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A REVIEW ON SYNTHESIS OF SILICA NANOCOMPOSITES WITH CONDUCTING POLYMERS: POLYANILINE

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Abstract:

Conducting nanostructures have achieved a prominent position in nanotechnology. Because of larger surface area it can be used in various applications. In recent scenario a class of conducting polymers is becoming popular due to its mechanical and electrical properties. Polyaniline is a conducting polymer which is popularly known as an environmentally stable and highly tunable polymer which can be produced in the form of bulk powder, cast films, or fibers. Polyaniline is of low cost, large-scale production, it is extensively used in vast applications. Polyaniline term corresponding to a class of polymers with up to 1000 repeat units (also known as MER) and was firstly it was known in 1862. Nanocomposite material is a solid phase multi-phase one of which has one, two or three dimensions less than 100 nanometers (nm) , or structures having repeating distances nanoscale between the different phases within the material. Silica Nanocomposites combined with conducting polymers such as polyaniline are prepared by in situ polymerization and can be used in various applications such as supercapacitors, pseudocapacitors, Layerings and coatings, metal uptake, Chemosensors, Encapsulation of Organic Light Emitting Devices, Proton exchange membrane, pervaporation membrane, biosensors, flexible nanoelectronic devices, drug delivery.

Keywords: Silica nanoparticles, Silica nanocomposites, Polyaniline, Conducting Polymers.

Introduction

Recently, the development of nanomaterials have received greater attention because of their optical, mechanical, electrical and chemical properties. These can be used in ultrasensitive detection of biological species. The various materials which are used to prepare nanoparticles, nanowires, nanotubes and nanocomposites are metals, semiconductors, carbon and polymers. The applications of these materials includes optical and electronic devices, chemical and bio medical fields. Fabrication and uses of these materials are reported for high density arrays.[1]

Conductive polymers were discovered in 1976. In mid of 1970s , the first polymer polyacetylene



Amritpal Kaur, Anupreet Kaur, Deepak Saini

able to conduct electricity, was prepared accidentally by Shirakawa. Although it was not stable in air, the fact that it may become conductive due to doping and it has led to further experiments with other known conjugated polymers. Since 1976, a number of conductive polymers, namely polypyrrole, polythiophene, and polyaniline, have become the subject of many studies. The importance of driving polymers is illustrated by the award of the Nobel chemistry prize in 2000 to MacDiarmid, Shirakawa, and Heeger for the discovery and upliftment of conducting polymers.

Conjugated polymers such as polyaniline (PANI), polypyrrole (PPy), polythiophene, and their derivatives has initialised up a new promising field in material science and engineering. There has been developing interest in the past two decades on nanostructured conjugated polymers because of their unique electronic and optical properties and their potential applications in a various advanced devices ranging from organic electronics, sensors, batteries, actuators, to electro-optic and electro-chromatic devices. PANI is regarded as most attractive conducting polymers due to its special features like low cost, high environmental stability, good electrical conductivity, ease of synthesis, and interesting redox properties associated with the chain nitrogen. A differentiable feature of PANI as compared to other conjugated polymers is the reversibly tunable redox characteristics which permits the control of electrical conductivity over a wide range by protonation and charge-transfer doping.

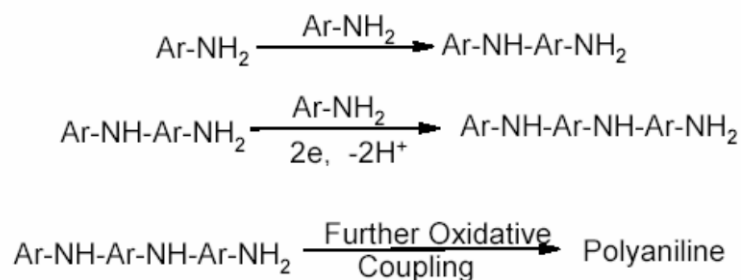


Fig 1: Polyaniline formation

Silica Nanocomposites/polyaniline -received much attention because of the greater surface area which enables the fast distribution of gas molecules in the structure. There are several routes to prepare nanocomposites of various conductive polymers. They were prepared for chemical polymerization of aniline. In the same way polypyrrole (ppy) were synthesized nanofibers (60-100 nm diameter) in the presence of p- hydroxy - azobenzene acid a functional dopant . Conducting nano - dimensional

Polymers reported properties show that a higher conductivity and more increase in electrochemical switching speed.[1]

Polyaniline is a typical phenylene based polymer that have chemically flexible –NH group in a polymer chain supported either side by a phenylene ring. The other definition of polyaniline It can also be as the simple 1, 4- coupling product of monomeric aniline molecule. The

Amritpal Kaur, Anupreet Kaur, Deepak Saini

protonation and deprotonation including many other physico-chemical properties of polyaniline is due to the presence of the $-NH-$ group. Polyaniline is oxidative polymeric product of aniline under acidic conditions and has been popular since 1862 as black aniline. There are various reports of polyaniline which are found in the literature over the decades about the structure and constitutional aspect of aniline polymerization. Polyaniline can be synthesized either chemically or electrochemical oxidative polymerization.

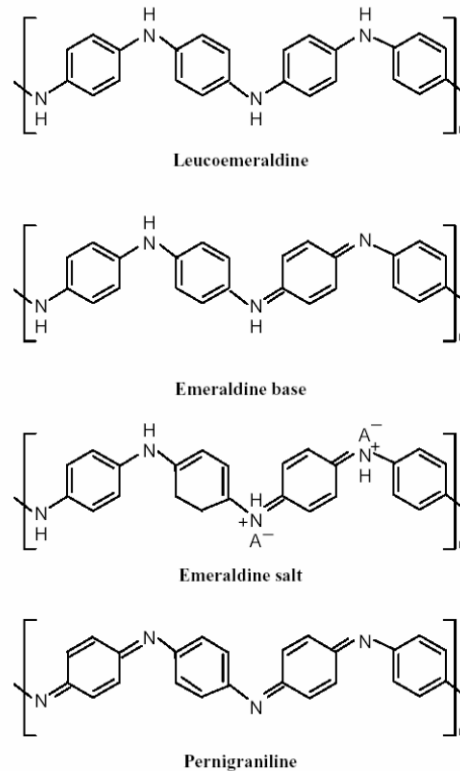


Fig 2. Oxidation states of polyaniline

Polymer nano - composite materials have gained the interest of a number of researchers, because of synergic and their derivation of hybrid components from various components.

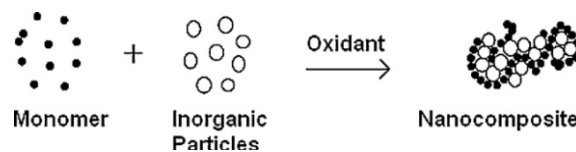


Fig 3. Formation of nanocomposites.[1]

Easy processability of an organic polymer combined with improved mechanical and optical properties of nanoparticles led to the production of many devices. But, their compatibility has been a serious problem and that can be hiked by functionalization or by the deposition of ultra thin film of composite nanomaterials which are finely dispersed. Nowadays,

Amritpal Kaur, Anupreet Kaur, Deepak Saini

conductive polymers / carbon nanotube composite materials - have gained considerable interest not only because the carbon nanotubes are capable of improving the electrical and mechanical properties of polymers , but because the composites acquired properties of individual components , with a synergistic effect. [1]

Silica Nanoparticles

Silica nanoparticles achieved a definite position in scientific research because they can be easily prepared. A sequential - method was used firstly to prepare the monodispersed silica nanoparticles of uniform size using ultrasonic sol- gel process . The silica particles have therefore obtained by hydrolysis of tetraethylorthosilicate (TEOS) in the medium of ethanol and study was done on the effects of different reagents in grain sizes . Particles of various sizes in the 20-460 nm range were synthesized . The ammonia reagents (2.8 to 28 mol L - 1) , ethanol (1-8 mol L - 1) , the water (3-14 mol L - 1) , and TEOS (0.012 to 0.12 mol L - 1) were used and the particle size has been examined in scanning electron microscope and transmission electron microscopy.[2]

Hydrolysis: $\text{Si}-(\text{OR})_4 + \text{H}_2\text{O} \rightarrow \text{Si}-(\text{OH})_4 + 4\text{R}-\text{OH}$

Condensation: $2\text{Si}-(\text{OH})_4 \rightarrow 2(\text{Si}-\text{O}-\text{Si}) + 4\text{H}_2\text{O}$.[2]

Nanoscale materials shows improved characteristics in comparison to macro scale materials. In present scenario there has been demand and increased interest for nanoscale materials, mainly in the scope of industrial applications. Silica nanoparticles are used as electronic substrates, thin films, electrical/thermal insulators, emulsifiers, stabilizers, etc. The quality of these materials is sharply dependent on the size and distribution of the silica particles. Different and adjacent levels of metal contaminants and enhanced size distribution of commercialized silica nanoparticles have shown promotion in initiatives to produce purer particles with narrow size distribution.[2]

Preparation of PANI/SiO₂ Nanocomposites

The PANI/SiO₂ nanocomposites were synthesized by in situ chemical oxidative polymerization method of aniline in the presence of silica nanoparticles. Firstly, in five 250 mL round bottom flasks, aniline (9.3 g, 0.1 mmol) and 50 mL of HCl (1 M) were mixed and stirred for 10 min to permit the aniline monomer to be doped by HCl. Then, sufficient amounts of SiO₂ nanoparticles (0.1, 0.2, 0.3, 0.4, and 0.5 g) were separately inserted into five mixtures of aniline-hydrochloric acid. After adding SiO₂ to the flasks, the mixtures were sonicated in an ultrasound bath for 30 min to prevent aggregation of SiO₂ nanoparticles and allowing aniline-HCl to deposit on surface of SiO₂ through the attraction between aniline and the positive charge of inorganic oxides. After that, APS (22.8 g, 0.1 mmol) was dissolved in 100 mL of HCl (1 M) and added dropwise into the above mixtures at -5°C with stable stirring. The polymerization was continued for 4 h with constant stirring at -5°C. Dark green precipitates were collected on a Buchner funnel, and washed several times with distilled water until the filtered substances became almost colorless.[3]



A Review of Literature

Due to increasing popularity plenty of work is publishing on polymer/silica nanocomposites. The review has been made on present achievements on the preparation, properties, characterizations, and application of this type of nanocomposites. Basically three methods are employed for the preparation of polymer/silica nanocomposites namely blending, in situ polymerization and the sol-gel process. Investigations have been done on these three methods. Colloidal polymer/silica nanocomposites are more attractive. Not only the properties of components individually in a nanocomposite, significant role is played by the degree of dispersion of nanoparticles in the polymer and the interfacial interaction to enhance or limit the systems overall properties of the. Universal patterns cannot be deduced generally but some patterns could be visualised to check the behavior and nature of polymer nanocomposites. Polymer/silica nanocomposites exhibits good properties as compared to pure polymer. Mechanical properties and thermal stability is improved. Because of this large interfacial area and interfacial volume, it is advantageous in very unique combinations of properties of nanocomposites polymers. Perhaps sufficient work has been explored on different features of polymer/ silica nanocomposites, but still more researchwork have been required so as to further explore the complex structure and properties. Interfacial interaction of filler/matrix will provide the best understanding of the relationships.[4] Particularly, inorganic-polymer core-shell nanoparticles are more promising in such new applications as surface-enhanced Raman scattering, photonic crystals, catalysis, nano-electronic devices, and biochemical sensor.[5]

Peng Liu et al. introduced in situ chemical oxidative graft polymerization of aniline from silica nanoparticles in which Polyaniline (PANI) grafted silica nanoparticles (PANI-SNs) was prepared for the first time by in situ chemical oxidating of aniline with ammonium peroxodisulfate (APS) from the surfaces of the aminopropyl silica nanoparticles (APSNs) successfully with a dispersion polymerization method.[5] A percentage of grafting (PG) of 205.2% and a grafting efficiency (GE) of 37.7% were achieved, calculated from the results of elemental analysis (EA).[6]

Chia-Fen Lee et al. described the Properties and various Synthesis techniques of Conductive Composite Particles such as Silica/Polystyrene/Polyaniline. Synthesis of these SiO₂ nanosized particles were done from tetraethoxysilane (TEOS) used in sol-gel process in which water was used as a medium of solvent, surface modification was followed with triethoxyvinylsilane; seeds were produced of surface modified SiO₂ particles for the synthesis of SiO₂/PS composite particles and polymerization of seeded soapless was done. The discussion was made on the sol-gel process implemented on SiO₂, surface modification effect, and various other factors which have influenced of the styrene polymerization in the emulsion that is soapless seeded. Either potassium persulfate (KPS) or 2,2'-azobis (isobutyramidine) dihydrochloride (AIBA) was used as the initiator to synthesize the uniform SiO₂/PS particles successfully.[7]

Xiao-Xia et al. have done anchoring of silica nanoparticles on polyaniline (PANI) chains chemically and it was done by the electro-co-polymerization process on aniline and *N*-substituted aniline was grafted on surface pattern of silica nanoparticles. The realization was made through the hydrolysis of triethoxysilylmethyl *N*-substituted aniline (ND42) and the following condensation reaction on surfaces of SiO₂ nanoparticles with the groups of silanol of grafting of *N*-substituted aniline.

Therefore, the morphologies of obtained hybrid film PANI/ND42–SiO₂ was nano-fibrous of 50 nm in diameter displayed morphologies (ca.). Consequently, PANI/ND42–SiO₂ exhibited an average specific capacitance of 380 F g⁻¹, ca. 40% higher than that of PANI/SiO₂ (276 F g⁻¹)[8]. The hybrid film also showed improved cyclic stability[8].

Tar-Hwa Hsieh et al. studied the Synthesis and electromagnetic properties of polyaniline-coated silica/maghemite nanoparticles[9]. Both In situ polymerization method and sol gel process were used in the synthesis of Polyaniline coated silica/maghemite nanoparticles (PANI/SiO₂/c-Fe₂O₃ composites). Multilayer core-shell structure was derived from the the PANI/SiO₂/c- Fe₂O₃ composites , whereas PANI comprises on composites outer shell. The doping level and the conductivity of PANI/SiO₂/c-Fe₂O₃ composites decreased with increasing the TEOS content due to the presence of the less coated PANI on the SiO₂/c-Fe₂O₃ core at higher TEOS content[9].

Fabrication of semiconducting polyaniline/nano-silica nanocomposite particles and their enhanced electrorheological and dielectric characteristics was demonstrated by Ying Dan Liu et al.[10] As a new electroresponsive electrorheological (ER) polymer/inorganic nanocomposite material, polyaniline (PANI)/nano-silica nanocomposite was synthesized via an in situ chemical oxidative polymerization method. [10]

G. D. Prasanna et al. introduced In Situ Synthesis, Characterization And Frequency Dependent Ac Conductivity Of Polyaniline/CoFe₂O₄ Nanocomposites[11]. The AC conductivity was of stable value up to 1MHz and afterwards it rises steeply and it attained the maximum value for the PANI with 60 wt% of CoFe₂O₄ nanocomposites. As the frequencies are decreased at low values simultaneously the values dielectric constant is increased maximum for pure CoFe₂O₄ nanoparticles.[11]

Minkyu Kim et al. achieved the Controllable Synthesis of Highly Conductive Polyaniline Coated Silica Nanoparticles Using Self-Stabilized Dispersion Polymerization[12] In this system, the important role has been played by the organic phase para-direction oriented polymerization of the PANi on the surface of silica nanoparticles. Because of its para-direction polymerized structure, the synthesized silica/PANi core/shell NPs exhibited enhanced electrical conductivity (25.6 S cm⁻¹) compared with NPs (1.4 S cm⁻¹) prepared by homogeneous polymerization[12].

Jing Zheng et al. have done Preparation, characterizations, and explored the potential applications of PANi/ graphene oxide nanocomposite[13] Graphene oxides plus conducting polymers such as polyaniline are some importantly functional materials, which are comprised in various applications such as lithium ion battery with high energy, supercapacitor, catalysts, solar cells, nanodevices, chemical sensors, biosensors and



Amritpal Kaur, Anupreet Kaur, Deepak Saini

biomedical fields[13]. Chemical oxidation method was used to obtain In this paper, Graphene Oxide was obtained by using chemical oxidation method at 25 degree Celsius (Room Temperature), and in situ polymerization method was used nano/micro-structured GO/PANi composites in the Graphene Oxide suspension presence. [13]

Bo-Tau Liu et al. indicated the Conductive polyurethane composites which comprises of polyaniline-coated on silica nanoparticles in which 1.2-Aminopropyltriethoxysilane (APTS) was used as a coupling agent to synthesize silica polyaniline (PANI) core-shell nanoparticles. The reactions of core-shell nanoparticles and PANI oligomers was done with isocyanates for the preparation of the conductive polyurethane (PU)-PANI-silica nanocomposites[14]. With the neat PU, tensile strength and elongation of the nanocomposite containing silica-PANI core-shell nanoparticles can increase 3.1 and 3.8 times, respectively[14].

Hongbo Gu et al. studied the Giant Magnetoresistive Phosphoric Acid Doped Polyaniline-Silica Nanocomposites[16]. The synthesization of phosphoric acid doped conductive polyaniline (PANI) polymer nanocomposites (PNCs) occupied with silica nanoparticles (NPs) was realised using method of facile surface initiated polymerization.[15]

Aijie Liu et al. described the Synthesis and Characterization of Conducting Polyaniline-Copper Composites. Polyaniline-copper (PANI-Cu) conductive composites were synthesized by in-situ polymerization of aniline in the fabricated suspension of copper. These suspensions were obtained in the range of 200-900nm for the Optical absorption in the UV-visible region. Scanning electron microscopy (SEM), X-ray diffraction (XRD) and Fourier-transform infrared spectra (FTIR) were used for the characterization and morphologies.[16]

Li Wang et al. Studied Graphene-based polyaniline nanocomposites that how they are prepared, their different properties and various applications. Because of lower cost PANI is a useful conducting polymer that has been extensively used for electronic, optical and electrochemical applications. It has good environmental stability, interesting electroactivity, high pseudocapacitance and unusual doping/dedoping chemistry. In summary, the applications of graphene-based PANI nanocomposites, such as supercapacitors, sensing platforms, fuel cells, solar cells, electrochromic devices, lithium ion batteries and so on, are described[17].

Mirzaagha Babazadeh et al. have done Fabrication of Conductive Polyaniline Nanocomposites Based on Silica Nanoparticles via In-Situ Chemical Oxidative Polymerization Technique[3]. The obtained nanocomposites were characterized by UV-vis, FT-IR, XRD, TGA, and SEM techniques. The results have shown that nanoparticles of SiO₂ are encapsulated by PANI had a strong effect on the morphology of nanocomposites. At lower values of the conductivity obtained was higher but with the increasing amount of SiO₂ lowers the value of conductivity.[3]



Amritpal Kaur, Anupreet Kaur, Deepak Saini

Nipapan Ruecha et al. discussed the Sensitive electrochemical sensor using a graphene–polyaniline nanocomposite for simultaneous detection of Zn(II), Cd(II), and Pb(II)[18]. The G/PANI-modified electrode have passed the selective determination of the target metals in the presence of common metal interferences which consists of Mn(II), Cu(II), Fe(III), Fe(II), Co(III), and Ni(II). Repeatedly assays on the same device depicts good reproducibility (%RSD < 11) over 10 serial runs. Finally, this system was utilized for determining Zn(II), Cd(II), and Pb(II) in human serum using the standard addition method.[18]

Lei Zu et al. illustrated the Preparation and Electrochemical Characterization of Mesoporous Polyaniline-Silica Nanocomposites as an Electrode Material for Pseudocapacitors[19], The vapor phase approach was used for the synthesis of Mesoporous polyaniline-silica nanocomposites with a full interpenetrating structure for pseudocapacitors. Uniform particle morphology is possessed by the mesoporous nanocomposites and full interpenetrating structure, which leads to a continuous conductive polyaniline network with a greater specific surface area. [19]

Applications of Conducting Nanocomposites

The silica/polymer Nano composites gained huge interest in modern industries because of their ability to improve the mechanical properties like mechanical and thermal properties while showing various unique properties. These Nano composites have many other applications other than plastics and strengthening of rubber, like various resistive and reinforced fire coatings, sensors, electronic devices, ultra permeable membranes, , flame-retardant materials, optical devices, electronics and optical packaging materials, photo resist materials, photoluminescent conducting film, ultrapermeable reverse-selective membranes, proton exchange membranes, grouting materials, sensors, materials for metal uptake, etc. the various morphologies of these Nano composites show some unique and improved properties when compared to usual Nano composites thereby having many unexplored applications like catalysis and coatings. Some of the applications are explored here.[4]

Layers/Coatings

The combination of flexibility of polymers and stiffness of inorganic materials are seen in the hybrid coatings. Generally, they show increased resistance and adhesive strength when compared to old coatings. When acrylates are strengthened with nano silica particles, they form acrylate nanocomposite materials which show superior resistance to scratch and wear & tear. There are various applications of these coatings on surfaces, such as wood, plastics etc. When compared with the nano composites, these in addition to silica nanoparticles show enhanced resistance to rub. Due to these exemplary properties these nanohybrid composites are used in coats for flooring. Since these polymer nano composites can be produced in various different structures, they find use in film formation which is spontaneous with better abrasion resistance due to inorganic nanoparticles present in the polymer.[4]



Proton Exchange Membranes

The proton exchange membrane (PEM) find use as important components of various solid-type fuel cells. There is an ongoing research on the usage of silica polymer nanocomposites as PEM. Hybrid materials as PEMs are formed when Sulfonated poly (phthalazinone ether ketone) having 1.23 sulfonation degree is mixed with silica nanoparticles. The hybrid membranes shows enhanced swelling properties, thermal steadiness, and mechanical properties. The suppression of methanol crossover behavior of the membrane made it possible for it to be used in high methanol concentration environment in a cell test. An optimum power density of 52.9 mW cm⁻² at a current density of 264.6 mA cm⁻² with an open cell potential of 0.6 V were shown with membrane having 5 phr silica nanoparticles which was a certain increase in performance when compared to Nafion and pristine sPPEK membrane.

A polyelectrolyte membrane of Sulfonated P(St-co-MA)-PEG/silica nanocomposite was prepared changed silica content with usage of PEG of various molecular weight for having spacing between silica domains in nanometers. Having their specific use in Direct Methanol Fuel cell(DMFC),these nanocomposite polyelectrolyte membranes did not show much advantage in properties when compared to Nafion membrane if seen proton conductivity and ion-exchange capacity. Although, the proton transport activation energy, current-voltage polarization characteristics were comparable, these have relatively lower methanol permeability which are better for DMFC as compared to Nafian. The improvement is seen in selectivity parameter values because of low methanol permeability at 30°C and 70 °C temperatures. Almost same selectivity parameter values can be seen in the case of Nafian at both temperatures. High temperature applications can be targeted because of relatively high selectivity parameter values of these relatively high selectivity parameter values at 70 °C of these polyelectrolyte membranes when compared to Nafion membranes.[4]

Pervaporation Membranes

The pervaporation separation process involves separation of a liquid from a mixture making it to come in direct contact with membrane so that it can be separated in the form of a vapour on the other side of the membrane. It works by maintaining the the saturation pressure of liquid mixture higher than the downstream partial pressure. The high solubility of permeants in this process is the distinguishing factor of this process among other separation processes involving transport of liquids across the membranes. Studies have been carried out on the pervaporation properties of PPO dense membranes having silane modified silica fillers and silica.

Both unfilled and filled membranes were used in carrying out pervaporation separation over the entire scale of concentration of methanol/methyl *tert*-butyl ether (MTBE) mixtures. When compared with the unfilled PPO membrane, filled one showed lower permeability and greater selectivity of methanol.

If compared to the unfilled PPO and silica filled PPO membranes, the methanol selectivity was higher of silane-modified silica filled PPO membranes for liquid feed mixture having methanol concentration less than 50 wt %. The modified silica nanoparticles showed enhanced compatibility and strong affinity with PPO polymer when compared with

Amritpal Kaur, Anupreet Kaur, Deepak Saini

unmodified silica nanoparticles. The diffusion of MTBE and methanol is reduced decreasing the pervaporation permeation flux.[4]

Encapsulation of Organic Light-Emitting Devices

A photocurable *co*-polyacrylate/silica nanocomposite resin with high transparency is used to make the encapsulation of organic light-emitting devices (OLEDs). The electrical and physical properties with the driving voltage/luminance/lifetime measurement of these resins determines the feasibility of such a resin for these encapsulation. A higher than normal electrical insulation of $3.20 \times 10^{12} \Omega$ was seen with the analysis of electrical property of these resins with $1.18 \times 10^{12} \Omega$ of oligomer film at 6.15 V which can drive bare OLED. This yielded in a lower leakage current, and the device driving voltage was effectively reduced such that the nanocomposite-encapsulated OLED can be driven at a lower driving voltage of 6.09 V other than 6.77 V for the oligomer-encapsulated OLED at the current density of 20 mA/cm². Luminance measurements declared a less than 1.0% luminance difference of OLEDs encapsulated by many types of resins, which defined that the photopolymerization took very small effect on the light emitting property of OLEDs. Lifetime calculations of OLEDs revealed that t_{80} , the time span for the normalized luminance of device declines to 80%, for nanocomposite encapsulated OLED was 350.17 h in comparison to 16.83 h for bare OLED and 178.17 h for the oligomer-encapsulated OLED. This illustrated that nanocomposite resin with optimum properties was permeable for OLED packaging and a compact device structure can be acquired via the experiment of direct encapsulation.[4]

Chemosensors

A commence for making polydiacetylene/silica nanocomposite for use as a chemosensor was checked. The disarray 10,12-pentacosadiynoic acid (PCDA) gross result could absorb on the surfaces of silica nanoparticles in aqueous solution. The disordered PCDA molecules in sum total were turned into an ordered permutation by assigning the help of a silica nanoparticle template. After irradiation with UV light, polydiacetylene/silica nanocomposites acquired blue color. Various number of environmental perturbations, such as temperature, pH, and amphiphilic molecules, can yield a colorimetric shift of the polydiacetylene/silica nanocomposites from the blue to the red color. The materials seems interesting and potential applications can be found in a chemosensor.[9]

Uptake of metals

The nanocomposites of electroactive polymers PANI or PPy with ultrafine SiO₂ particles have highly commercial applications for metal uptake as it is based on the fact that they acquire a surface area substantially above than that estimated from the particle size and therefore can provide the phenomenon of metal uptake. The need of electroactive polymer/SiO₂ nanocomposites for the uptake of gold and palladium from AuCl₃ and PdCl₂ in acid solutions, respectively, was checked. In the case of gold uptake, the reaction rate



Amritpal Kaur, Anupreet Kaur, Deepak Saini

escalated with temperature from 0 to 60 °C. The absorbance of elemental gold on the nanocomposites surged the diameter and declined the surface area. The surface Au/N ratio as demonstrated using XPS has high dependence on the rate of reactions even for the constant amount of gold uptake. The uptake of palladium from PdCl₂ was much more complex to achieve. Accelerated rates of uptake could only be acquired with the electroactive polymers fall to their lowest oxidation state, and in contrast to gold uptake, the palladium on the microparticles does not exist in the elemental form but as a Pd(II) compound.[4]

Supercapacitors

Supercapacitors have received much attention in these years because of their high power density, relatively high energy density, reversibility, long cycle life, and small impact on environment. Generally, there are two basic types as according to their charge storage mechanism. The electric double layer capacitance (EDLC) type originates capacitance from charge separation at the electrode/electrolyte interface, while the second type pseudocapacitance produces capacitance from rapidly fast Faradaic reactions in the electrode material. Hence, it is therefore important to use electrode materials which has good conductivity and large specific surface areas in EDLCs, and excellent conductivity, increased capacitance and fast charge– discharge kinetics in pseudocapacitors.

Sensing Platforms

Silica-based PANI nanocomposites is also used as sensing platforms because they exhibit good electrocatalytic activity, high specific surface area, excellent reliability, and low cost properties. Successfully these composites are successfully used for DNA 4-aminophenol, dopamine, artesunate, hydrogen peroxide and hydrazine detection, hydrogen (H₂), methane (CH₄) and ammonia (NH₃) sensing of ammonia (NH₃).

Electrochromic Devices

Electrochromic devices change light transmission or reflection properties during electrochemical redox processes and it can be used as large area displays, smart mirrors and windows. PANI materials have been expandly used as active layers of electrochromic devices since they can reversibly change color upon electrochemical doping and de-doping treatments, as well as having high environmental stability. But, the main barrier to the commercially used PANI as an electrochromic material is that it has electroactivity only in aqueous solutions with less pH values.[4]

Summary and Conclusion

Conducting nanostructures have achieved a leading position in nanotechnology. Because of greater surface area which can be used in various applications. In the recent scenario a class of conducting polymers is becoming popular due to its mechanical and electrical properties. In



the synthesis of polyaniline/silica (PANI/SiO₂) nanocomposites by in-situ oxidative polymerization of aniline in the presence of different ratios of SiO₂ nanoparticles the achieved nanocomposites were characterized by UV-vis, FT-IR, XRD, TGA, and SEM techniques. The experimentation results shown that SiO₂ nanoparticles are being encapsulated by PANI with very strong effect on the morphology of nanocomposites. The thermal decomposition temperature of PANI in nanocomposites was less than that of pure PANI. The electrical conductivity of nanocomposites at lower values of SiO₂ content was higher than that of neat PANI, but with inclining contents of SiO₂, the conductivity declined. Silica nanocomposites combined with conductive polymers such as polyaniline can be used in various applications such as supercapacitors, pseudocapacitors, layers and coatings, metal uptake, chemical sensors, encapsulation Organic Light Emitting devices exchange membrane proton, the pervaporation membrane, biosensors, flexible nanoelectronic devices, drug delivery.

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