in those one-of-a-kind training of substances. The complementarity results in a great synergy of houses of favored fabric and ultimately an end-product. The variety of resultant houses and substances used within the production of hybrids results in a completely vast variety of software regions generated through attractive very one-of-a-kind studies communities. We offer right here a fashionable type of hybrid substances, in which organics–in-inorganics (inorganic substances changed through organic moieties) are prominent from inorganics–in–organics (organic substances or matrices changed through inorganic constituents). In the previous area, the floor functionalization of colloids is prominent as a stand-by myself sub-area. The latter area—functionalization of organic substances through inorganic additives—is the point of interest of the modern evaluation. Inorganic constituents, frequently within the shape of small debris or structures, are the product of minerals, clays, semiconductors, metals, carbons, and ceramics. They are proven to be integrated into organic matrices, which may be prominent as training: chemical and biological. Chemical organic matrices encompass coatings, motors and drugs assembled into: hydrogels, layer-through-layer assembly, polymer brushes, block co-polymers and different assemblies. Biological organic matrices embody bio-molecules (lipids, polysaccharides, proteins and enzymes, and nucleic acids) in addition to better stage organisms: cells, bacteria, and microorganisms. In addition to imparting info of the above type and evaluation of the composition of hybrids, we additionally spotlight a few hostile yin-&-yang houses of organic and inorganic substances, evaluation packages and offer an outlook to rising trends.

6.2. Hybrid and Composite Materials

Examples include improvements or modifications to mechanical and elasticity, optical, catalytic, electrochemical properties, sensors, waterproofing, corrosion prevention, insulation, and more for cell adhesion [204-208]. Figure **12** shows the selected uses of inorganic-organic hybrid materials and shows some images of the corresponding materials. The various applications shown in Figure **12** are the result of the combination of complementary properties of the corresponding materials. Further applications of these materials are discussed [131-137].

The introduction of inorganic particles into the hydrogel coating allows the formation of a catalytic active interface, while the addition of nanoparticles allows the hydrogel to be controlled [131-133]. Incorporating magnetic nanoparticles into organic coatings is used to induce release functions and manipulate tissue for tissue engineering. Magnetic nanoparticles are also used to impart magnetic response properties to magnetic hydrogels. The hybrid

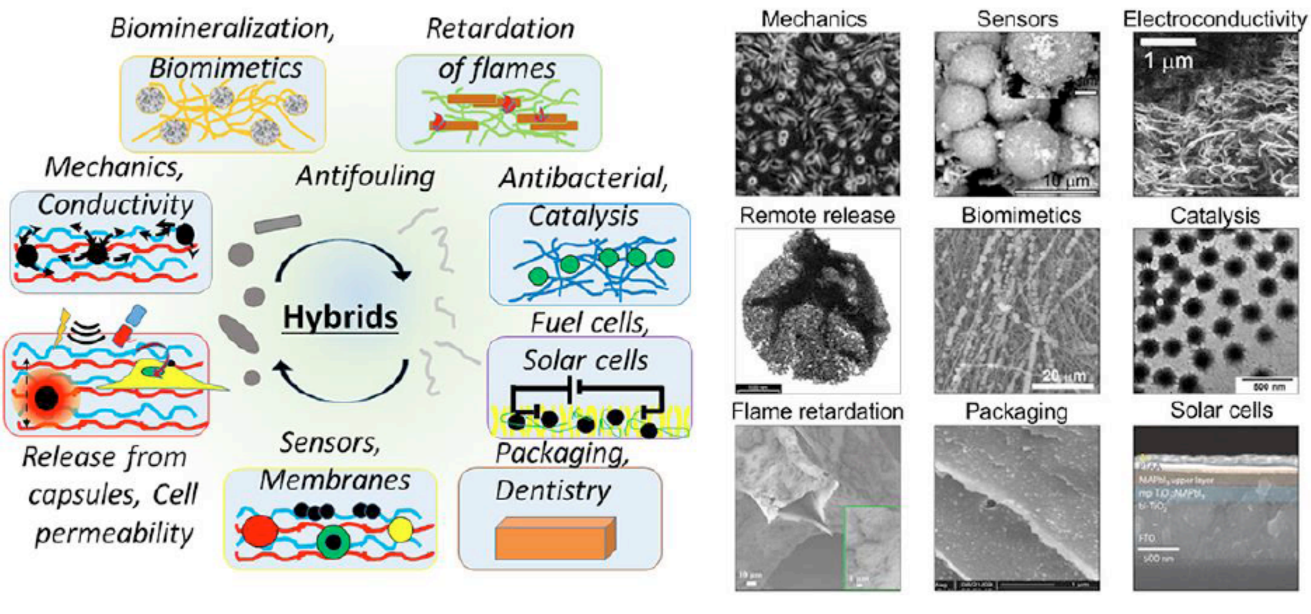

Figure 12: Various changes to the organic matrix due to inorganic components are classified according to their application [131-137].

interfaces created by surface radical polymerization have also been shown to respond to stimuli. Various functions and possibilities for incorporating inorganic components into organic/inorganic coatings have been demonstrated (Figure **12**). Hybrid and functional hybrid materials with precisely designed inorganic/organic interfaces or special properties can overcome a variety of biomedical challenges, including bone tissue regeneration. Figure **3**. Microparticles made of calcium carbonate (father) containing the RGD peptide sequence have a positive effect on biogenicity and serve as templates for the stimulation of mineralization and differentiation of Meekma'll electricity (MSC) *in vitro*. Calcium carbonate is used in a variety of regions [134-137]. The crystallization process of calcium carbonate is complex and involves the formation of various crystalline phases such as calcite, aragonite, and father. Father is an unstable polymorphism that rarely occurs in nature [209-212]. Porous parent calcium carbonate particles are spherical, mesoporous polycrystalline, and possess a number of advantageous properties, including biocompatibility and high biochrome capacity, which is useful for drug delivery applications. Fathe rite microparticles were also used as stabilizers in suspension polymerization and regenerative medicine approaches in industrial settings. One of the most promising applications for this particle is active coating or efficient drug collection as it penetrates micrometer-sized structures such as cells and tissues. The synthesis of CACO3 particles with different properties such as size, surface, porosity, and hydrophobicity makes them good candidates for surface coatings, while loading them with bioactive polymers makes them attractive carriers for the protection and release of medicinal products [138-139]. The morphology and crystalline form of calcium carbonate changed in association with protein-mediated nucleation during biomineralization. CaCO3-lentinane microspheres with hierarchical composite pore structure were prepared by self-assembling of nanoparticles. These structures can significantly reduce the release rate and extend the release time of anticancer drugs, potentially reducing their potential side effects. Nanoparticles were used to synthesize hybrid crystals of CaCO3 and bovine serum (CaCO3/BSA) in the form of flying plates. Crystal nucleation and aggregation have been shown to influence the secondary structure of proteins and provide a promising route for the encapsulation and delivery of various substances in pharmaceutical applications. It should be noted that biomineralization using calcium phosphate is also an important process. Furthermore, the father CACO3 crystals serve as sacrificial templates for the development of bio functional structures for drug harvesting, such as mesoporous carriers from PEG and proteins. In addition to mechanical properties, surface functionalization of the coatings was identified as an important feature. It was confirmed that functionalization of the coating stimulates stimulation and promotes cell proliferation by enzymes and proteins. Recently, it has been shown that adding ALP (alkaline phosphate) to the surface of hybrid scaffolds promotes cell adhesion and lifespan ability through functionalization of hydrogels and calcium carbonate particles [213-216]. The antibacterial properties of coatings are always an important property of coatings. Improving environmentally friendly materials such as pectin is an important advance. It should be noted that organic-inorganic hybrid coatings continue to attract much attention, especially in tissue engineering, where mechanical properties are important. Traditionally, modulation of mechanical properties plays an important role in controlling cell adhesion. The addition of nanoparticles to the polymer matrix is associated with the formation of further chemical crosslinks with the polymer, which improves mechanical properties and therefore must be tailored to cell and tissue adhesion. Figure **13**, Functionalization of polymer films and coatings with remotely activated microcapsules opens up further possibilities for drug delivery from coatings. Metal nanoparticles have also been shown to act as local heating centers and guide cells to the polymer/nanoparticle surface [140]. Lasers can also be used for selective control of polymer surfaces by releasing adsorbed molecules on the surface. Another desirable feature is morphological surface modification. Graduate coatings and recently proposed spongy structures are considered important functional components. Conditioning mechanical properties are recognized as a very important feature and are enhanced by the addition of inorganic particles to the polymer matrix. This is tailored to the materials required to absorb different cells with very different mechanical properties (Figure **13**). Figure**13** shows that organic coatings can be used to adapt the mechanical properties of cells by setting the inorganic fraction (weight fraction). The combination of organic molecules and inorganic nanoparticles has been shown to improve mechanical properties. Similar effects were observed with the addition of carbon nanotubes and carbon nanotube failures containing calcium carbonate particles [217-219]. Furthermore, we used a completely different filler, nanocellulose, to improve the mechanical properties of the soft coating. An investigation of the influence of inorganic feeding on the mechanical properties of soft coatings was also carried out [141].

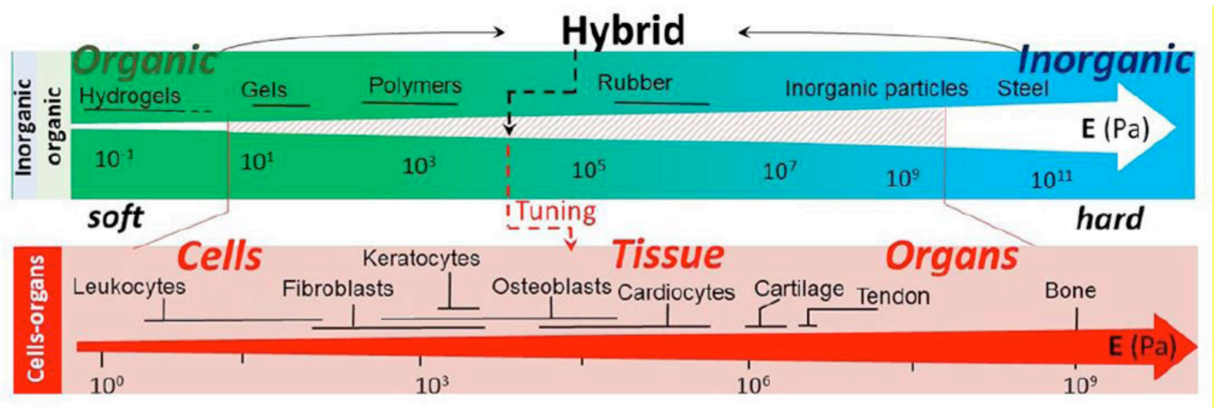

Figure 13: Relationship between the mechanical properties (Young's modulus) of cells, tissues, and organs and the mechanical properties (Young's modulus) of various components of organic hybrid materials [140-141].

6.3. Biodegradability/Sustainability

Reinforced composite materials based on synthetic fibers are used in a variety of industries, including the automotive, aerospace, construction, and medical sectors. This is mainly due to its unique properties and multifunctionality. However, these composite materials are not biodegradable and are harmful to the environment. To overcome this problem, biopolymers were used instead of synthetic fibers to strengthen the composites. The use of biopolymers makes the composite partially biodegradable. However, problems arise when biopolymers are used in composite materials. The biopolymers used are hydrophilic, whereas the matrix materials are mostly hydrophobic. This weakens the interface responsibility between these two components and reduces the properties of the composite material. To solve this problem, nanophytomaterials are used in composite materials. These nanofilm materials improve the interfacial responsibility between these components and clearly improve the properties of the composite materials. The use of Nano plot materials has been shown to improve the mechanical properties, thermal properties, electrical properties, water absorption, etc. of composite materials. The use of nano filters in Com-Positive helps to promote the use of biopolymers to reinforce composites instead of synthetic fibers. This uses non-toxic materials inside the car body, reducing the emission of toxic gases from synthetic parts of the car interior when the car body is heated. This usually occurs when the vehicle is left in the sunlight for a long time. Additionally, the fibers are lighter than synthetic fibers, which increases the strength and weight of the car's components, which improves fuel economy and reduces the pollution caused by the car. Over the past decade, much research has been conducted in various fields related to polymeric nanocomposites, as well as improving the properties of bio composites by adding Nano surfaces and finding locations where Nano surfaces can be used. Currently, nanocomposites are often used in various areas due to their better properties compared to composite materials. We use nanofillers that help significantly improve the properties of composite materials. Currently, the materials used in industry are not biodegradable, so if they can remain in the environment for a long time, they lead to the production of toxins, harming the environment and the organisms themselves. However, these materials are useful for better properties of the environment and the life and health of countless people and animals. During the selection of materials for the production of nanocomposites, there are three main characteristics of materials to be examined: biological degradation, sustainability, and nanotoxicity [143-145].

6.3.1. Biodegradability

As the name explains, biological deterioration is the ability of a companion to deteriorate if it remains in nature for some time without the aid of external treatment. This is done with the help of microorganisms in the ground, which break down the material into smaller compounds such as carbon dioxide, water, and basic elements. When a material deteriorates, it must break down into its constituent materials and return to the soil or nature. These biodegradable materials do not scorch the environment during deterioration. Biologically degradable components can be found to produce nanocomposites from natural sources such as plants, animals, and microorganisms. Some examples of biodegradable ingredients that can be used in nanocomposites include chitin, cellulose, flax fiber, jute fiber, and coconut fiber [146-148]. These materials are suitable for use in nanocomposites and also have excellent properties. However, nanocomposites do not effectively provide the properties required as synthetic materials and require special treatment to adapt the properties to the synthetic components. Therefore, they are not used frequently. However, due to the growing awareness among people of environmental pollution, these materials are attracting increasing attention, and in recent years, much research has been studied in the production of various organic nanocomposites. It has been found that only a small number of biopolymers, such as cellulose, gelatin, polyacid, polyhydroxybutyrate, polycaprolactone, and polybutylene succinate, have excellent properties such as thermal stability, antibacterial properties and antioxidant properties suitable for food packaging applications. Similarly, some polymeric nanocomposites consisting of polylactide, polycaprolactone, polyvinyl alcohol, polyvinylpyrrolidone and cellulose were examined in detail to replace the non-biodegradable nanocomposites used in electronics. These nanocomposites can be used as substrates, dielectric layers, and active layers in electronic components. However, the biggest concern is the lifespan of biodegradable components. These components tend to deteriorate under appropriate conditions. A rough classification of polymers is shown in Figure **14**. In most cases, the addition of nano flyers to polymer composites did not directly affect the biodegradability of the composites. Adding Nano plot fabrics to composites improves the properties of polymer composites in manufacturing where natural materials are used, and is suitable for use in a variety of industries, thus contributing to the replacement of already used synthetic materials. Nano plots with antibacterial properties may have some effect on the biological degradation of composites, which in the long run does not affect the degradation of composites and is easier to reduce than synthetic materials. Bio composites usually do not have properties because synthetic materials offer better properties and are suitable for the job. However, the addition of nanoforging materials improves the properties of the bio composite, making it a more suitable alternative to synthetic materials. This allows for the use of more biodegradable materials and exempts the environment [149-151].

Glaskova-Kuzmina etal[152] investigate the durability of bio-nanocomposites. The authors found that using biodegradable polymers as the basis for nanocomposites reduces the mechanical properties of the nanocomposites. However, this lack of real estate can be overcome by using appropriate nano areas. In this study, we investigated the influence of various facts such as atmospheric humidity and temperature on the degradation of nanocomposites. It was found that the addition of certain nanonets with antibacterial properties improved the barrier properties of the composites and reduced the degradation of the nanocomposites.

Silva *et al*. [153] outlined the development of various biodegradable polymers that can be used for ribbon/tendon tissue reproduction. The authors reported polymers such as collagen, alginate, silk, and polysaccharides in the field of tissue reproduction. Collagen and polyacids have been found to be materials used in the manufacture of biodegradable scaffolds.

Guo *et al*. [154] developed a thermally conductive and conductive biodegradable polymer using graphene

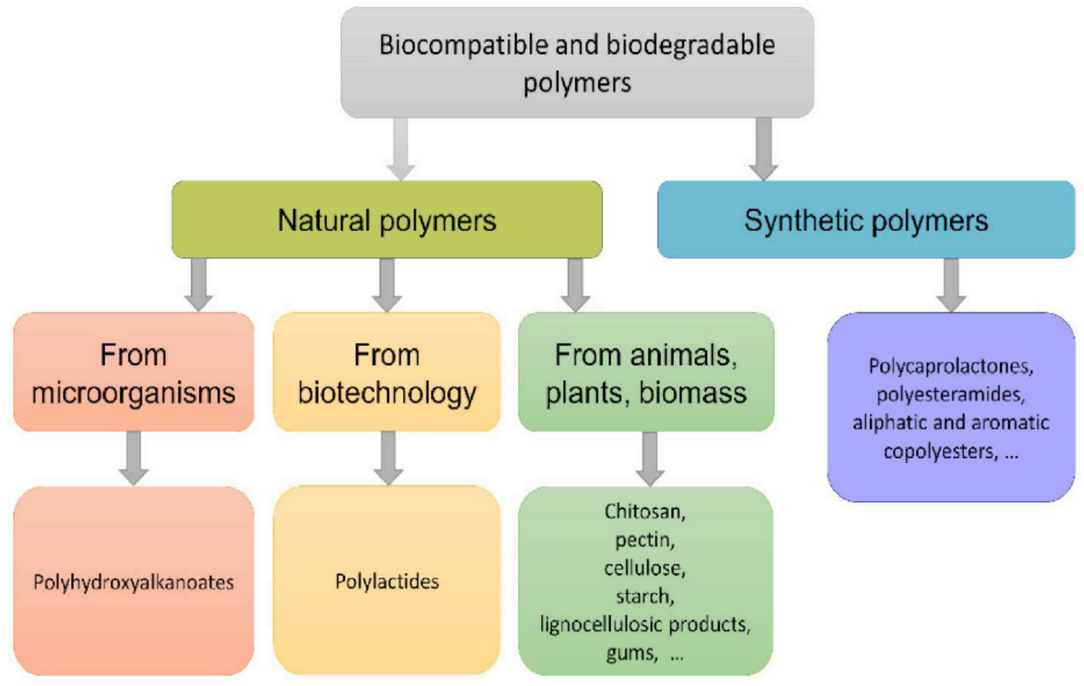

Figure14: Biodegradable polymers [151].

nanosheets and poly (butylene adipate-co-butylene terephthalate) (PBAT) and blended it with polylactic acid (PLA). PBAT was used because it could accommodate high filling of graphene nanosheets, but PLA was used because it had a low affinity for graphene and limited dispersion of graphene within PBAT. This combination allowed for 40wt% graphene filling, resulting in high thermal conductivity (338 S/m) and electrical conductivity (3.15 W/m K) of the formed nanocomposites. This property allows the use of nanocomposites in the electronics industry, and also allows the nanocomposites to become completely biodegradable depending on the material used.

6.3.2. Sustainability

Sustainability is a goal that takes into account three main pillars: the environment, the economy and society. Summary of the various definitions available for sustainability: sustainability means using resources available to the current generation in a way that is successfully met without compromising the ability to meet the needs of future generations. The focus of nanocomposites is on supporting environmental sustainability. To ensure that nanocomposites are sustainable, the materials needed to manufacture nanocomposites are available from renewable resources such as plants, animals, and microorganisms. These sources also produce biodegradable components, which make these materials extremely beneficial to the environment and to the people. It also lends itself to sustainable nanocomposites if the material is based on waste from another process or is recyclable. It also shows that biological degradation and sustainability go hand in hand. In addition to the sustainability of ecological sustainability, it also helps to achieve social sustainability as we know it today. The masses try to find natural products everywhere, be it in everyday objects or other tools used. The use of organic nanocomposites in the industry will be advantageous for companies as they are purchased by environmentally conscious customers based on their superior choice over other synthetic materials, which will help improve the company's image in the long run. Another aspect of sustainability, which is economic sustainability, is also achieved by using bio composites, as most of the materials used to produce composites are natural. They are cheaper and more easily available compared to the synthetic materials used. The production of these materials does not cause pollution and is therefore healthy for the environment. The waste generated after the production of bio-nanocomposites is also mostly biodegradable, which helps reduce waste treatment processes and can be sold for use as fertilizer in farms and other industries, providing economic benefits to companies in the long run. Therefore, bio-nanocomposites can achieve all three sustainability aspects: environmental sustainability, social sustainability, and economic sustainability [156-158].

Kafy *et al*. [158] investigated the use of porous cellulose/graphene oxide nanocomposites as electrode materials that can be used in supercapacitors. With cellulose, nanocomposites are renewable and sustainable, as cellulose is collected from renewable sources that do not harm the environment. The authors found that adding graphic oxides to Cellulose Trix results in improved power density, zinc cargo, discharge time and specific capacity. This improvement makes nanocomposites available with supercapacitors.

Majeed *et al*. [159] We conducted a review of potential materials from nanocomposites filled with nanotubes/natural fibers. This can be used for food packaging activities. The authors found that there is a number of research work focusing on the use of nanocomposites based on natural materials in the food packaging industry. This is an advantage because composites are completely biodegradable, inexpensive and sustainable due to the use of such materials. However, the problem can lead to poor properties of these natural ingredients compared to synthetic materials and shortening their storage capacity, leading to the penetration of foods stored therein. For these reasons, these natural materials-based nanocomposites are not widely used in the food packaging industry.

Chaturvedi *et al*. [160] investigated the role of carbon nanotubes on the flexural strength and dielectric properties of fly ash/epoxy-based nanocomposites. The fly ash used in nanocomposites is a waste product produced from the combustion of coal. When coal is burned, it is released along with exhaust gases. Using this fly ash is similar to using or recycling waste that would otherwise be disposed of. This fact makes nanocomposites sustainable. Adding carbon nanotubes to the composite material slightly increased the water absorption capacity. It also improves the bending strength and dielectric constant of nanocomposites, making them suitable for use as economical and environmentally friendly construction and construction materials.

Mogadam *et al*. [161] We developed paper coated with nanocomposites based on carboxymethylcell-serose bases containing Nano kaolin and nanomachines and synthesized with waste paper for packaging applications. Coated paper is suitable for use as wrapping paper because it exhibits excellent tensile strength and good mechanical properties such as air overall.

7. EMERGING APPLICATIONS OF POLYMER NANOCOMPOSITES

Polymer composites are widely used in a variety of industries. However, its scope was still inadequate in some areas. This problem was overcome by adding nanofillers to the polymer composite, and polymer nanocomposites were formed. Polymer nanocomposites are widely used in a variety of industries, including automotive, aerospace, injection molding products, coatings, adhesives, flame retardants, packaging materials, microelectronic packaging, optical integrated circuits, drug delivery, sensors, membranes, medical devices, consumer products, and more. Polymer nanocomposites can replace other materials due to their excellent properties such as lightweight, biodegradability, low density, excellent barrier properties, excellent thermal and electrical properties, and high strength to weight ratio. Furthermore, the properties of polymer nanocomposites vary according to the properties or properties required for the task by modifying the Nano full material or matrix components used to generate polymer nanocomposites. A wide range of applications is shown in Figure **15**. This means that polymer nanocomposites can be produced suitable for the task, but this is not possible with other materials. As such, polymer nanocomposites have a wide range of applications. Many studies on the use of polymer nanocomposites have been manipulated in different regions [162].

Punia *et al*. [163] did an evaluation of the current development in software of nanocomposites in wastewater remedy. The authors observed that diverse varieties of nanocomposites like carbon-primarily based totally nanocomposite, metal-primarily based totally nanocomposite, ceramic primarily based totally nanocomposite, and magnetic-primarily based totally nanocomposite were used for wastewater remedy. It became additionally observed that recently, ferrite-primarily based totally nanocomposites were studied for wastewater remedy due to the fact it may be without problems separated, regenerated, and reused numerous instances without loss in its functioning.

Nasir *et al*. [164] studied approximately the current improvements in polymer nanocomposite movies for use in wastewater treatment. The authors determined that those movies have appropriate traits like low cost, power efficient, eco-friendly, operational flexibility, and feasibility, which lead them to appropriate for utilization in wastewater treatment. In addition to this, to in addition boom their floor adsorption, mechanical and antibacterial residences crosslinking marketers are dispersed calmly within the polymer nanocomposite matrix. Some of the used polymer nanocomposite movies have been polyvinyl alcohol/zinc, polyvinyl alcohol/copper, chitosan/ silver, chitosan/polyaniline/NiOx, and polyether sulfone/ cobalt.

Kalia *et al*. [165] studied approximately the usage of magnetic polymer nanocomposite for biomedical

Figure15: applications of polymer nanocomposites [162].

application. These magnetic nanocomposites are organized by the use of strategies like in situ, ex situ, microwave reflux, co-precipitation, soften blending, ceramic–glass processing, and plasma polymerization techniques. These nanocomposites are used for *in vivo* imaging, as superparamagnetic or bad assessment agents, drug carriers, heavy metallic adsorbents, and magnetically recoverable photocatalysts for degradation of natural pollutants.

Wen *et al*. [166] studied using antibacterial nanocomposite fashioned of polyvinyl alcohol changed with zinc oxide–doped multiwalled carbon nanotube. The addition of zinc oxide–doped multiwalled carbon nanotube into the matrix brought about a boom within the thermal stability, water vapor transmission rate, hydrophobicity, and antibacterial assets of the composite. A similarly take a look at indicates that the nanocomposite can save you the lack of water from greens for four days; it's also able to maintain chook secure from microorganisms even as saved in a fridge for 36 h, making it appropriate for meals packaging.

Malik [167] studied approximately the homes of thermally exfoliated graphene oxide bolstered polycaprolactone-primarily based totally bactericidal nanocomposite. The addition of the nanofiller into the matrix ends in the development of the mechanical, antibacterial, and water soaking up capacities of the nanocomposite, making it match for utilization in meals packaging applications.

8. CONCLUSIONS AND CURRENT SITUATION AND FUTURE OUTLOOK

- In order to identify dangerous compounds and cations, anions, and fair particles using colorimetric and fluorescence frameworks, we investigated chemical sensors based on common particles in this study. Because of its strength, nano silica may be functionalized with regular atoms to create half-breed nanomaterials. Inorganic materials based on nano-silica and crossover characteristics provide high selectivity for identifying dangerous metal particles, common chemicals, and anions. Additionally, examples of the use of interesting nanoparticles functionalized with distinctive species as chemical sensors with common and distinctive uses are provided within the discussion.

- In general, attractive opportunities await research in the field of hybrid materials, as the wide range of different properties of highly complementary types of materials is advancing. Critical masses of researchers interested in this topic. Different approaches to different research communities. A wide range of interdisciplinary approaches used by researchers working in this field. High demand from other research communities is, for example, biological sciences, which use not only hybrid materials but also approaches that work with them. In particular, further research is being conducted in various fields of inorganic within the organization to use the synergy of materials and research communities. In the area of hydrogels, the development of biogenic enrichment in which inorganic particles provide a network is advantageous for the use of remote modification (network) or laser activation possibilities. Hydrogels appear to be of great importance in many fields, particularly tissue engineering. In particular, controlling and adapting mechanical properties is a challenge. Modification of hydrogels with enzymes, proteins, active biomolecules and nanoparticles provides a rich environment to further improve the development of the intrinsic and desirable properties of organic matrices. The antibacterial and anticorrosive functions often achieved by adding positive connections to nanoparticles are another important feature of materials associated with the biomedical and nanomedical sectors. In LBL, the complementarity of organic and inorganic materials affects advanced drug taxes and capsule construction, including ambiguous release *in vivo*, control of microcontroller reactions, LBL production and more reliably further investigation of possibilities. The placement of nanoparticles is considered an important mechanism that controls mechanical properties and allows for the spontaneous and distant release of indifferent biomolecules. LBL coatings on flat substrates also benefit from mechanical properties, sensor functions and long-range effects of various stimuli. This was obtained by placing inorganic nanoparticles and nanostructures. Additionally, the development of gradient coatings provides additional functionality. In polymer brushes, the introduction of inorganic nanoparticles further affects the control of the properties of microarray and macro ray probes, which sensor functions can particularly notice. In the nasal area of block-Co polymers and polymers, sponsorship and sensor functions are features that should be further developed in hybrids. In polymerase and other delivery vehicles, this drive allows for the development of advanced applications by adding inorganic nanoparticles. In the region of lipid bilayers, the introduction of inorganic nanoparticles can help us to better understand the fundamental mechanisms of lipid membrane function. This is expected to not only be useful for basic science but also affect the drug tax. Liposomes are effective taxes, particularly in the development of "stealth" preposes called in SO, and modifications with inorganic nanoparticles will further expand the area of release function. Other biologically relevant molecules such as DNA can ultimately be used for self-organization of -idy nanoparticles, which can be used to construct advanced sensors. Label-unfastened sensing is likewise applicable for microorganisms and inorganic nanoparticles can offer important enhancement. In mobiliary biology, both of the constructs defined above may be used, or inorganic nanoparticles can launch from cells, imparting in addition powerful methods of turning in drugs. In addition, analytical strategies will permit the tailoring and manipulation of the mobiliary adhesion, wherein the houses of inorganic nanoparticles and nanostructures are tough to replace. A big wide variety of upcoming developments, well-placed and interdisciplinary in nature, will each make a contribution and advantage from a really perfect synergy among organic and inorganic materials. In short, the outlook is vibrant for hybrids.

- We discussed the impact on different types of nanofillers, properties, preparation methods, applications, and more. All of these sections offered different benefits of using Nano flyers in polymer networks and showed the various locations where polymer nanocomposites could be used. This section discusses various limitations regarding the use of nanofillers. The most common factor that acts as a limitation is the inappropriate distribution of Nano flyers within the matrix. The distribution of nanofillers along the matrix is difficult to control, and if the distribution is not uniform, the properties of the nanocomposite can be worse than improved. Another limitation in the use of nanofillers is nanotoxicity. Because of their small size, nanofillers can cause a variety of complications when they enter a living body, causing organ damage and ultimately death. This is because its size is so small that it can cause different behavior from the same element when present in large quantities or more. Another limitation of using nanofillers is that their size is small, which requires special methods for their manufacture and incorporation into the matrix. Also, not all matrices and nanofillers are compatible with each other, so a specific nanofiller must be used. Aggregation of nanofillers within the matrix is also one of the limitations in the use of nanofillers. Although agglomeration can sometimes be beneficial to nanocomposites, it is mostly detrimental to nanocomposites. Therefore, using nanofillers to form nanocomposites has both advantages and disadvantages.

- Polymer nanocomposites were examined in detail and analyzed in various aspects. Various possibilities for synthesis of various polymer nanocomposites, their properties, degradation, sustainability, nanotoxicity, and applications are covered. Polymer nanocomposites are increasingly used in a variety of industries, and we have found that certain traditional materials such as aluminum and plastics are being replaced. Different properties that can be controlled by adjusting the Nano and Matrix components allow fine adjustments for the job by varying the concentration of the Nano flyer in the polymer nanocomposite or by changing the materials used. However, there are some issues associated with the use of polymer nanocomposites such as nanotoxicity, unique synthetic techniques, and nanoyl liquids such as expensive carbon nanotubes. Natural materials such as cellulose and chitin are cheap, marginally available and biodegradable, making them environmentally friendly. Chitosan, nanotubes, and other such components were investigated for use as fillers in polymer composites for use as cost-effective and environmentally friendly sewage treatment solutions. Natural materials such as cellulose and chitosan have certain antimicrobial properties that lead to their use as nano foils in biomedical applications. Silver nanoparticles, in addition to other natural materials, also have excellent antimicrobial properties that are useful for biomedical applications. Various unique natural materials such as pectin, chitosan, alginate, agar, carrageenan, whey, and gelatin were used for food packaging applications. Similarly, conductive nanomaterials such as graphene and graphite are used to create polymer nanocomposites for the electrical industry. Various automotive companies also use certain nanocomposites made of boron fiber, glass fiber and carbon fiber instead of plastic parts in their automotive parts. In the future, more research should focus on finding ways to strengthen natural materials to the extent that they can be used in polymer nanocomposites instead of synthetic materials.

DATA AVAILABILITY

All data generated or analyzed during this study are included in this published article.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

COMPETING INTERESTS

The authors declare that they have no conflict of interest.

FUNDING

Not applicable.

ACKNOWLEDGEMENTS

Not applicable.

CLINICAL TRIAL NUMBER

Not applicable

ETHICS CONSENT TO PARTICIPATE, AND CONSENT

Not applicable

CONTRIBUTION STATEMENT

Amar Yasser Jassim: Writing – review & editing, Writing – original draft, Investigation.

Wesam R. Kadhum: Writing – review & editing, Investigation.

Ehsan kianfar: Writing – review & editing, Writing – original draft, Supervision, Investigation.

REFERENCE

[1] Martinez-Manez, R., & Sancenon, F. (2003). Fluorogenic and chromogenic chemosensors and reagents for anions. Chemical reviews, 103(11), 4419-4476. https://doi.org/10.1021/cr010421e

[2] Kim, J. S., & Quang, D. T. (2007). Calixarene-derived fluorescent probes. Chemical Reviews, 107(9), 3780-3799. https://doi.org/10.1021/cr068046j

[3] Han, W. S., Lee, H. Y., Jung, S. H., Lee, S. J., & Jung, J. H. (2009). Silica-based chromogenic and fluorogenic hybrid chemosensor materials. Chemical Society Reviews, 38(7), 1904-1915. https://doi.org/10.1039/b818893a

[4] James, T. D., Sandanayake, K. S., Iguchi, R., & Shinkai, S. (1995). Novel saccharide-photoinduced electron transfer sensors based on the interaction of boronic acid and amine. Journal of the American Chemical Society, 117(35), 8982-8987. https://doi.org/10.1021/ja00140a013

[5] Motsenbocker, M., Ichimori, Y., & Kondo, K. (1993). Metal porphyrin chemiluminescence reaction and application to immunoassay. Analytical Chemistry, 65(4), 397-402. https://doi.org/10.1021/ac00052a015

[6] Jung, J. H., Lee, J. H., & Shinkai, S. (2011). Functionalized magnetic nanoparticles as chemosensors and adsorbents for toxic metal ions in environmental and biological fields. Chemical Society Reviews, 40(9), 4464-4474. https://doi.org/10.1039/c1cs15051k

[7] Das, S., Das, P. P., & Thomas, S. (2024). Introduction: State of the Art, New Challenges and Opportunities of Sensory Devices, Polymer-Based Nano-bio Materials, Opto-electrochemical Devices as Sensor. Organic and inorganic materials based sensors, 1, 1-11. https://doi.org/10.1002/9783527834266.ch1

[8] Ghorai, P., Mondal, U., Hazra, A., & Banerjee, P. (2024). Luminescent metal organic frameworks (LMOFs) and allied composites for the unveiling of organic environmental contaminants (explosive NACs, PAHs and EDCs) sensing through 'Molecular Recognition': A chronicle of recent penetration and future modelling. Coordination Chemistry Reviews, 518, 216085. https://doi.org/10.1016/j.ccr.2024.216085

[9] Hajivand, P., Jansen, J. C., Pardo, E., Armentano, D., Mastropietro, T. F., & Azadmehr, A. (2024). Application of metal-organic frameworks for sensing of VOCs and other volatile biomarkers. Coordination Chemistry Reviews, 501, 215558. https://doi.org/10.1016/j.ccr.2023.215558

[10] Dhahi, T. S., Dafhalla, A. K. Y., Tayfour, O. E., Mubarakali, A., Alqahtani, A. S., Ahmed, A. E. T., ... & Gopinath, S. C. (2024). Advances in nano sensors for monitoring and optimal performance enhancement in photovoltaic cells. Iscience. https://doi.org/10.1016/j.isci.2024.109347

[11] Cao, Y., Wu, R., Gao, Y. Y., Zhou, Y., & Zhu, J. J. (2024). Advances of electrochemical and electrochemiluminescent sensors based on covalent organic frameworks. Nano-Micro Letters, 16(1), 37. https://doi.org/10.1016/j.isci.2024.109347

[12] Li, Y., Cui, Z., Huang, L., Zhang, D., Shen, Y., Cheng, J., & Wang, J. Aggregation-based analytical chemistry in point-of-care nanosensors. Aggregate, e559.

[13] Qu, X., Hu, Y., Xu, C., Li, Y., Zhang, L., Huang, Q., ... & Fu, Y. (2024). Optical sensors of volatile organic compounds for non-invasive diagnosis of diseases. Chemical Engineering Journal, 149804. https://doi.org/10.1016/j.cej.2024.149804

[14] Darwish, M. A., Abd-Elaziem, W., Elsheikh, A., & Zayed, A. A. (2024). Advancements in Nanomaterials for Nanosensors: A Comprehensive Review. Nanoscale Advances. https://doi.org/10.1039/D4NA00214H

[15] Dong, W., Fan, Z., Shang, X., Han, M., Sun, B., Shen, C., ... & Deng, B. (2024). Nanotechnology-based optical sensors for Baijiu quality and safety control. Food Chemistry, 138995. https://doi.org/10.1016/j.foodchem.2024.138995

[16] Swami, S., Sharma, N., & Saini, A. (2024). Captivating nano sensors for mercury detection: a promising approach for monitoring of toxic mercury in environmental samples. RSC advances, 14(27), 18907-18941. https://doi.org/10.1039/D4RA02787F

[17] Rajput, S. K., & Mothika, V. S. (2024). Powders to Thin Films: Advances in Conjugated Microporous Polymer Chemical Sensors. Macromolecular Rapid Communications, 45(10), 2300730. https://doi.org/10.1002/marc.202300730

[18] Kim, C., Kang, M. S., Raja, I. S., Oh, J. W., Joung, Y. K., & Han, D. W. (2024). Current issues and perspectives in nanosensors-based artificial olfactory systems for breath diagnostics and environmental exposure monitoring. TrAC Trends in Analytical Chemistry, 117656. https://doi.org/10.1016/j.trac.2024.117656

[19] Zhong, X., Xie, Q., Liu, Y., He, Y., Zhong, N., Zhang, Z., ... & Lichtfouse, E. (2024). Recent advances in optical fiber grating sensors for detection of organic substances. Chemical Engineering Journal, 152260. https://doi.org/10.1016/j.cej.2024.152260

[20] Fakayode, S. O., Lisse, C., Medawala, W., Brady, P. N., Bwambok, D. K., Anum, D., ... & Grant, C. (2024). Fluorescent chemical sensors: applications in analytical, environmental, forensic, pharmaceutical, biological, and biomedical sample measurement, and clinical diagnosis. Applied Spectroscopy Reviews, 59(1), 1-89. https://doi.org/10.1080/05704928.2023.2177666

[21] Xia, L., Liu, Y., Chen, R. T., Weng, B., & Zou, Y. (2024). Advancements in miniaturized infrared spectroscopic-based volatile organic compound sensors: A systematic review. Applied Physics Reviews, 11(3). https://doi.org/10.1063/5.0197236

[22] Saleem, S., Kaur, K., Kumar, V., Khan, A. A., & Malik, A. (2024). An overview of Metal–Organic Frameworks as potential platform for sensing application to environmental pollutants and drug delivery. Journal of Molecular Structure, 138389. https://doi.org/10.1016/j.molstruc.2024.138389

[23] Janardhanan, J. A., & Yu, H. H. (2024). Recent Advances on PEDOT/PProDOT Derived Nano Biosensors: Engineering Nano Assemblies for Fostering Advanced Detection Platforms for Biomolecules Detection. Nanoscale.

[24] Blachowicz, T., Kola, I., Ehrmann, A., Guenther, K., & Ehrmann, G. (2024, April). Magnetic Micro and Nano Sensors for Continuous Health Monitoring. In Micro (Vol. 4, No. 2, pp. 206-228). MDPI. https://doi.org/10.3390/micro4020015

[25] Hu, C., Wang, L., Liu, S., Sheng, X., & Yin, L. (2024). Recent Development of Implantable Chemical Sensors Utilizing Flexible and Biodegradable Materials for Biomedical Applications. ACS nano, 18(5), 3969-3995. https://doi.org/10.1021/acsnano.3c11832

[26] Gong, L., Chen, L., Lin, Q., Wang, L., Zhang, Z., Ye, Y., & Chen, B. (2024). Nanoscale Metal–Organic Frameworks as a Photoluminescent Platform for Bioimaging and Biosensing Applications. Small, 2402641. https://doi.org/10.1002/smll.202402641

[27] Zhang, Q., Xing, S., Han, J., Feng, L., Li, J., Qian, Z., & Zhou, J. (2024). Organic pollutant sensing for human health based on carbon dots. Chinese Chemical Letters, 110117. https://doi.org/10.1016/j.cclet.2024.110117

[28] Zhang, X., Dai, Y., Sun, J., Shen, J., Lin, M., & Xia, F. (2024). Solid-state nanopore/nanochannel sensors with enhanced selectivity through pore-in modification. Analytical Chemistry, 96(6), 2277-2285. https://doi.org/10.1021/acs.analchem.3c05228

[29] Kaur, P., Parmar, A., & Chopra, H. K. (2024). Recent Advances in Synthesis and Applications of Organic Ionic Saltsbased Sensor Arrays. Mini-Reviews in Organic Chemistry, 21(6), 655-670. https://doi.org/10.2174/1570193X20666230614141728

[30] Lakavath, K., Kafley, C., Sajeevan, A., Jana, S., Marty, J. L., & Kotagiri, Y. G. (2024). Progress on Electrochemical Biomimetic Nanosensors for the Detection and Monitoring of Mycotoxins and Pesticides. Toxins, 16(6), 244. https://doi.org/10.3390/toxins16060244

[31] Velusamy, P., Su, C. H., Ramasamy, P., Arun, V., Rajnish, N., Raman, P., ... & Gopinath, S. C. (2023). Volatile organic compounds as potential biomarkers for noninvasive disease detection by nanosensors: A comprehensive review. Critical Reviews in Analytical Chemistry, 53(8), 1828-1839. https://doi.org/10.1080/10408347.2022.2043145

[32] Shen, Z., Huang, W., Li, L., Li, H., Huang, J., Cheng, J., & Fu, Y. (2023). Research progress of organic field-effect transistor based chemical sensors. Small, 19(41), 2302406. https://doi.org/10.1002/smll.202302406

[33] Nangare, S. N., Patil, A. G., Chandankar, S. M., & Patil, P. O. (2023). Nanostructured metal–organic framework-based luminescent sensor for chemical sensing: current challenges and future prospects. Journal of Nanostructure in Chemistry, 13(2), 197-242. https://doi.org/10.1007/s40097-022-00479-0

[34] Lagopati, N., Valamvanos, T. F., Proutsou, V., Karachalios, K., Pippa, N., Gatou, M. A., ... & Efstathopoulos, E. (2023). The role of nano-sensors in breath analysis for early and non-invasive disease diagnosis. Chemosensors, 11(6), 317. https://doi.org/10.3390/chemosensors11060317

[35] Wen, C., Li, R., Chang, X., & Li, N. (2023). Metal-organic frameworks-based optical nanosensors for analytical and bioanalytical applications. Biosensors, 13(1), 128. https://doi.org/10.3390/bios13010128

[36] Nath, N., Kumar, A., Chakroborty, S., Soren, S., Barik, A., Pal, K., & de Souza Jr, F. G. (2023). Carbon nanostructure embedded novel sensor implementation for detection of aromatic volatile organic compounds: an organized review. ACS omega, 8(5), 4436-4452. https://doi.org/10.1021/acsomega.2c05953

[37] Ghasemi, F., Fahimi-Kashani, N., Bigdeli, A., Alshatteri, A. H., Abbasi-Moayed, S., Al-Jaf, S. H., ... & Hormozi-Nezhad, M. R. (2023). based optical nanosensors–A review. Analytica Chimica Acta, 1238, 340640. https://doi.org/10.1016/j.aca.2022.340640

[38] Ayivi, R. D., Adesanmi, B. O., McLamore, E. S., Wei, J., & Obare, S. O. (2023). Molecularly imprinted plasmonic sensors as nano-transducers: An effective approach for environmental monitoring applications. Chemosensors, 11(3), 203. https://doi.org/10.3390/chemosensors11030203

[39] Hajivand, P., Jansen, J. C., Pardo, E., Armentano, D., Mastropietro, T. F., & Azadmehr, A. (2024). Application of metal-organic frameworks for sensing of VOCs and other volatile biomarkers. Coordination Chemistry Reviews, 501, 215558. https://doi.org/10.1016/j.ccr.2023.215558

[40] Abd Karim, N. F. N., Supian, F. L., Musa, M., Ayop, S. K., Azmi, M. S., Yazid, M. D., & Yi, W. Y. (2023). Calixarene derivatives: a mini-review on their synthesis and demands in nanosensors and biomedical fields. Mini Reviews in Medicinal Chemistry, 23(6), 734-745. https://doi.org/10.2174/1389557522666220928120727

[41] Khatib, M., & Haick, H. (2022). Sensors for volatile organic compounds. ACS nano, 16(5), 7080-7115. https://doi.org/10.1021/acsnano.1c10827

[42] Krämer, J., Kang, R., Grimm, L. M., De Cola, L., Picchetti, P., & Biedermann, F. (2022). Molecular probes, chemosensors, and nanosensors for optical detection of biorelevant molecules and ions in aqueous media and biofluids. Chemical reviews, 122(3), 3459-3636. https://doi.org/10.1021/acs.chemrev.1c00746

[43] Jouyban, A., & Rahimpour, E. (2022). Optical sensors for determination of water in the organic solvents: a review. Journal of the Iranian Chemical Society, 19(1), 1-22. https://doi.org/10.1007/s13738-021-02290-0

[44] Hassan, D., Bakhsh, H., Khurram, A. M., Bhutto, S. A., Jalbani, N. S., Ghumro, T., & Solangi, A. R. (2022). Fluorescent nanotechnology: An evolution in optical sensors. Current Analytical Chemistry, 18(2), 176-185. https://doi.org/10.2174/1573411017666201215121420

[45] Kushwaha, C. S., Singh, P., Shukla, S. K., & Chehimi, M. M. (2022). Advances in conducting polymer nanocomposite based chemical sensors: An overview. Materials Science and Engineering: B, 284, 115856. https://doi.org/10.1016/j.mseb.2022.115856

[46] Adam, T., & Gopinath, S. C. (2022). Nanosensors: Recent perspectives on attainments and future promise of downstream applications. Process Biochemistry, 117, 153-173. https://doi.org/10.1016/j.procbio.2022.03.024

[47] Luo, L., & Liu, Z. (2022). Recent progress in organic field-effect transistor-based chem/bio-sensors. View, 3(1), 20200115. https://doi.org/10.1002/VIW.20200115

[48] Sha, R., Basak, A., Maity, P. C., & Badhulika, S. (2022). ZnO nano-structured based devices for chemical and optical sensing applications. Sensors and Actuators Reports, 4, 100098. https://doi.org/10.1016/j.snr.2022.100098

[49] Thobakgale, L., Ombinda-Lemboumba, S., & Mthunzi-Kufa, P. (2022). Chemical sensor nanotechnology in pharmaceutical drug research. Nanomaterials, 12(15), 2688. https://doi.org/10.3390/nano12152688

[50] Fei, L., Bilal, M., Qamar, S. A., Imran, H. M., Riasat, A., Jahangeer, M., ... & Iqbal, H. M. (2022). Nano-remediation technologies for the sustainable mitigation of persistent organic pollutants. Environmental Research, 211, 113060. https://doi.org/10.1016/j.envres.2022.113060

[51] Caroleo, F., Magna, G., Naitana, M. L., Di Zazzo, L., Martini, R., Pizzoli, F., ... & Paolesse, R. (2022). Advances in optical sensors for persistent organic pollutant environmental monitoring. Sensors, 22(7), 2649. https://doi.org/10.3390/s22072649

[52] Tsogas, G. Z., Vlessidis, A. G., & Giokas, D. L. (2022). Analyte-mediated formation and growth of nanoparticles for the development of chemical sensors and biosensors. Microchimica Acta, 189(11), 434. https://doi.org/10.1007/s00604-022-05536-7

[53] Leong, S. X., Leong, Y. X., Koh, C. S. L., Tan, E. X., Nguyen, L. B. T., Chen, J. R. T., ... & Ling, X. Y. (2022). Emerging nanosensor platforms and machine learning strategies toward rapid, point-of-need small-molecule metabolite detection and monitoring. Chemical Science, 13(37), 11009-11029. https://doi.org/10.1039/D2SC02981B

[54] Kabir, K. M., Baker, M. J., & Donald, W. A. (2022). Micro-and nanoscale sensing of volatile organic compounds for early-stage cancer diagnosis. TrAC Trends in Analytical Chemistry, 153, 116655. https://doi.org/10.1016/j.trac.2022.116655

[55] Çorman, M. E., Ozcelikay, G., Cetinkaya, A., Kaya, S. I., Armutcu, C., Özgür, E., ... & Ozkan, S. A. (2022). Metal-organic frameworks as an alternative smart sensing platform for designing molecularly imprinted electrochemical sensors. TrAC Trends in Analytical Chemistry, 150, 116573. https://doi.org/10.1016/j.trac.2022.116573

[56] Wang, S., Li, H., Huang, H., Cao, X., Chen, X., & Cao, D. (2022). Porous organic polymers as a platform for sensing applications. Chemical Society Reviews, 51(6), 2031-2080. https://doi.org/10.1039/D2CS00059H

[57] Avolio, R., Grozdanov, A., Avella, M., Barton, J., Cocca, M., De Falco, F., ... & Magni, P. (2022). Review of pH sensing materials from macro-to nano-scale: Recent developments and examples of seawater applications. Critical Reviews in Environmental Science and Technology, 52(6), 979-1021. https://doi.org/10.1080/10643389.2020.1843312

[58] Majhi, S. M., Mirzaei, A., Kim, H. W., Kim, S. S., & Kim, T. W. (2021). Recent advances in energy-saving chemiresistive gas sensors: A review. Nano Energy, 79, 105369. https://doi.org/10.1016/j.nanoen.2020.105369

[59] Li, Z., & Yang, Y. W. (2022). Macrocycle-based porous organic polymers for separation, sensing, and catalysis. Advanced Materials, 34(6), 2107401. https://doi.org/10.1002/adma.202107401

[60] Wen, F., He, T., Liu, H., Chen, H. Y., Zhang, T., & Lee, C. (2020). Advances in chemical sensing technology for enabling the next-generation self-sustainable integrated wearable system in the IoT era. Nano Energy, 78, 105155. https://doi.org/10.1016/j.nanoen.2020.105155

[61] Gomez-Romero, P. (2001). Hybrid organic–inorganic materials—in search of synergic activity. Advanced Materials, 13(3), 163-174. https://doi.org/10.1002/1521-4095(200102)13:3<163::AID-ADMA163>3.0.CO;2-U

[62] Ahmad, Z., & Mark, J. E. (1998). Biomimetic materials: recent developments in organic-inorganic hybrids. Materials Science and Engineering: C, 6(2-3), 183-196. https://doi.org/10.1016/S0928-4931(98)00044-7

[63] Wang, S., Kang, Y., Wang, L., Zhang, H., Wang, Y., & Wang, Y. (2013). Organic/inorganic hybrid sensors: A review. Sensors and Actuators B: Chemical, 182, 467-481. https://doi.org/10.1016/j.snb.2013.03.042

[64] Sanchez, C., Galo, J., Ribot, F., & Grosso, D. (2003). Design of functional nano-structured materials through the use of controlled hybrid organic–inorganic interfaces. Comptes Rendus Chimie, 6(8-10), 1131-1151. https://doi.org/10.1016/j.crci.2003.06.001

[65] Vijayakanth, T., Liptrot, D. J., Gazit, E., Boomishankar, R., & Bowen, C. R. (2022). Recent advances in organic and organic–inorganic hybrid materials for piezoelectric mechanical energy harvesting. Advanced Functional Materials, 32(17), 2109492. https://doi.org/10.1002/adfm.202109492

[66] Pandey, S., & Mishra, S. B. (2011). Sol–gel derived organic–inorganic hybrid materials: synthesis, characterizations and applications. Journal of sol-gel science and technology, 59(1), 73-94. https://doi.org/10.1007/s10971-011-2465-0

[67] Zhang, L., Huang, X., Liu, L., Nasar, N. K. A., Gu, X., Davis, T. P., ... & Qiao, R. (2025). Fabrication of Organic/Inorganic Nanocomposites: From Traditional Synthesis to Additive Manufacturing. Advanced Materials, 2505504. https://doi.org/10.1002/adma.202505504

[68] Zhang, D. S., Wang, L., Zhang, X., Li, X. B., Xu, H., Tung, C. H., & Wu, L. Z. (2025). Emerging inorganic–organic hybrid photocatalysts for solar-driven overall water splitting: progress and perspectives. Chemical Society Reviews. https://doi.org/10.1039/D5CS00378D

[69] Saveleva, M. S., Eftekhari, K., Abalymov, A., Douglas, T. E., Volodkin, D., Parakhonskiy, B. V., & Skirtach, A. G. (2019). Hierarchy of hybrid materials—The place of inorganics-in-organics in it, their composition and applications. Frontiers in chemistry, 7, 179 https://doi.org/10.3389/fchem.2019.00179

[70] Kadhum, W. R., & Jassim, A. Y. (2025). A theoretical study of 8-Hydroxy quinoline with fullerenes and carbon nanotubes as Nano vectors for drug delivery. Intelligent Pharmacy. https://doi.org/10.1016/j.ipha.2025.09.003

[71] Jassim, A. Y., Al-Ali, B. S., & Kadhum, W. R. (2025). Heavy Metal Removal from Wastewater Using Functionalized Nano-Structures and Graphene Oxide. Hybrid Advances, 100552. https://doi.org/10.1016/j.hybadv.2025.100552

[72] Beden, M. A., shiaa Dagher, A., & Faghih, S. M. (2025). Effects of Nano and Micro Reinforcements on the Viscoelastic Behavior and Thermal Stability of Silicone Rubber. Chemical Data Collections, 101201. https://doi.org/10.1016/j.cdc.2025.101201

[73] Kianfar, E. (2025). Biocompatibility Study of Silica-Based Magnesium Composites: A Review. Trends in Sciences, 22(9), 9868-9868. https://doi.org/10.48048/tis.2025.9868

[74] Kianfar, E. (2025). Dendrimers in Medicine: Properties, Drug Encapsulation Mechanisms and Applications. Trends in Sciences, 22(8), 10085-10085. https://doi.org/10.48048/tis.2025.10085

[75] Hsu, C. Y., Mahmoud, Z. H., Kamolova, N., Muzammil, K., Alsultany, F. H., Al-Abdeen, S. H. Z., & Kianfar, E. (2025). Photosynthesis of polypyyrole/$ZnFe_2O_4$-WO_3 nanocomposite for biodiesel production. Fuel Processing Technology, 271, 108193. https://doi.org/10.1016/j.fuproc.2025.108193

[76] Majeed, A. H., Hussen, W. A., Abd, A. N., & Mahmoud, Z. H. (2025). Graphene–Tungsten Oxide Hybrid Nanocomposites for High-Performance Dielectric Films in Conductive Polymer Matrices. South African Journal of Chemical Engineering. https://doi.org/10.1016/j.sajce.2025.05.009

[77] Mahmoud, Z. H., & Abdulla, D. N. (2025). Synthesis and Electrochemical Characterization of C-doped $LiFePO_4$ material for Supercapacitor Application. International Journal of Electrochemical Science, 101075. https://doi.org/10.1016/j.ijoes.2025.101075

[78] Kianfar, E. (2025). Advances in Nanoelectronics: Carbon Nanotubes, Graphene, and Smart Polymers: A review. Trends in Sciences, 22(7), 9843-9843. https://doi.org/10.48048/tis.2025.9843

[79] Kianfar, E., Mirani, A., Mahmoud, Z. H., & Mohammadkhani, A. (2025). Latest Advances in Application of Liposomes and Nanoliposomes. Liposomes as Pharmaceutical and Nutraceutical Delivery Systems, 51. https://doi.org/10.5772/intechopen.1005822

[80] Al-Hetty, H. R. A. K., Al-Dulaimi, A. A., Saleem, H. M., & Kianfar, E. (2025). Numerical simulation of stability of diffusion depth of deterrents into cylindrical nitrocellulose composite under different conditions. BMC chemistry, 19(1), 120. https://doi.org/10.1186/s13065-025-01495-1

[81] Mishbak, H. H. M., Merza, M. S., & Shanshool, E. T. (2025). Chemical and biological assessment of biosynthesized Magnetite (Fe3O4) nanoparticles (NPs) mediated quercetin extracted from Allium cepa. Results in Materials, 100712. https://doi.org/10.1016/j.rinma.2025.100712

[82] Muringayil Joseph, T., Azat, S., Kianfar, E., Joshy, K. S., Moini Jazani, O., Esmaeili, A., ... & Thomas, S. (2025). Identifying gaps in practical use of epoxy foam/aerogels: review-solutions and prospects. Reviews in Chemical Engineering, 41(3), 269-308. https://doi.org/10.1515/revce-2024-0044

[83] Kianfar, E., & Joseph, T. M. (2025). Nanostructures for Virus Detection and Tracking: An Overview. Trends in Sciences, 22(6), 9452-9452. https://doi.org/10.48048/tis.2025.9452

[84] Kadhum, W. R., Budai, M., & Budai, L. (2025). Adsorption and release profile analysis of oxytetracycline drug on functionalized graphene oxide nanoparticles. Results in Materials, 100711. https://doi.org/10.1016/j.rinma.2025.100711

[85] Hsu, C. Y., Mahmoud, Z. H., Hussein, U. A. R., Abduvalieva, D., Alsultany, F. H., & Kianfar, E. (2025). Biosurfactants: Properties, applications and emerging trends. South African Journal of Chemical Engineering. https://doi.org/10.1016/j.sajce.2025.04.002

[86] Kianfar, E. (2025). Gold nanoparticles in photothermal cancer therapy: Current trends and outlook. Trends in Sciences, 22(5), 9433-9433. https://doi.org/10.48048/tis.2025.9433

[87] Mahmoud, Z. H., Hussein, U. A. R., Aljbory, N., Alnajar, M. J., Maleknia, L., & Mirani, A. (2025). Development of Vitex-derived polymer nanofibers using electrochemical sensors for the treatment of polycystic ovarian syndrome in rats as an animal model. Biosensors and Bioelectronics: X, 22, 100570. https://doi.org/10.1016/j.biosx.2024.100570

[88] Joseph, T. M., Thomas, M. G., Mahapatra, D. K., Unni, A. B., Kianfar, E., Haponiuk, J. T., & Thomas, S. (2025). Adaptive and intelligent polyurethane shape-memory polymers enabling next-generation biomedical platforms. Case Studies in Chemical and Environmental Engineering, 101165. https://doi.org/10.1016/j.cscee.2025.101165

[89] Al-Jamal, A. N., Al-Hussainy, A. F., Mohammed, B. A., Abbas, H. H., Kadhim, I. M., Ward, Z. H., ... & Thomas, S. (2025). Photodynamic Therapy (PDT) in Drug Delivery: Nano-innovations enhancing treatment outcomes. Health Sciences Review, 100218. https://doi.org/10.1016/j.hsr.2025.100218

[90] Branch, G., & Branch, S. T. (2024). Electrospun ZnO and GSH co-loaded PU/CS nanofibrous films as potential antibacterial wound dressings. World, 2450028, 16. https://doi.org/10.1142/S1793984424500284

[91] Karkh, N. S., & Branch, G. (2025). Recent advances in the applications of smart nanomaterials in Biomedicine: A Review. World, 2530005, 21.

[92] Mahmoud, Z. H., Hussein, U. A. R., Dhiaa, A. M., Al-Hussainy, A. F., Aljbory, N., Shuhata, M. H., ... & Thomas, S. (2025). Nano-based drug delivery in cancer: Tumor tissue characteristics and targeting. Trends in Sciences, 22(2), 9078-9078. https://doi.org/10.48048/tis.2025.9078

[93] Mahmoud, Z. H., Al-Salman, H. N. K., & Kianfar, E. (2024). Nanoindentation: Introduction and applications of a non-destructive analysis. Nano TransMed, 3, 100057. https://doi.org/10.1016/j.ntm.2024.100057

[94] Bader, Q. A., Al-Sharify, Z. T., Dhabab, J. M., Zaidan, H. K., Rheima, A. M., Athair, D. M., & Joseph, T. M. (2024). Cellulose nanomaterials in oil and gas industry and bio-manufacture: Current situation and future outlook. Case Studies in Chemical and Environmental Engineering, 10, 100993. https://doi.org/10.1016/j.cscee.2024.100993

[95] Mahmoud, Z. H., Hussein, S. A., Hassan, E. A., Abduvalieva, D., Mhaibes, R. M., Kadhum, A. A. H., ... & Faghih, S. (2024). Characterization and catalytic performance of rGO-enhanced MnFe2O4 nanocomposites in CO oxidation. Inorganic Chemistry Communications, 169, 113037. https://doi.org/10.1016/j.inoche.2024.113037

[96] Mahmoud, Z. H., & Kianfar, E. (2024). Application of nano technology in the self-cleaning finishing of textiles: A review. J Textile Eng & Fash Tech, 6(1), 01-13. https://doi.org/10.33140/JTEFT.06.01.01

[97] Bader, Q. A., Ahmed, N. N., Mohaimeed, A. A., Rheima, A. M., Al-Sharify, Z. T., Athair, D. M., & Kianfar, E. (2024). Recent advances in the applications of continuous and non-continuous nanofibrous yarns in biomedicine. Fibers and Polymers, 25(10), 3623-3647. https://doi.org/10.1007/s12221-024-00683-5

[98] Mahmoud, Z. H., AL-Salman, H. N. K., Hussein, S. A., Hameed, S. M., Nasr, Y. M., Khuder, S. A., ... & Sayadi, H. (2024). Photoresponse performance of Au (nanocluster and nanoparticle) TiO2: Photosynthesis, characterization and mechanism studies. Results in Chemistry, 10, 101731. https://doi.org/10.1016/j.rechem.2024.101731

[99] Mirani, A., Rheima, A. M., Jawad, S. F., Athair, D. M., Al-Sharify, Z. T., Esmaili, M., & Sayadi, H. (2024). Effect and investigating of oxygen/nitrogen on modified glassy carbon electrode chitosan/carbon nanotube and best detection of nicotine using Cyclic voltammetry measurement technique. Results in Chemistry, 10, 101739. https://doi.org/10.1016/j.rechem.2024.101739

[100] Huang, X., Zhu, Y., & Kianfar, E. (2021). Nano biosensors: properties, applications and electrochemical techniques. Journal of Materials Research and Technology, 12, 1649-1672. https://doi.org/10.1016/j.jmrt.2021.03.048

[101] Kianfar, E. (2021). Protein nanoparticles in drug delivery: animal protein, plant proteins and protein cages, albumin nanoparticles. Journal of Nanobiotechnology, 19(1), 159. https://doi.org/10.1186/s12951-021-00896-3

[102] Kianfar, E. (2021). Magnetic nanoparticles in targeted drug delivery: a review. Journal of Superconductivity and Novel Magnetism, 34(7), 1709-1735. https://doi.org/10.1007/s10948-021-05932-9

[103] Hsu, C. Y., Rheima, A. M., Kadhim, M. M., Ahmed, N. N., Mohammed, S. H., Abbas, F. H., ... & Kianfar, E. (2023). An overview of nanoparticles in drug delivery: Properties and applications. South African Journal of Chemical Engineering, 46, 233-270. https://doi.org/10.1016/j.sajce.2023.08.009

[104] Hsu, C. Y., Mahmoud, Z. H., Abdullaev, S., Ali, F. K., Naeem, Y. A., Mizher, R. M., ... & Habibzadeh, S. (2024). Nano titanium oxide (nano-TiO2): A review of synthesis methods, properties, and applications. Case Studies in Chemical and Environmental Engineering, 9, 100626. https://doi.org/10.1016/j.cscee.2024.100626

[105] Kianfar, E. (2019). Recent advances in synthesis, properties, and applications of vanadium oxide nanotube. Microchemical Journal, 145, 966-978. https://doi.org/10.1016/j.microc.2018.12.008

[106] Kianfar, E. (2019). Nanozeolites: synthesized, properties, applications. Journal of Sol-Gel Science and Technology, 91(2), 415-429. https://doi.org/10.1007/s10971-019-05012-4

[107] Raya, I., Kzar, H. H., Mahmoud, Z. H., Al Ayub Ahmed, A., Ibatova, A. Z., & Kianfar, E. (2022). A review of gas sensors based on carbon nanomaterial. Carbon Letters, 32(2), 339-364. https://doi.org/10.1007/s42823-021-00276-9

[108] Salimi, M., Pirouzfar, V., & Kianfar, E. (2017). Enhanced gas transport properties in silica nanoparticle filler-polystyrene nanocomposite membranes. Colloid and Polymer Science, 295(1), 215-226. https://doi.org/10.1007/s00396-016-3998-0

[109] Salimi, M., Pirouzfar, V., & Kianfar, E. (2017). Novel nanocomposite membranes prepared with PVC/ABS and silica nanoparticles for C2H6/CH4 separation. Polymer Science, Series A, 59(4), 566-574. https://doi.org/10.1134/S0965545X17040071

[110] Kianfar, E., & Cao, V. (2021). Polymeric membranes on base of PolyMethyl methacrylate for air separation: a review. Journal of Materials Research and Technology, 10, 1437-1461. https://doi.org/10.1016/j.jmrt.2020.12.061

[111] Kadhim, M. M., Rheima, A. M., Abbas, Z. S., Jlood, H. H., Hachim, S. K., & Kadhum, W. R. (2023). Evaluation of a biosensor-based graphene oxide-DNA nanohybrid for lung cancer. RSC advances, 13(4), 2487-2500. https://doi.org/10.1039/D2RA05808A

[112] Ansari, M. J., Kadhim, M. M., Hussein, B. A., Lafta, H. A., & Kianfar, E. (2022). Synthesis and stability of magnetic nanoparticles. BioNanoScience, 12(2), 627-638. https://doi.org/10.1007/s12668-022-00947-5

[113] Gao, C., Liao, J., Lu, J., Ma, J., & Kianfar, E. (2021). The effect of nanoparticles on gas permeability with polyimide membranes and network hybrid membranes: a review. Reviews in Inorganic Chemistry, 41(1), 1-20. https://doi.org/10.1515/revic-2020-0007

[114] Sohrabi, N., Alihosseini, A., Pirouzfar, V., & Pedram, M. Z. (2020). Analysis of dynamics targeting CNT-based drug delivery through lung cancer cells: Design, simulation, and computational approach. Membranes, 10(10), 283. https://doi.org/10.3390/membranes10100283

[115] Heydari, S., & Pirouzfar, V. (2016). The influence of synthesis parameters on the gas selectivity and permeability of carbon membranes: empirical modeling and process optimization using surface methodology. RSC Advances, 6(17), 14149-14163. https://doi.org/10.1039/C5RA27772H

[116] Hashemzehi, M., Pirouzfar, V., Nayebzadeh, H., & Alihosseini, A. (2020). Application of response surface methodology to optimize high active Cu-Zn-Al mixed metal oxide fabricated via microwave-assisted solution combustion method. Advanced Powder Technology, 31(4), 1470-1479. https://doi.org/10.1016/j.apt.2020.01.010

[117] Hashemzehi, M., Pirouzfar, V., Nayebzadeh, H., & Su, C. H. (2022). Modelling and optimization of main independent parameters for biodiesel production over a Cu0. 4Zn0. 6Al2O4 catalyst using an RSM method. Journal of Chemical Technology & Biotechnology, 97(1), 111-119. https://doi.org/10.1002/jctb.6916

[118] Soleymanipour, S. F., Dehaghani, A. H. S., Pirouzfar, V., & Alihosseini, A. (2016). The morphology and gas separation performance of membranes comprising multiwalled carbon nanotubes/polysulfone–Kapton. Journal of Applied Polymer Science, 133(34). https://doi.org/10.1002/app.43839

[119] Pirouzfar, V., Hosseini, S. S., Omidkhah, M. R., & Moghaddam, A. Z. (2014). Modeling and optimization of gas transport characteristics of carbon molecular sieve membranes through statistical analysis. Polymer Engineering & Science, 54(1), 147-157. https://doi.org/10.1002/pen.23553

[120] Pirouzfar, V., & Omidkhah, M. R. (2016). Mathematical modeling and optimization of gas transport through carbon molecular sieve membrane and determining the model parameters using genetic algorithm. Iranian polymer journal, 25(3), 203-212. https://doi.org/10.1007/s13726-016-0414-z

[121] Saeedi Dehaghani, A. H., & Pirouzfar, V. (2017). Preparation of high-performance membranes derived from poly (4-methyl-1-pentene)/zinc oxide particles. Chemical Engineering & Technology, 40(9), 1693-1701. https://doi.org/10.1002/ceat.201600693

[122] Saeedi Dehaghani, A. H., Pirouzfar, V., & Alihosseini, A. (2020). Novel nanocomposite membranes-derived poly (4-methyl-1-pentene)/functionalized titanium dioxide to improve the gases transport properties and separation performance. Polymer Bulletin, 77(12), 6467-6489. https://doi.org/10.1007/s00289-019-03086-2

[123] Behnia, N., & Pirouzfar, V. (2019). Author Correction: Effect of operating pressure and pyrolysis conditions on the performance of carbon membranes for CO2/CH4 and O2/N2 separation derived from polybenzimidazole/Matrimid and UIP-S precursor blends. Polymer Bulletin, 76(1), 523-523. https://doi.org/10.1007/s00289-018-2365-3

[124] Salimi, M., & Pirouzfar, V. (2018). Preparation and characterization of a novel MMMs by comprising of PSF–HNT/TiO2 nanotubes to reduce organic sediments. Polymer Bulletin, 75(6), 2285-2299. https://doi.org/10.1007/s00289-017-2145-5

[125] Salimi, M., & Pirouzfar, V. (2018). Synthesis of a novel nano-ceramic membrane for hydrogen separation and purification. Journal of the Australian Ceramic Society, 54(2), 271-277. https://doi.org/10.1007/s41779-017-0151-6

[126] Pirouzfar, V., Roustaie, N., & Su, C. H. (2023). Gas transport characteristics of mixed matrix membrane containing MIL-100 (Fe) metal-organic frameworks and PEBAX precursors. Korean Journal of Chemical Engineering, 40(9), 2138-2148. https://doi.org/10.1007/s11814-023-1501-4

[127] Dehaghani, A. H. S., Rashidian, S., Pirouzfar, V., & Su, C. H. (2021). The novel composite membranes containing chloride and acid functionalized multiwall carbon nanotube fillers for gas separation. Colloid and Polymer Science, 299(12), 1933-1944. https://doi.org/10.1007/s00396-021-04903-9

[128] Pirouzfar, V., Tehrani, M. R., Su, C. H., Hasanzad, A., & Hosseini, S. M. H. (2024). Mixed-Matrix Membranes: Preparation Methods, Applications, Challenges and Performance. Walter de Gruyter GmbH & Co KG. https://doi.org/10.1515/9783111284347

[129] Sarmadi, R., Salimi, M., & Pirouzfar, V. (2022). Pebax2533 Gas Separation Membrane for CO2 Capture Applications: Incorporation and Assessment of New Configured UiO-66 Metal-organic Frameworks. Polymer Science, Series A, 64(6), 781-793. https://doi.org/10.1134/S0965545X22700511

[130] Hosseini, S. M., Pirouzfar, V., & Azami, H. (2017). The influence of synthesis parameters on vertically aligned CNT sheets: empirical modeling and process optimization using response surface methodology. The Journal of membrane biology, 250(6), 651-661. https://doi.org/10.1007/s00232-017-9993-7

[131] Schmidt, S., Madaboosi, N., Uhlig, K., Köhler, D., Skirtach, A., Duschl, C., ... & Volodkin, D. V. (2012). Control of cell adhesion by mechanical reinforcement of soft polyelectrolyte films with nanoparticles. Langmuir, 28(18), 7249-7257. https://doi.org/10.1021/la300635z

[132] Schmidt, S., Uhlig, K., Duschl, C., & Volodkin, D. (2014). Stability and cell uptake of calcium carbonate templated insulin microparticles. Acta biomaterialia, 10(3), 1423-1430. https://doi.org/10.1016/j.actbio.2013.11.011

[133] Parakhonskiy, B. V., Bedard, M. F., Bukreeva, T. V., Sukhorukov, G. B., Mohwald, H., & Skirtach, A. G. (2010). Nanoparticles on polyelectrolytes at low concentration: controlling concentration and size. The Journal of Physical Chemistry C, 114(5), 1996-2002. https://doi.org/10.1021/jp904564v

[134] Parakhonskiy, B., Haase, A., & Antolini, R. (2012). Sub-Micron Vaterite Containers: Synthesis, Substance Loading, and Release. Angewandte Chemie. International Edition, 51(5), 1195-1197. https://doi.org/10.1002/anie.201104316

[135] Parakhonskiy, B. V., Svenskaya, Y. I., Yashchenok, A. M., Fattah, H. A., Inozemtseva, O. A., Tessarolo, F., ... & Gorin, D. A. (2014). Size controlled hydroxyapatite and calcium carbonate particles: Synthesis and their application as templates for SERS platform. Colloids and Surfaces B: Biointerfaces, 118, 243-248. https://doi.org/10.1016/j.colsurfb.2014.03.053

[136] Grossiord, N., Loos, J., Van Laake, L., Maugey, M., Zakri, C., Koning, C. E., & Hart, A. J. (2008). High-conductivity polymer nanocomposites obtained by tailoring the characteristics of carbon nanotube fillers. Advanced Functional Materials, 18(20), 3226-3234. https://doi.org/10.1002/adfm.200800528

[137] Jeon, N. J., Noh, J. H., Kim, Y. C., Yang, W. S., Ryu, S., & Seok, S. I. (2014). Solvent engineering for high-performance inorganic–organic hybrid perovskite solar cells. Nature materials, 13(9), 897-903. https://doi.org/10.1038/nmat4014

[138] Vidiasheva, I. V., Abalymov, A. A., Kurochkin, M. A., Mayorova, O. A., Lomova, M. V., German, S. V., ... & Sukhorukov, G. B. (2018). Transfer of cells with uptaken nanocomposite, magnetite-nanoparticle functionalized capsules with electromagnetic tweezers. Biomaterials Science, 6(8), 2219-2229. https://doi.org/10.1039/C8BM00479J

[139] Muderrisoglu, C., Saveleva, M., Abalymov, A., Van der Meeren, L., Ivanova, A., Atkin, V., ... & Skirtach, A. G. (2018). Nanostructured biointerfaces based on bioceramic calcium carbonate/hydrogel coatings on titanium with an active enzyme for stimulating osteoblasts growth. Advanced Materials Interfaces, 5(19), 1800452. https://doi.org/10.1002/admi.201800452

[140] Kuznetsova, T. G., Starodubtseva, M. N., Yegorenkov, N. I., Chizhik, S. A., & Zhdanov, R. I. (2007). Atomic force microscopy probing of cell elasticity. Micron, 38(8), 824-833. https://doi.org/10.1016/j.micron.2007.06.011

[141] Moeendarbary, E., & Harris, A. R. (2014). Cell mechanics: principles, practices, and prospects. Wiley Interdisciplinary Reviews: Systems Biology and Medicine, 6(5), 371-388. https://doi.org/10.1002/wsbm.1275

[142] Goswami, P., & O'Haire, T. (2016). Developments in the use of green (biodegradable), recycled and biopolymer materials in technical nonwovens. Advances in Technical Nonwovens, 97-114. https://doi.org/10.1016/B978-0-08-100575-0.00003-6

[143] EL Messiry, M. (2022). Biodegradable fibers, polymers, composites and its biodegradability, processing and testing methods. Bio-Fiber Reinforced Composite Materials: Mechanical, Thermal and Tribological Properties, 75-104. https://doi.org/10.1007/978-981-16-8899-7_5

[144] Tong, H. S., Kabeb, S. M., Abd Hamid, H., & Zulkifli, F. H. (2025). A review of biodegradability of natural rubber products: Physicochemical, thermal and mechanical properties. International Journal of Biological Macromolecules, 318, 144973. https://doi.org/10.1016/j.ijbiomac.2025.144973

[145] Domínguez-Solera, E., Gadaleta, G., Ferrero-Aguar, P., Navarro-Calderón, Á., & Escrig-Rondán, C. (2025). The biodegradability of plastic products for agricultural application: European regulations and technical criteria. Clean Technologies, 7(1), 11. https://doi.org/10.3390/cleantechnol7010011

[146] Lors, C., Leleux, P., & Park, C. H. (2025). State of the art on biodegradability of bio-based plastics containing polylactic acid. Frontiers in Materials, 11, 1476484. https://doi.org/10.3389/fmats.2024.1476484

[147] Hubbe, M. A., Daystar, J. S., Venditti, R. A., Pawlak, J. J., Zambrano, M. C., Barlaz, M., ... & Pires, S. (2025). Biodegradability of Cellulose Fibers, Films, and Particles: A Review. BioResources, 20(1). https://doi.org/10.15376/biores.20.1.Hubbe

[148] Gadaleta, G., Andrade-Chapal, J. C., López-Ibáñez, S., Mozo-Toledo, M., & Navarro-Calderón, Á. (2025). Biodegradability of Bioplastics in Managed and Unmanaged Environments: A Comprehensive Review. Materials, 18(10), 2382. https://doi.org/10.3390/ma18102382

[149] Han, H. R. (2025). Antibiotic Action, Drug Delivery, Biodegradability, and Wound Regeneration Characteristics of Surgical Sutures and Cutting-Edge Surgical Suture Manufacturing Technologies. Journal of Functional Biomaterials, 16(4), 135. https://doi.org/10.3390/jfb16040135

[150] Charerntanom, W., Buddhakala, M., & Buddhakala, N. (2025). Mechanical Properties, Morphology and Biodegradability of Biopolymer Composites Prepared from Thermoplastic Starch and Polybutylene Succinate Reinforced with Rice Straw Fiber. Trends in Sciences, 22(6), 9767-9767. https://doi.org/10.48048/tis.2025.9767

[151] Zhuikova, Y., Zhuikov, V., & Varlamov, V. (2022). Biocomposite materials based on poly (3-hydroxybutyrate) and chitosan: a review. Polymers, 14(24), 5549. https://doi.org/10.3390/polym14245549

[152] Glaskova-Kuzmina, T., Starkova, O., Gaidukovs, S., Platnieks, O., & Gaidukova, G. (2021). Durability of biodegradable polymer nanocomposites. Polymers, 13(19), 3375. https://doi.org/10.3390/polym13193375

[153] Silva, M., Ferreira, F. N., Alves, N. M., & Paiva, M. C. (2020). Biodegradable polymer nanocomposites for ligament/tendon tissue engineering. Journal of Nanobiotechnology, 18(1), 23. https://doi.org/10.1186/s12951-019-0556-1

[154] Guo, Y., Zuo, X., Xue, Y., Tang, J., Gouzman, M., Fang, Y., ... & Rafailovich, M. H. (2020). Engineering thermally and electrically conductive biodegradable polymer nanocomposites. Composites Part B: Engineering, 189, 107905. https://doi.org/10.1016/j.compositesb.2020.107905

[155] Purvis, B., Mao, Y., & Robinson, D. (2019). Three pillars of sustainability: in search of conceptual origins. Sustainability science, 14(3), 681-695. https://doi.org/10.1007/s11625-018-0627-5

[156] U. Nations, Sustainability | United Nations. [Online]. Avail able: https:// www. un. org/ en/ acade mic- impact/ susta inabi lity. Accessed 02 Nov 2022.

[157] Arora B, Bhatia R, Attri P. (2018) Bionanocomposites: green materials for a sustainable future. New Polymer Nanocomposites for Environmental Remediation: 699-712. https://doi.org/10.1016/B978-0-12-811033-1.00027-5

[158] Kafy, A., Akther, A., Zhai, L., Kim, H. C., & Kim, J. (2017). Porous cellulose/graphene oxide nanocomposite as flexible and renewable electrode material for supercapacitor. Synthetic Metals, 223, 94-100. https://doi.org/10.1016/j.synthmet.2016.12.010

[159] Majeed, K., Jawaid, M., Hassan, A. A. B. A. A., Bakar, A. A., Khalil, H. A., Salema, A. A., & Inuwa, I. (2013). Potential materials for food packaging from nanoclay/natural fibres filled hybrid composites. Materials & Design (1980-2015), 46, 391-410. https://doi.org/10.1016/j.matdes.2012.10.044

[160] Chaturvedi, A. K., Gupta, M. K., & Pappu, A. (2021). The role of carbon nanotubes on flexural strength and dielectric properties of water sustainable fly ash polymer nanocomposites. Physica B: Condensed Matter, 620, 413283. https://doi.org/10.1016/j.physb.2021.413283

[161] Mortazavi Moghadam, F. A., Resalati, H., Rasouli, S., & Asadpour, G. (2021). Fabrication of high mechanical properties papers coated with CMC-based nanocomposites containing nanominerals synthesized from paper waste. Cellulose, 28(17), 11153-11164. https://doi.org/10.1007/s10570-021-04241-7

[162] Radhakrishnan, S., Das, P. P., & Chaudhary, V. (2024). Deciphering the pathways for evaluation of nanofillers for polymer composites: biodegradability, sustainability, and emerging applications. Biomass Conversion and Biorefinery, 14(13), 13659-13690. https://doi.org/10.1007/s13399-022-03548-0

[163] Punia, P., Naagar, M., Chalia, S., Dhar, R., Ravelo, B., Thakur, P., & Thakur, A. (2021). Recent advances in synthesis, characterization, and applications of nanoparticles for contaminated water treatment-A review. Ceramics International, 47(2), 1526-1550. https://doi.org/10.1016/j.ceramint.2020.09.050

[164] Nasir, A., Masood, F., Yasin, T., & Hameed, A. (2019). Progress in polymeric nanocomposite membranes for wastewater treatment: Preparation, properties and applications. Journal of Industrial and Engineering Chemistry, 79, 29-40. https://doi.org/10.1016/j.jiec.2019.06.052

[165] Kalia, S., Kango, S., Kumar, A., Haldorai, Y., Kumari, B., & Kumar, R. (2014). Magnetic polymer nanocomposites for

environmental and biomedical applications. Colloid and Polymer Science, 292(9), 2025-2052. https://doi.org/10.1007/s00396-014-3357-y

[166] Wen, Y. H., Tsou, C. H., de Guzman, M. R., Huang, D., Yu, Y. Q., Gao, C., ... & Wang, Z. H. (2022). Antibacterial nanocomposite films of poly (vinyl alcohol) modified with zinc oxide-doped multiwalled carbon nanotubes as food packaging. Polymer Bulletin, 79(6), 3847-3866. https://doi.org/10.1007/s00289-021-03666-1

[167] Malik, N. (2022). Thermally exfoliated graphene oxide reinforced polycaprolactone-based bactericidal nanocomposites for food packaging applications. Materials Technology, 37(5), 345-354. https://doi.org/10.1080/10667857.2020.1842150

[168] Babaei, E., Valery, V., Blinov, A., Povetkin, S., Baklanov, I. (2025). 'Synthesis of chromenen derivatives using multicomponent reactions and SiO_2/Fe_3O_4 nanoparticles', Journal of Medical, Chemical and Biomedical Engineering, 1(3), pp. 194-205.

[169] Barzegar, M., Zare, A. (2022). 'Nano-[Fe_3O_4@SiO_2@$RNHMe_2$][HSO_4]: an effectual catalyst for the production of 1-amidoalkyl-2-naphthols', Progress in Chemical and Biochemical Research, 5(1), pp. 68-76.

[170] Benson, A., Akinterinwa, A., Milam, C., Hammed, A. M. (2023). 'Chemical Profiling of Minerals and Elemental Composition of Rock and Soil Samples from Bakin Dutse Hills, Madagali, Adamawa State Nigeria', Eurasian Journal of Science and Technology, 3(4), pp. 232-245.

[171] Dousti, M., Firoozfar, A. (2022). 'Compacted Kerman Clay Liner, Different Permeants and Different Additives', Journal of Engineering in Industrial Research, 3(1), pp. 54-68.

[172] Egwuatu, O. Peter, Ori, M. Oluchi, Samuel, H. Sam, Ekpan, F. Makong (2024). 'AI-enabled Diagnostics and Monitoring in Nanomedicine', Eurasian Journal of Science and Technology, 4(3), pp. 208-229.

[173] Farajpour, M., Vahdat, S. M., Baghbanian, S. M., Hatami, M. (2023). 'Ag-SiO2 Nanoparticles: Benign, Expedient, and Facile Nano Catalyst in Synthesis of Decahydroacridines', Chemical Methodologies, 7(7), pp. 540-551.

[174] Hassani, H., Heidary, S., Banitaba, S. H. (2025). 'Application of Basic Magnetic Phase Transfer Nanocatalysts in the One-Pot and Multicomponent Synthesis of Poly-Substituted Aniline', Chemical Methodologies, 9(6), pp. 403-416.

[175] Hojjati, M., Valery, V., Blinov, A., Povetkin, S., Baklanov, I. (2025). 'Green synthesis of novel pyrimido [1, 8] naphthyridine using multicomponent reactions of carbodiimides: investigation of biological activity', Journal of Medical, Chemical and Biomedical Engineering, 1(3), pp. 147-163.

[176] Ibukun, A. E., Bin Abd Hamid, M. A., Mohamed, A. H., Mohamad Zain, N. N., Kamaruddin, M. A., Loh, S. H., Kamaruzaman, S., Yahaya, N. (2024). 'A Review on the Toxicity and Properties of Organochlorine Pesticides, and Their Adsorption/Removal Studies from Aqueous Media Using Graphene-Based Sorbents', Journal of Chemical Reviews, 6(2), pp. 237-303.

[177] Karampour, F. (2024). 'Green Synthesis of γ-Fe2O3@SiO2 Coated by an Antiviral Drug Cidofovir as New Magnetic Nanoparticles: Synthesis, Characterization and Cytotoxicity Properties', International Journal of Advanced Biological and Biomedical Research, 12(4), pp. 357-370.

[178] Karampour, F. (2024). 'Green Synthesis of γ-Fe2O3@SiO2 Coated by an Antiviral Drug Cidofovir as New Magnetic Nanoparticles: Synthesis, Characterization and Cytotoxicity Properties', International Journal of Advanced Biological and Biomedical Research, 12(4), pp. 357-370.

[179] Khodayari Mafi, M., Rouhi, S. (2025). 'Design and Fabrication of Nano Solar Cell on Ultra-Light Silica Substrate', Asian Journal of Green Chemistry, 9(1), pp. 101-114.

[180] Khodayari Mafi, M., Rouhi, S. (2025). 'Investigating and Studying the Effects of Coating Converter Colors with the Approach of Converting Solar Energy into Electric Current in Solar Cells on Porous Silica', Asian Journal of Green Chemistry, 9(2), pp. 129-138.

[181] Mashal, N., Valery, V., Blinov, A., Povetkin, S., Baklanov, I., Chernov, A. Y., Rzhepakovsky, I., Shaposhnikov, E. (2025). 'Ag/Fe_3O_4/SiO_2@GO promoted green synthesis of new pyrimidine derivatives via one-pot multicomponent reactions', Journal of Medical, Chemical and Biomedical Engineering, 1(2), pp. 76-92.

[182] Mhaibes, R. M., Arzehgar, Z., Mirzaei Heydari, M., Fatolahi, L. (2023). 'ZnO Nanoparticles: A Highly Efficient and Recyclable Catalyst for Tandem Knoevenagel-Michael-Cyclocondensation Reaction', Asian Journal of Green Chemistry, 7(1), pp. 1-8.

[183] Mohsin, M.M., Ali, F.H. (2023). 'Enhancement of Pigments Hydrophobicity by Mixing with Cr Doped SiO2 Nanoparticles', Chemical Methodologies, 7(5), pp. 335-347.

[184] Ndung'u, S. N., Wanjau, R. N., Nthiga, E. W. (2024). 'Efficacy of Adsorption of Congo Red Dyes from an Aqueous Media using Silicon Nitride (Si3N4) Adsorbent Derived from Sand and Coffee Husk Wastes', Eurasian Journal of Science and Technology, 4(3), pp. 253-263. https://doi.org/10.33886/ajpas.v4i3.426

[185] Peiman, S., Maleki, B., Ghani, M. (2024). 'Fe_3O_4@SiO_2@Mel-Rh-Cu: A High-Performance, Green Catalyst for Efficient Xanthene Synthesis and Its Application for Magnetic Solid Phase Extraction of Diazinon Followed by Its Determination through HPLC-UV', Chemical Methodologies, 8(4), pp. 257-278.

[186] Reagen, M. Alvin, Oktiarni, D., Yudha S.S. (2025). 'Derivatized Products from Oil Palm Leaves and Magnesium Salt for Application in Congo Red Adsorption', Advanced Journal of Chemistry, Section A, 8(8), pp. 1317-1328.

[187] Sadik, A. Faisal, Mostafa, E. Mohamed, El-Sherif, R. M. (2025). 'Advanced Functionalization of Polysulfone Membranes with Green-Synthesized Silica (Si) and Silica-Silver (Si-Ag) Nanocomposites for Water Desalination and Environmental Applications', Asian Journal of Green Chemistry, 9(5), pp. 716-737.

[188] Sajjadifar, S., Abakhsh, F., Arzehgar, Z. (2024). 'Design and Characterization of Fe_3O_4@n-pr-NH_2@$Zn_3(BTC)_2$ Magnetic MOF: A Catalyst for Dihydropyrimidine and 2-Amino-4H-Chromene Synthesis', Chemical Methodologies, 8(8), pp. 550-568.

[189] Sajjadifar, S., Zarrouk, A., Arzehgar, Z., Hamidi, H., Hajiabbasi Tabar Amiri, P., Rahimi, A., Mirzaei Heydari, M., Khan, S. L., Rilwan, U., Jamal, R. Kamel, Abubaker, M. Aamer (2025). 'A recent advancement on the applications of modified electrochemical sensors in determination of morphine-a review', Journal of Environmental and Bioanalytical Electrochemistry, 1(1), pp. 53-73. doi: 10.48309/jebe.2025.501875.1009.

[190] Shehu, U. Ishaq, Usman, B. (2023). 'Corrosion Inhibition of Iron Using Silicate Base Molecules: A Computational Study', Advanced Journal of Chemistry, Section A, 6(4), pp. 334-341.

[191] Sohrabi-Kashani, L., Zolriasatein, A., Eftekhari Yekta, B. (2023). 'Effect of silica nanoparticles modified with different concentrations of stearic acid on microstructure, mechanical & electrical properties of RTV-2 silicone rubber nanocomposite', Journal of Medicinal and Nanomaterials Chemistry, 5(1), pp. 16-32.

[192] Taheri, A., Jafari, A., Jafari, F. (2024). 'Production of Modified Superplasticizer by Two-Step Synthesis of Nanosilica-Polycarboxylate Ether', Advanced Journal of Chemistry, Section B: Natural Products and Medical Chemistry, 6(1), pp. 31-45.

[193] Zare, A., Oraki, M., Rostami, E., Jazinizadeh, E., Abshirini, Z. (2024). 'Efficacious Fabrication of 2-Amino-4H-chromenes using a New Inorganic-Organic Hybrid Nanomaterial', Chemical Methodologies, 8(6), pp. 478-491.

[194] A. Hassan Idan, O. H. Salah, Z. Hamzaa Abud Alzahraa, B. Abdukrazzaq Mohammed, A. Ismael Saber, A. M. Hashim and Z. Mashhadani, "Powdered of Highly Porous Hydrogel Nanocomposite Prepared from Acrylamide- Acrylic Acid -Treated by Activated Carbon for Brilliant Blue Dye Removal, " Advanced Journal of Chemistry, Section A, 7 5 (2024): 607-616,

[195] Ahmed, R. A., Salah, O. H., Al-Saedi, H. F. S., Karim, M. M., Khuder, S. A., Kareem, A. H., Hammady, F. J. (2024). 'A Green Surface Prepared with Highly Applicable of Advanced Oxidative Processes AOPs for Removal of Riboflavin Drug Pollutant Remediation', Asian Journal of Green Chemistry, 8(3), pp. 296-307.

[196] Akighirga, A. T., Bada, B. S., Meer, B. B., Japheth, D. H. (2025). 'Evaluation of Anticipated Performance Index of Some Urban Trees along Selected Roads in Makurdi, Nigeria', Eurasian Journal of Science and Technology, 5(3), pp. 293-301.

[197] Akinbami, O.R., Oderinde, P.A., Olutimehin, T.A., Mohammed, M.A. (2025). 'Bio-Adsorbent Potential of Coconut Shell-Derived Cellulose for Methylene Blue Removal from Wastewater Treatment', International Journal of Advanced Biological and Biomedical Research, 13(2), pp. 188-196.

[198] Badr, A. A. (2023). 'Effect of Methyl-Tertiary Butyl Ether on Body Weight Trend in Male Wistar Rats', International Journal of Advanced Biological and Biomedical Research, 11(1), pp. 10-15.

[199] Behzadi, R. (2023). 'Investigating the Problems of Sulfur in Hydrocarbon Cuts', Eurasian Journal of Science and Technology, 3(4), pp. 185-202.

[200] Einad, N. A., Merza, M. M., Ismail, A. H. (2024). 'Experimental and DFT Studies of Comparison Between CuO and CuO-Fe_2O_3 to Remove Dye Pollutants from Aqueous Solution', Advanced Journal of Chemistry, Section A, 8(4), pp. 700-715.

[201] Hadadi, T., Shahraki, M., Karimi, P. (2024). 'Adsorption of some Nitrophenols onto Graphene and Functionalized Graphene Sheets: Quantum Mechanics Calculations, Monte Carlo, and Molecular Dynamics Simulations', Chemical Methodologies, 8(10), pp. 753-775.

[202] Hadadi, T., Shahraki, M., Karimi, P. (2024). 'Methane, Chlorofluorocmethane and Chlorodifluoromethane Adsorption onto Graphene and Functionalized Graphene Sheets: Computational Methods', Asian Journal of Green Chemistry, 8(6), pp. 652-671.

[203] Hadadi, T., Shahraki, M., Karimi, P. (2024). 'Methane, Chlorofluorocmethane and Chlorodifluoromethane Adsorption onto Graphene and Functionalized Graphene Sheets: Computational Methods', Asian Journal of Green Chemistry, 8(6), pp. 652-671.

[204] Hadi, E., Jasim, K. K. (2025). 'Responsive UV-light Photocatalytic of Ag/ZnO Nanocomposites for Removal of Brilliant Blue Dye: As a Model for Advanced Chemical Studies', Advanced Journal of Chemistry, Section A, 8(3), pp. 604-614.

[205] Mhaibes, R. M., Arzehgar, Z., Mirzaei Heydari, M., Fatolahi, L. (2023). 'ZnO Nanoparticles: A Highly Efficient and Recyclable Catalyst for Tandem Knoevenagel-Michael-Cyclocondensation Reaction', Asian Journal of Green Chemistry, 7(1), pp. 1-8.

[206] Onuoha, V. Adaeze, Maduka, K. Solomon (2024). 'Comparative Analysis of Air Quality in Different Markets of Owerri Metropolis in Relation to Vehicular Emission', Advanced Journal of Chemistry, Section B: Natural Products and Medical Chemistry, 6(4), pp. 394-404.

[207] Ori, M. O., Ime, E. P., Ekpan, F. M., Samuel, H. S., Egwuatu, O. P., Ajor, E. J. (2024). 'Revisiting on Applications of Industrial Filters in Enhancing Polymer Product Quality and Performance', Eurasian Journal of Science and Technology, 4(2), pp. 116-132.

[208] Peikari, N., Lotfi, R., Makhdomi, H. (2015). 'Social Networks, Cyberspace and Formation of Virtual Identity of the Users', International Journal of Advanced Studies in Humanities and Social Science, 4(2), pp. 92-101.

[209] Rashid, R., Maaz, M., Shafiq, I., Hussain, M., Abbas, N., Gilani, M. R. H. S., Voskressensky, L., Luque, R. (2024). 'Dual-Function Polymeric Nanomaterials for Adsorption/Photo-Treatment of Oil Spills in Aqueous Solutions', Chemical Methodologies, 8(12), pp. 930-943.

[210] Rostami Charati, F., Ansori, A. N. M., Jakhmola, V. (2025). 'Cu/Clinoptilolite@MWCNTs nanocomposite facilitated the syn Sajjadifar, S., Abakhsh, F., Arzehgar, Z. (2024). 'Design and Characterization of Fe_3O_4@n-pr-NH_2@$Zn_3(BTC)_2$ Magnetic MOF: A Catalyst for Dihydropyrimidine and 2-Amino-4H-Chromene Synthesis', Chemical Methodologies, 8(8), pp. 550-568.

[211] Sabouri, Z., Sammak, S., Sabouri, S., Tabrizi Hafez Moghaddas, S. S., Darroudi, M. (2024). 'Green Synthesis of Ag-Se doped ZnO-Co3O4-NiO Fivenary Nanocomposite using Poly Anionic Cellulose and Evaluation of Their Anticancer and Photocatalyst Applications', Chemical Methodologies, 8(3), pp. 164-176.

[212] Safajou-Jahankhanemlou, M., Saboor, F. Hooriabad, Esmailzadeh, F. (2023). 'Treatment of Tire Industry Wastewater through Adsorption Process using Waste Tire Rubber', Advanced Journal of Chemistry, Section A, 6(1), pp. 85-91.

[213] Sajjadifar, S., Zarrouk, A., Arzehgar, Z., Hamidi, H., Hajiabbasi Tabar Amiri, P., Rahimi, A., Mirzaei Heydari, M., Khan, S. L., Rilwan, U., Jamal, R. Kamel, Abubaker, M. Aamer (2025). 'A recent advancement on the applications of modified electrochemical sensors in determination of morphine-a review', Journal of Environmental and Bioanalytical Electrochemistry, 1(1), pp. 53-73.

[214] Samimi, M., Amiri, K. (2024). 'Zinc Alginate Beads as an Effective Biosorbent for the Removal of Eosin-B from Aquatic Solutions: Equilibrium, Kinetics, and Thermodynamic Behaviors', Chemical Methodologies, 8(5), pp. 351-363.

[215] Sheshagir, M. B., Dhanpal, S., Yadav, R., Sahoo, S. C., Upadhyay, V. K. (2024). 'Formaldehyde Emission-Correlation between Different Standard Methods in Three Different Panel Products', Chemical Methodologies, 8(10), pp. 713-732.

[216] Suborna, S. A., Lubna, F. I., Hasan, M. H., Arabi, I. I., Bhowmik, P. (2025). 'Is the Amino Acid HIS458 and ASP/ASN206 of Laccase from $T. Versicolor$ and $T. Hirsuta$ Crucial for the Decolorization of Polycyclic Aromatic Textile Dyes? An $In\ Silico$ Investigation', Eurasian Journal of Science and Technology, 5(1), pp. 106-124.

[217] Tabugbo, B. I., Ogbuagu, O. J., Chris- Okafor, P. U., Nwokoye, J. N., Usman, R. (2024). 'Assessment of Polychlorinated Biphenyl (PCB) Contamination in River Waters of Anambra State, Nigeria: Implications for Ecosystem Health and Human Well-Being', Eurasian Journal of Science and Technology, 4(4), pp. 373-383.

[218] Thesis of novel quinazolines and the reduction of organic pollutants', Journal of Medical, Chemical and Biomedical Engineering, 1(1), pp. 11-23.

[219] Yussuf, M. D., Abdulazeez, U. T., Ibe, B. O., Asem, T. K., Salaudeen, A. T., Eberechukwu, T. E., Adewale, S. D., Arthur, C., Oke, K. O. (2025). 'Polycyclic Aromatic Hydrocarbons (PAHs) in Soil: Sources, Analytical Techniques, Environmental Impact, and Remediation Strategies', International Journal of Advanced Biological and Biomedical Research, 13(5), pp. 616-640.

https://doi.org/10.12974/2311-8717.2025.13.03