Advanced Nanomaterials - present scenario, future perspectives

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Applications Of Nanomaterials In Food Industry: A Review

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Abstract

TA nanoparticle is a small particle whose size ranges between 1 to 100 nanometres at least in one dimension. Undetectable by the human eye, nanoparticles can exhibit significantly different physical and chemical properties compared to their larger material counterparts. This is due to a very large surface area to volume ratio when compared to bulk material. When the particle size goes to nanometer range quantum mechanical effects such as quantum confinement dominate the material properties. This feature enables nanoparticles to possess unexpected optical, physical and chemical properties. Due to these unexpected properties, nanoparticles find enormous applications in various fields such as medicine, agriculture, food, energy storage, electronics, pharmaceuticals etc. In this article we concentrate on applications of nanoparticles in food industry.

I.INTRODUCTION

Materials with any external dimension in the nanoscale (size range from approximately 1 – 100 nm) or having internal structure or surface structure in the nanoscale are called nanomaterials. The sources of nanomaterials are natural or incidental or engineered. Nano-objects are often categorized as to how many of their dimensions fall in the nanoscale. A nanoparticle is defined as a nano-object with all three external dimensions in the nanoscale. A nanofiber has two external dimensions in the nanoscale, with nanotubes being hollow, nanofibers and nanorods being solid nanofibers. A nanoplate/nanosheet has one external dimension in the nanoscale, and if the two larger dimensions are significantly different it is called a nanoribbon. The first observations and size measurements of nano-particles were made during the first decade of the 20th century. Zsigmondy made detailed studies of gold sols and other nanomaterials with sizes down to 10 nm and less. He published a book in 1914.He used an ultramicroscope that employs a dark field method for seeing particles with sizes much less than light wavelength. There were some other traditional methods employed for characterising nanomaterials such as light scattering, ultrasound attenuation spectroscopy. For characterizing surface charge or zeta potential of nano-particles in solutions, microelectrophoresis, electrophoretic light scattering and electroacoustics techniques were used.Novel effects can occur in materials when structures are formed with sizes in nanometer scale. In these cases, quantum mechanical effects can dominate material properties. Inaddition to this, high surface area to volume ratio of nanomaterials totally change the characteristics of these materials. Hence, nanomaterials find applications, with improved properties, virtually in every field of science and technology.

The food industry is beginning to use nanotechnology to develop nanoscale ingredients to improve colour, texture and flavour of food.Nanotechnology also impacts every aspect of the food system from cultivation to food production to processing, packaging, transportation, shelf life and bioavailability of nutrients. Detailed discussion on applications is discussed in the next section.

2.APPLICATIONS

As it has been discussed in earlier section, nanomaterials have applications virtually in every walk of life. However, we are confined to applications in food industry only in this article.
The benefits of nanotechnology for the food industry are many and are expected to grow with

time. This new, rapidly developing technology impacts every aspect of the food system from cultivation to food production to processing, packaging, transportation, shelf life and bioavailability of nutrients.

- Nanomaterialsas antimicrobial agents: Fresh fruits, vegetables, meat and poultry products are potential vehicles for the transmission of human pathogens leading to foodborne disease outbreaks which draw public attention to food safety. Therefore, there is a need to develop new antimicrobials to ensure food safety. Because of the antimicrobial properties of nanomaterials, nanotechnology offers great potential for novel antimicrobial agents for the food and food-related industries. Also, the antimicrobial properties of nanomaterials enable them to preserve food during storage and transport. A wide range of nanomaterials have been demonstrated to possess antimicrobial effects, including iron (III) oxide, zinc oxide, magnesium oxide, silver, gold, copper and copper oxide, calcium oxide, titanium dioxide and cadmium oxide among others.
- Nanomaterials for colour, texture and flavour of food:The food industry is beginning to use nanotechnology to develop nanoscale ingredients to improve colour, texture and flavour of food. The nanoparticles TiO2 and SiO2 and amorphous silica are used as food additives. TiO2 is used as a colouring in the powdered sugar coating on doughnuts. It is added as colouring agent to make food more visually appealing. Silica is used as an anti-caking agent to improve flow property of powered ingredients and as a carrier for flavours or active compounds in food.
- Nanomaterials in food production and packaging:Nanomaterials used for food packaging provide many benefits such as improved mechanical barriers, detection of microbial contamination and potentially enhanced bioavailability of nutrients. This is perhaps the most common application of nanotechnology in food and food-related industries. A number of nanocomposites, polymers containing nanoparticles, are used by the food industry for food packaging and food contact materials[16]. The use of ZnO and MgO nanoparticles for food packaging has been reported. Amorphous silica is used in food and in food containers and packaging. Engineered water nanostructures generated as aerosols are very effective at killing foodborne pathogens such as Escherichia coli, Listeria and Salmonella on steel food production surfaces.
- Nanomaterials in nutrients and dietary supplements:Nanomaterials are used as ingredients and additives in nutrients and health supplements (e.g., vitamins, antimicrobials, antioxidants) for enhanced absorption and bioavailability. Also, using nanotechnology nano-encapsulated nutrients such as vitamins or nano-sized calcium or iron are created and added to drinks and food with no effects on clarity or visual appeal. Nutrientsin nano stateare absorbed faster in the body. Fortification of edible products (e.g., food, food constituents or supplements) with nutrients or non-nutrient bioactive components can help to balance the total nutrient profile of a diet and supplement nutrients lost in processing and thus to correct or to prevent insufficient nutrient intake and from the associated deficiencies.Compounds of natural origin, such as curcumin (CUR) occurring in turmeric, ω-3-fatty acid in fish oil, vitamins from fruits, when encapsulated in an appropriate nanocarrier, will be released after consumption of the food in the target organ and utilized according to its nutritional property.
- Food nanosensors:Nanomaterials are used as sensors to detect contamination and regulate the food environment. They can detect pathogenic bacteria, food-contaminating toxins, adulterants, vitamins, dyes, fertilizers, pesticides, taste and smell. Therefore, they are used as sensors in food production andat packaging plants. They can monitor the condition of food during transport and storage.They can detect nutrient deficiency in edible plants and dispensers containing nutrients can deliver them to plants when needed. Therefore, nanomaterials can be used as nanosensors and nanotracers with almost unlimited potential by the food industry. Nanosensors can detect pathogenic bacteria, food-contaminating toxins, adulterant, vitamins, dyes, fertilizers, pesticides, taste and smell. Food freshness can be monitored using time–temperature and oxygen indicators. Overall, nanosensors with unique properties are improving food security.

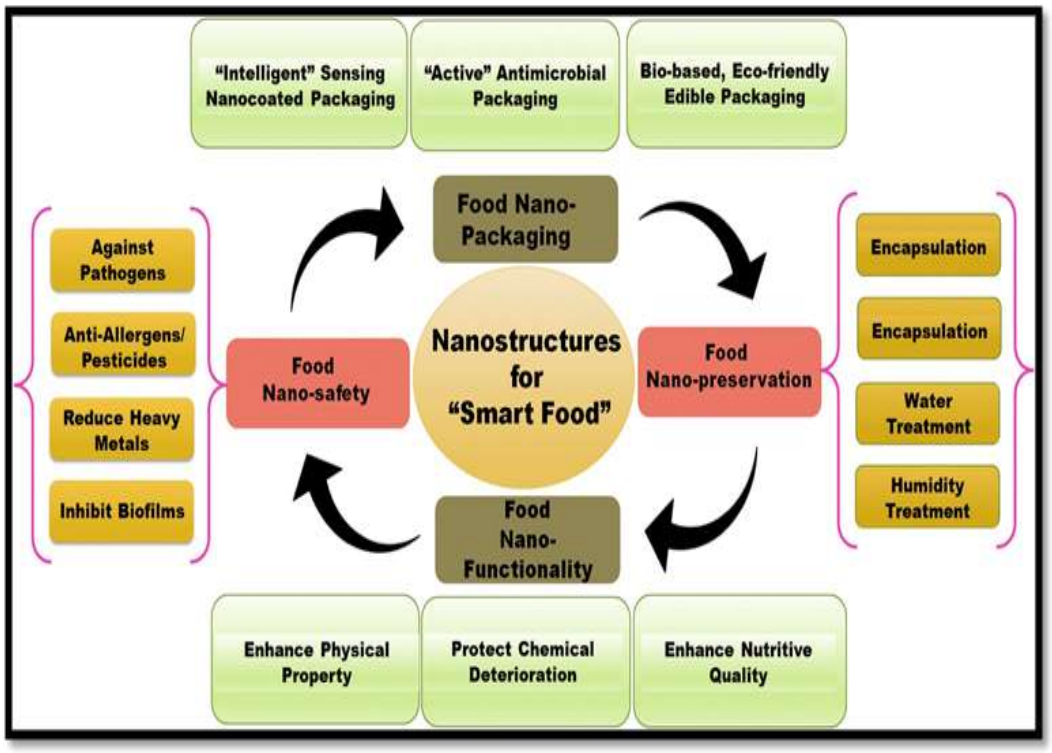

Figure: Applications of nanomaterials in various areas food industry

CONCLUSION

Undoubtedly, the nano materials have potential applications in every walk of life. Hence, much more research is to be done in nanotechnology to improve the quality of life. At the same time a note of caution is the health impact of nanomaterials in food which is of public interest and concern. Public acceptance of food and food-related products containing nanomaterials will depend on their safety. These potential risks of using nanomaterials in food industry are determined by nanoscientists using nanotoxicology, which is a branch of toxicology and an interdisciplinary field that concerns varied toxic aspects of nanomaterials. A greater concentration on nanotoxicology is the need of the hour.Finally, a uniform international regulatory framework for nanotechnology in food is necessary to address all these issues.

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Groundwater Quality Assessment In Nellimarla Area Of Vizianagaram District, Andhrapradesh, India

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Abstract

An assessment of the groundwater quality was carried out in Nellimarla area of Vizianagaram District, Andhra Pradesh. The study was aimed at examining the various samples of groundwater and groundwater quality was assessed for drinking. Eight groundwater samples were taken from boreholes of different locations and were analyzed for pH, Electrical conductivity, total dissolved solids, total alkalinity, total hardness, chloride, calcium and magnesium using standard methods. The results were compared with World Health Organization and BIS: 10500 standards. The usefulness of these parameters in predicting groundwater quality characteristics were discussed. Thus an attempt has been made to find the quality of groundwater in Nellimarla area suitable for drinking purposes or not.

I.introduction

Water is a prime need for human survival and industrial development. For many rural and small scale communities, groundwater is the only source of drinking water. Assessment of groundwater for drinking and irrigation has become a necessary and important task for present and future groundwater quality management. Groundwater quality depends on the quality of recharged water, atmospheric precipitation, inland surface water and subsurface geochemical processes. Temporal changes in the origin and constitution of the recharged water, hydrologic and human factors may cause periodic changes in groundwater quality. Water pollution not only affects water quality but also threats human health, economic development and social prosperity. So, the assessment of water quality is very important factor for knowing the suitability for various purposes.

2.Materials And Methods

In the present investigation groundwater samples were collected from eight different locations in the study area in the month of February 2020. Sample locations are shown in the Table 1. Samples were collected in polythene bottles, pre-cleaned by washing with non-ionic detergents, rinsed with water, 1:1 hydrochloric acid and finally with de-ionized water . Before sampling, the bottles were rinsed three times with sample water. Tube wells were operated at least five minutes before collection of the water samples. The water quality parameter estimation was done using standard methods and techniques. Samples were brought to the laboratory for analysis of physic-chemical parameters. Samples were brought to the laboratory and kept at 4◦C until used for analysis of physico-chemical parameters. pH parameter was measured by digital pH meter (Elico LI- 120), EC measured by conductometer (Elico CL-351), TDS determined by Gravimetry, and other parameters such as Total Hardness (TH), Total Alkalinity (TA), Calcium, Magnesium, Chloride ions are determined by titrimetrically.

3.Results And Discussions

The results obtained from analysis of different groundwater samples are shown in Table-2. The statistical evaluations are given in Table-3.

In the present investigation most ofwater samples are colorless and odorless. However some water samples are slightly colored due to muddiness. The main sources of natural alkalinity are rocks, which contain carbonate, bicarbonate, hydroxide compounds and phosphates. The value of Total alkalinity in study area is ranged from 350 to 620 mg/l with mean value of 457.5 ±93.465. Alkalinity itself is not harmful to human being, but in large quantity, imparts bitter taste to water and may cause eye irritation in human.

The mean value of total hardness of studied groundwater samples is 377.5 mg/l with the standard deviation of ±73.046 mg/l.

The value of calcium in study area is ranged from 20 to 160 mg/l with mean value of 87.5 mg/l and standard deviation of ±53.65 and the value of magnesium is ranged from 30 to 250 mg/l with mean value of 86.25 and standard deviation of ±75.0119.

Table 1: Location of Samples

S.No	Sample Id	Sampling station	Latitude	Longitude
1	S1	Gushini	18.1133	83.3264
2	S2	LN Puram	18.1014	83.2348
3	S3	Ommi	18.0954	83.3318
4	S4	Parasam	18.1414	83.2394
5	S5	Ramateertham	18.0998	83.2993
6	S6	Saripalli	18.078	83.2883
7	S7	Valluru	18.1768914	83.599686

Table 2: Measured Parameter values at different sampling stations

Parameters	S1	S2	S3	S4	S5	S6	S7	BIS/WHO desirable-permissible values
pH	7.59	7.22	7.19	7.23	7.24	7.15	7.44	6.5-8.5
EC	809	1673	1985	1845	1860	1341	2407	750-3000
TDS	530	1090	1290	1200	1210	875	1560	500-2000
TH	350	420	350	490	270	300	410	300-500
Ca	40	80	20	70	50	160	160	75-200
Mg	60	40	70	70	30	140	250	30-150
Cl	90	290	85	320	110	150	310	250-1000
TA	360	490	400	500	350	410	620	200-400

All the units are expressed in mg/l except pH (no units) and EC (micro Siemens/cm), EC=Electrical Conductivity, TDS=Total Dissolved Solids, TH=Total Hardness, TA=Total Alkalinity, Ca=Calcium, Mg=Magnesium, Cl= Chloride

Table 3: Descriptive statistics of parameters

Parameters	Min	Max	Mean	SD	%CV
pH	7.15	7.59	7.285	0.15014	2.06
EC	809	2407	1707.13	470.889	27.58
TDS	530	1560	1110.63	303.65	27.34
TH	270	490	377.5	73.046	19.35
Ca	20	160	87.5	53.6523	61.32
Mg	30	250	86.25	75.0119	86.97
Cl	85	340	211.875	112.756	53.22
TA	350	620	457.5	93.465	20.43

Desirable limit of TDS is 500mg/l (IS: 10500 standards).The mean value of TDS of studied groundwater samples is 1110.63 mg/l with the standard deviation of ±303.65. The value of EC in study area is ranged from 809 to 2407 mg/l with mean value of 1707.013 and standard deviation of ±470.889.

Chloride is an important quality parameter that affects the aesthetic property of water including taste and renders it unsuitable for drinking purpose if present in high concentration. The chloride concentration in study area ranged from 85 to 340 with mean values of 211.875 ± and standard deviation of 112.756 mg/l. The values in the present study are on higher side considering WHO maximum limit of 250mg/l.

4.Conclusions

The objective of present work is to study the water quality of groundwater in Nellimarla area of Vizianagaram District so as to assess its suitability for domestic purpose. From the analysis, Total Hardness observed was higher in Water samples S1, S2 and S3 than desirable value 300mg/l and Total alkalinity observed in samples S2, S4, S6, S7 and S8 was higher than desirable value 400 mg/l. Chloride content observed in samples S2, S4, S7 and S8 was higher than desirable value 250 mg/l. Magnesium content observed in water samples (S1, S3, S4, S7 & S8) was higher than calcium content. Continuous monitoring of groundwater is necessary for the health of human. According to the overall assessment of the focused area, some of the parameters analyzed are above the desirable limits of BIS /WHO and needs some degree of treatment before consumption.

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A Review on Green Synthesis of Nano Particles from Solanaceaea Members

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Abstract

Green synthesis of Nanoparticles (NPs) is the novel desirable method of obtaining NPs from plant source. Solanaceae members are very familiar plants through out the world. These plants can also be considered as good source of NPs, mostly AgNPs, as per the available latest literature. Solanaceae plants are able to produce stable NPs that are having good applications in various fields.

I.introduction

The objectification of green chemistry approaches and procedures into nanotechnology is of accomplished interest which has gained consequential attention over the past ten years.Likewise, NPs are extensively applied to mortal contact areas and there›s a growing need to develop processes for conflation that don›t use harsh poisonous chemicals . The nanoparticles synthesized from chemical and physical styles generally bear high temperature, pressure, precious outfit, poisonous chemicals, and reagents and most importantly circumscribing agents for the stabilization of nanoparticles; therefore, these styles are poisonous to the terrain and non-eco-friendly.With their antioxidant or reducing parcels they›re generally responsible for the reduction of essence composites into their separate nanoparticles. The conventional styles for the product of NPs are precious, poisonous, andnon-environment friendly. To overcome these problems, experimenters have plant precise green routes like the naturally being sources and their products that can be used for the conflation of NPs .Thus, green/ natural production of NPs is a feasible alternative to chemical and physical techniques. Biological approaches of synthesis have therefore paved way for the "greener conflation" of nanoparticles and these have proven to be better approaches due to slower kinetics.now, green methodologies using Phyto extracts have been developed as an option for common chemical and physical approaches to synthesize noble metal NPs. Due to the presence of reducing agents like alkaloids, polyphenols, and flavonoids which are major phytoconstituents of the plant extracts, and stabilizing agents similar as polysaccharides and proteins, stable metal NPs can be readily synthesized using the plant extracts. Green synthesis provides enhancement over chemical and physical system as its economically affordable, atmosphere friendly, easily measured up for large scale synthesis.

2.Solanaceae family:

Solanaceae family comprises 90 genera and 3000–4000 species. The family is highly diversified, that includes perennial trees as well as herbaceous annual species and distributed widely in a range of terrestrial habitats from deserts to rainforests. Compared with the large size of the family, only few members of the Solanaceae attained importance in human civilizations as food sources (potato, tomato, eggplant), ornamentals (petunia, Datura, some Solanum species, Schizanthus) and drugs (Tobacco, Atropa, Hyoscyamus, Mandragora).

3.General Method of Green synthesis of NP's :

Green conflation of the nanoparticles has achieved significant concentration in recent times. Several metallic nano particles like asGold (Au), Silver (Ag), Cobalt (Co), Copper (Cu), Lead (Pb), Manganese (Mn), Zinc (Zn), Iron (Fe), Magnesium (Mg), Palladium (Pd), are employed in green synthesis. Among the several noble metal nanoparticles, Silver Nano Particles (AgNPs) have attracted special attention due to their unique qualities encompassing felicitous electrical conductivity, chemical firmness, catalytic and antimicrobial conditioning. Because of high face to volume proportion, silver in nanoscale has established comprehensively distinctive properties from bulk particles made from the same material.

Thus, conflation of the AgNPs is an arising area and fascinating subject. In plant grounded conflation, a solvent (generally water) is chosen and employed in step one. Anon-toxic reducing and stabilizer agents are employed in way two and three, independently. In this system, detergents, reducing, and stabilizers agents are named from naturalnon-toxic andeco-friendly substances without any adverse goods on the terrain.Here some of the plant species of Solanaceae members are described with reference to the NPs synthesis by green means and application aspects.

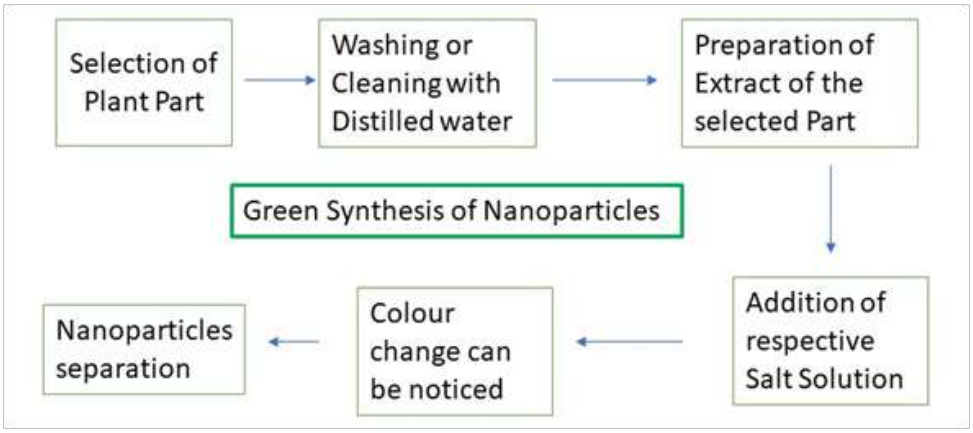

Fig: Flow chart of Green Synthesis of NP's (6)

(i). Datura metel:It has been reported that leaf extract of Datura metel is capable of producing AgNPs that shows good stability in solution. Silver nitrate with reducing agent i.e. plant extract has shown a remarkable colour change accompanied with change in pH of the solution.

(ii). Capsicum frutescence:Literature is available stating that fruits of Capsicum frutescence also act as a best source for the formation ofAgNPs. This green chemistry synthetic approach toward the nanoparticles has immense merits. The green synthesized silver nanoparticle from the fruits of Capsicum frutescence shows excellent bactericidal activity against the gram-negative bacteria and moderate activity against the gram-positive bacteria. The findings indicating that biosynthesized silver nanoparticles using the plant source will afford unique opportunities toward the growth of nanomedicine and thus has the budding for utilize in biomedical applications.

(iii).Nicotiana tobaccum:An antimicrobial activity assay of synthesized nanoparticle of Nicotiana tobaccum leaf extract showed maximum zone of inhibition when tested against .Pseudomonas aeruginosa and Escherichia coli. Use of tobacco leaf extract offers an affordable, environment friendly technique for synthesis of large scale AgNPs.

(iv).Solanummammosum:Some reported results suggest that the aqueous extract obtained from Solanummammosum fruit is an effectivelarvicide against Aedisaegypti. Additionally, the reported data showed that these fruit extracts can act as reducing agents for the synthesis of silver nanoparticles, and that said nanoparticle can kill larvae at significantly lower concentrations than the plant´s aqueous extract alone. In fact, the toxicity of AgNPs to mosquito larvae seems to be among the highest reported for AgNPs synthetized using any species belonging to the Solanaceae family. If further reseach will progress successfully to get required information is available,it would be possible definitely to establish whether any compounds derived from S. mammosumshould be considered for further development as insecticides.

(v). Solanum nigrum:Some experimental studies confirmed the synthesis of Ag nanoparticles fromSolanum nigrum leaf extract. Nanoparticles show considerably high anti-microbial effect against both the strains i.e.Salmonella typhi and Staphylococcus aureus when compared to standard antibiotic. This suggests that it could be used as a potential drug against both the bacterial strain in future.

(vi). Solanum xanthocarpum :A plant-mediated, green method of synthesizing silver nanoparticles was successfully performed by employing the leaf extract of Solanumxanthocarpum. The synthesized nanoparticles were characterized by UV-Vis spectrophotometer, FTIR and XRD methods of analysis that confirmed the reduction of Ag+ ions to Ag0 which is supposed through the plant extract as capping agents i.e., the phytochemical constituents found in this plant are acting as the reducing agents. It could be concluded that the biosynthesis of silver nanoparticles with leaf aqueous extracts of S. xanthocarbumprovides potential source for the preparation of

pharmacologically useful drugs.
(vii). Solanum lycopersicum:Copper Nanoparticles can be prepared from aqueous fruit extract of Solanum lycopersicum using reduction of Copper sulfate. Thenanoparticle size is 40-70 nm with uniform distribution. It also observed that by increasing the concentration of tomato juicethe concentration of copper nanoparticles is also increasedwith the same concentration of salt. The synthesized copper nanoparticles are of greater stability. This green method of preparation of copper nanoparticle is economical and cheap with no hazardous effect.
(viii). Withaniasomnifera: As a conclusion of some experiments described in the literature, aqueous leaf extracts of Withaniasomnifera are suitable for the green synthesis of AgNPs with potent antimicrobial activity. This is highly relevant since the biomass of this plant is con-sidered a waste product by the phytopharmaceutical indus¬try and hence can be used for further economic processes.These AgNPs have a potential application in many different industries including medical, food, and textiles.

4.Conclusion

'Green' synthesis of metal and metal oxide nanoparticles has been a highly attractive research area over the last decade. Numerous kinds of natural extracts (i.e., biocomponents like plant, bacteria, fungi, yeast, and plant extract) have been employed as efficient resources for the synthesis and/or fabrication of materials. Among them, plantextracts of Solanaceae have been proven to possess high efficiency as stabilizing and reducing agents for the synthesis of controlled materials. This review article explains synthesis mechanism and an updated literature study.

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Ceramic Materials - The Nano Phosphors

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Abstract

In recent years the phrase nano has become popular in several fields. It is a catch phrase for obtaining research funding, a hot topic for holding seminars and symposia. The popularity can be gauged from the fact that several consumer products, which include a car, use the phrase nano. However, promising and hoping for good results is one thing and achieving them is another. Several projects failed as these promises could not be kept and hopes dashed.

I.introduction

The work on the nanostructured luminescent materials received impetus with the discovery that luminescence efficiency increase due to quantum confinement. Nanoparticles, ribbons, rods, tubes, etc. were subsequently fabricated with the anticipation that phosphors with higher efficiencies and exotic properties will be obtained. Since the rapid advances in nanotechnologies, particularly, the development of new methods of materials synthesis, there have been growing interests in the spectroscopic erties and luminescence dynamic of activator ions in nanomaterials. Promising applications such as nano phosphors for high resolution display devices are driving forces of the research activities. In nanoparticles, particle size may affect emission lifetime, luminescence quantum efficiency, and concentration quenching.

At present a large fraction of the work on luminescent materials is related to the nano-structured materials. Synthesis and characterization of the nano materials, on the other hand, requires sophisticated instrumentation. Quite frequently, any new observation is assigned to the nano size without examining actual morphology of the phosphors. For nano-phophors one may anticipate modifications of emission and/pr excitation spectra, decrease in decay time, decrease in concentration quenching, decrease in non-radiative processes due to quantum confinement, increased quantum efficiency, tenability of host and activator energy levels for effective transfer, ease of dispersion for device fabrication, etc.

Majority of the phosphor community is focusing on obtaining nano phosphors with higher efficiencies. The efficiencies of nano phosphors seldom exceed those of the bulk, and researchers feel disappointed. However, apart from the high efficiencies there are several other aspects of the nano phosphors which can be exploited for the applications. Some of these are discussed here.

It is not uncommon to find huge reduction in TL output when phosphor size is increased. However, this decrease can be exploited for obtaining TL phosphors for high level dosimetry. Irradiation as a quarantine treatment of fresh fruits and vegetables and as a method to ensure the hygienic quality of food of animal origin is increasingly accepted and applied. The effectilveness of processing of food by ionizing radiation depends on proper delivery of absorbed dose and its reliable measurement. For food dosimetry, it is important that the dosimetry techniques used for dose determination should be simple and accurate. If the drop in the radiation sensitivity leads to the extension of the linearity range upto KGy, the phosphors will be useful for such applications.

Another aspect of the nano phosphors not much exploited by us is their dispersibility. Owing to the dispersibility in liquids, these can be easily applied on the surfaces. This can be immensely useful for obtaining luminescent solar concentrators in general and Silicon photocells for harnessing solar energy, in particular.Crystal silicon (c-Si) solar cells most effectively convert photons of energy close to the semiconductor band gap. The mismatch between the incident

solar spectrum and the spectral response of the c-Si have been estimated to be 29% by Shockley and Queisser.However, this limit is estimated to be improved up to 38.4% by modifying the solar spectrum by a quantum cutting down converting phosphor which converts one photon of high energy into two photons of the lower energy.

Applications in the field of biomedicine is perhaps the most important glamorous, but neglected by the Indian phosphor community- aspect of nano phosphor research. Size of biomolecules matches that of the nano phosphors. In principle, it is possible to attach nano phosphor particles to biomolecules.This fact can be exploited for applications in biomedical engineering. During the next decade this could be themost important application of nano phosphors. In vivo fluorescence imaging with near infrared (NIR) light holds enormous potential for a wide variety of molecular diagnostic and therapeutic applications. The recent emergence of infrared optical imaging systems has expanded the biomedical applications for infrared-emitting rare-earth doped naomaterials in diagnosis and imaging. Using conventional fluorescent probes with visible emissions to image deep organs such as liver and spleen are not adequate considering the low tissue penetration depth of visible light 9<1 cm). Tissue penetrating infrared light would be required for deep tissue imaging. By using near-infrared-emitting quantum dots and the tissue transparent regions centered at 840, 1110, 1320, and 1680nm to enable detection depths of (5-10) cm, tumor imaging sensitivity was reported to potentially improve by at least tenfold.

These newly emerging applications are elucidated here. It is concluded that nano phosphor research may be directed to these profiting areas rather than competing with the bulk phosphors in the traditional applications.

Phosphors the ceramic materials should able to work in touch environment surrounded and bombarded by high energy Vaccum Ultra Violet (VUV) or electron beam radiations in any discharge tube. The plasma display panel(PDP) is increasingly gaining attention over conventional cathode ray tube(CRT)-based TV s as a medium of large format(60+") television(TV), particularly high definition TVs (HDTVs). Improvements have been made not only in size but also in other areas such as resolution. Luminescence efficiency, brightness, contrast ratio, power consumption and cost reduction. The performance of a PDP depends on a complicated set of factors, for instance, phosphors, gas mixture, dielectric layer, reflective layer, black matrix, electrodes, cell dimension and shape, nature, size and shape of electrodes, address waveforms and operational voltages. The performance and lifetime of a PDP is strongly related to the nature of phosphors and their resistance to energetic discharge ions and electrons and solarization from vaccum UV (VUV) arising from the Xe/Ne gas discharge. Compared with standard, the performance and lifetime of a PDP is strongly related to the nature of phosphors and their resistance to energetic discharge ions and electrons and solarization emissive display such as CRTs(5-6 lm/W), the efficiency of a PDP is low (1-2 lm/W).

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Carbon Based Nanostructures For Energy Storage

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Abstract

Materials can be made from several types of elements, either in the pure elemental form or in the form of compounds and composites. Generally, bulk materials can be classified broadly as metals, semiconductors, and insulators. And when any of these materials is produced in the nanometer scale, each displays shape-/size-dependent properties. These new properties have the potential to provide enormous opportunities for both scientists and engineers to create many novel applications that are normally not possible with conventional bulk materials. Many of the nanometer-scale properties (e.g., size, shape, surface structure, and chemical composition) have only been deciphered since the advent of advanced microscopic techniques, which has enabled researchers to precisely measure and directly visualize materials at the atomic scale in real time, something impossible just a few decades ago. And, even more impressive is the ability of these characterization techniques to give us a glimpse of materials and processes in their own localized micro-/nanoscopic environment. The nanometer-scale materials had different and remarkable properties originated with the discovery of buckminster- fullerene (C60 or buckyball) in 1985. Subsequent studies ultimately led to the discovery of several other forms of exotic carbon structures, such as carbon nanotubes (CNTs; both single wall and multiwall), intercalated CNTs, carbon nanohorns, and recently graphene. These discoveries spurred researchers worldwide to actively investigate other nanometer- scale materials, especially those with inherently novel properties that could be proprietarily secured via trademarks and patents.Today, the range of elements and compounds successfully synthesized in nanometer-scale forms, characterized, and even deployed as commer- cial products include Metals, Metal oxides, Polymers, Semiconductors, Carbon compounds.The paper presents the processing and properties of different types of nanomaterials. In addition,the methods for the synthesis of different types of 1 D carbon nanotubes (CNTs) by the catalytic chemical vapour deposition (CCVD) technique by the pyrolysis of suitable hydrocarbons over selective alloy hydride catalysts and the processing of 2D.

I.introduction

Carbon nano tubes (CNTs) are currently the focus of intense research world wise because of their unique properties that could impact various areas of science and technology. Recent experimental studies have shown that CNTs have mechanical strength suggesting their potential for advanced composites.The remarkable electronic properties offer them great potential for novel applications including various nano-devices. Because of their small diameter involving only a small number of carbon atoms and due to their large aspect ratio, CNTs are classified as one-dimensional (1D) carbon systems and most of the theoretical studies on CNTs emphasize their 1D properties. The most interesting of these theoretical developments was the prediction that SWNTs could be either semiconducting or metallic depending on their geometrical characteristics. Extensive effort has been taken to study the structural, electrical, mechanical and chemical properties of CNTs in order to explore the potential applications of these novel materials. The properties and applications of CNTs have been extensively reviewed by several authors. The recent developments in this field have generated great excitement in the area of nano scale science and technology.

CNTs can be used individually or as assembly for its various applications such as to build

nano-electronic devices such as field effect transistors and rectifying electrodes. Bundles of nanotubes have been used for field emission based flat panel displays and other applications such as CNT based sensors and filters. Individual nanotubes have been used as tips for scanning probe microscopy. Bulk quantities of CNTs have also been used in other applications such as hydrogen storage media and composite materials with improved mechanical properties.

For realizing the possible applications of the CNTs, controlled and optimized growth of nanotubes is very significant. The nano-electronic applications require controlled and selective growth of CNTs on substrates.

Most of applications demand high quality nanotubes in high yield. Even though lots of work has been carried out in recent years towsrds overcoming these issues, growth methods for large scale production of CNTs that are simple, efficient and inexpensive is still a major challenge. In recent years, chemical vapour deposition (CVD) method has been shown to be promising for producing nanotubes with different morphologies in large quantities which is essential for various applications.

Graphene is a single sheet of graphitic carbon wherein the carbon atoms are tightly arranged in a 2D honeycomb like lattice. Graphene remained a theoretical construct for more than 70 years until its recent extraction in minute quantities by micromechanical cleavage. Whereas an efficient method to produce large quantities of single layer grapheme still eludes the scientific community, a variety of methods for preparing (few) layered grapheme sheets do exist: thermal exfoliation of graphite oxide, conversion from nanodiamond etc. Graphene sheets have excellent properties which make them suitable for a variety of applications. Intrinsic grapheme is a semi-metal or a zero gap semiconductor. It has a linear energy dispersion relation resulting in zero charge carrier density (Dirac fermions). Exceptionally high electron mobility at room temperatures, with values in excess of 15000cm2V-1s-1 has been reported. However, with the increase in the number of layers these properties are expected to evolve and finally match those of bulk graphite. Interestingly, though not unexpected, few layered grapheme is expected to retain many of the properties of single layer grapheme and are hence suitable for a host of applications: FETs, transparent conductors, integrated circuits, ultracapacitors etc. Graphene with its extremely large surface area is also expected to be excellent materials for gas sensing applications. It is expected that with the introduction of defects and suitable dopants, graphene sheets can be engineered to detect suitable gases.In this paper, we present the progress made in the synthesis of different types of nanomaterials and 1 D CNYs by CCVD and 2 D graphene by exfoliation of graphite oxide. Synthesis of MWNT, SWNT and metal/alloy encapsulated MWNT by pyrolysis of selective hydrocarbon over suitable alloy hydride catalysts, prepared by hydrogen decrepitation technique, will be focussed. The proposed growth mechanism of metal/alloy encapsulated MWNT produced by this technique and the various characterization methods employed are also discussed. Further, some of the applications of these CNTs with an emphasis on energy-related applications such as catalyst support material in hydrogen and alcohol based fuel cells (PEMFC, DMFC< DEFC), hydrogen sensors and hydrogen storage media are discussed in detail.

2.Synthesis of single walled carbon nanotubes, multi walled carbon nanotubes and magnetic metal-filled multi walled carbon nanotube by CCVD:

A novel, cost effective, easy and single step process for the synthesis of SWNT, MWNT and metal-filled MWNT, in large quantities using MIschmetal(Bharat Rare Earths Metals, India; composition: Ce 50%, La 35%, Pr 8%, Nd 5%, Fe 0.5% and other rare earth elements 1.5%) based AB3(B=Ni/Fe/Co) alloy hydridecatalyst, obtained through hydrogen decrepitation technique. Catalytic chemical vapour deposition (CCVD) technique using a single-stage furnace facility has been used to grow these nanostructures in the temperature range 9000C to 10500C.The carbon

deposit obtained at 9000C shows the presence of MWNT. SEM image of the as grown MWNT synthesized over Mm based AB3 alloy hydride catalyst with Ni at the B site at 9000C shows the presence of catalytic particles at the tips of the MWNTs. The selective EDAX pattern from the MWNT tips show the presence of Ni which is responsible for the nucleation of CNYs. These catalytic impurities can be removed by refluxing with con nitric acid for approximately 24hr. SEM, TEM and HRTRM images of purified MWNT show an inner diameter of about 15 nm and outer diameter of around 60 nm.

Raman spectrum obtained from a Renishaw aRaman spectrometer using 514.5 nm excitation of the MWNT and SWNT shows typical tangential modes corresponding to the Raman allowed optical mode E2g of two-dimensional graphite, centered around1580cm-1(G-band) observed for all the samples. In addition, a peak centered at around 1350-1(D-band) is mainly due to defects and carbonaceous particles present in the sample. The intensity of D- band gives the degree of disorder present along the tube.

3.Performance of PEMFC using Pt/MWNT-Pt/C composites as electrocatalysts for oxygen reduction reaction in PEMFC:

Purified MWNT were ultrasonicated in 10 ml of acetone for 1 hr and then 0.075 M H2PtCl6 was added slowly during stirring. After 12 hr, the mixture was reduced by adding reducing solution containing 0.1M NaBH4 and 1 M NaOH. After completion of reaction, the solution was washed with de-ionized water, filtered and dried by vaccum filtration using a filter. The recovered Pt loaded MWNT were dried at 800C for 3 hr. The crystallinity of the samples was obtained by X-ray powder diffraction (XRD) analysis, performed with a monochromatic Cu-Kα radiation. Morphological characteristics of CNTs were obtained using scanning electron microscopy (SEM) and Transmission electron microscopy(TEM).

The membrane electrode ass3embly (MEA) was obtained by sandwiching a pre-treated Nafion 1135 (Nafion R) membrane between the anode and the cathode. Both the anode and cathode layers consisted of a backing layer, a gas diffusion layer and a catalyst layer. To prepare the catalyst layer, the required amount of catalyst was suspended in de-ionized water and ultrasonicated by adding 5wt% Nafion solution. The suspension was spread uniformly over a carbon fabric (SGL Carbon). The electrodes were of 11.56 cm2 area. The electrodes were sandwiched by hot pressing at 1300C and 70 bar for 2 min. The anode was a 3.4*3.4 cm2 20% Pt/C electrode, with a platinum loading of 0.25 mg cm-2. The cathode was prepared from a suspension containing mixture of Pt/MWNT (Pt content of 20wt %) and Pt/C (Pt content of 20 wt%), with a platinum loading of 0.5 mg cm-2. A single PEMFC was assembled using the MEA, two graphite plates with gas channels machined with a serpentine geometry, two Teflon gaskets and two aluminium end plates. The performance of the PEMFC was studied in an indigenously fabricated Fuel Cell test station, using a dc electronic load box. Since hydration of the electrolyte membrane is important for attaining maximum performance of the PEMFC, reactant gases were humidified with water.

4.SEM, TEM HRTEM images of Pt loaded MWNT:

A TEM image of the Pt/MWNT shows more or less uniform distribution of noble metal particles of size of about 3-5 nm on the CNTs. The HRTEM image of Pt/MWNT clearly indicates lattice planes of Pt particles indicating crystalline nature of catalytic Pt. The energy dispersive analysis (EDAX) shows that the amount of Pt loaded on the carbon nanotube support with reference to carbon can be evaluated qualitatively as 20%. The polarization curves were obtained from the single cell PEMFC using the same type of anode. Prior to polarization studies, the electrodes were activated between open-circuit potential and high current densities. The activation cycle is necessary to activate the catalyst for the oxygen reduction reaction. The performance of

Pt/MWNT electrocatalysts, prepared using pre-treated MWNT grown over Mm based AB3 alloy hydride catalysts, mixed with varying amounts of commercial Pt/C as cathode catalyst in PEMFC, under an operating pressure of 1 bar. In the low current density region, the voltage drop in the potential-current curve, generally known as activation polarization, reflects the sluggish kinetics intrinsic to the oxygen reduction reaction at the cathode surface. The voltage drop in the mid to high current density range, or ohmic polarization, arises from limitations in proton transport through the electrolyte membrane from anode to cathode and/or limitations in electron flow in the electrode materials. Better performance of PEMFC was observed for cathode catalyst with Pt/MWNT content compared to those containing commercial Pt/c which could be attributed to higher catalytic relatively of smaller pt particles with uniform sizes decorated on the MWNT. The higher performance of the Pt/MWNT electrodes compared to the Pt/C electrodes could be ascribed to the networks and interiors of CNTs consisting of spaces for gas diffusion and high electric conductivity of MWNT. Pt/Ru/muitiwalled carbon nanotubes s electro catalyst for Direct methanol fuel cell.

5.Pt-Ru/multiwalled carbon nanotubes as electrocatalysts for Direct Methanol Fuel Cell:

Purified MWNT were ultrasonicated in 10 ml of the acetone for 1 h and then 0.075 MH2PtCl6 and 0.15 M Rucl2 solutions were added slowly during stirring. After 12 h the mixture was reduced by adding reducing solution containing 0.1 M NaBH4and 1M NaOH. After completion of reaction the solution was washed with de-ionised water ,filtered and dried by vaccum filteration. The recovered Pt-Ru loaded MWNT were dried at 800C for 3h. Here in DMFC,membrane electrode assembly(MEA) was obtained by sandwiching a pre-treated Nafion 1110 membrane between the anode and cathode . The anode was Pt-Ru/MWNT, with a loading of 2.5 mg cm-2 .The cathode was prepared from a suspension containing mixture of Pt/MWNT and 20% Pt/C, with a platinum loading of 5mg cm-2 . Humidified oxygen ws passed to the cathode at the flow rate of 180 sccm and 1M methanol at the anode through the serpentine channels of DMFC.

6.Conclusion:

Today, the entire world faces an energy crisis such as never seen before, and many nations have to rely exclusively on costly imported fossil fuels to generate electricity to power their economy and provide energy for the population. Even in advanced economies, fossil fuels are increas- ingly becoming expensive and have a polluting cost associated with their continued use. Nanotechnology has shown many glimpses of instances for manipulating nanomaterial to create new avenues for sustainable clean energy and potential solutions for the future.

The nanocarbons created in Laboratory can be used to coat a simple Cu metal foil and the temperature profile plotted versus time when this carbon-coated foil is placed in direct sunlight. The levels of coatings and nature of the nanocarbons contributing to the profile can be investigated. Carbon bucky paper can be readily made from either a commercial source of carbon nanotubes (CNTs) or using graphene-based materials. These can then be characterized with the nanotools described previously and made into electrode substrates for the microbes (either on its own or also doped with metallic NPs). Then, the efficiency of these cells can be evaluated. Fuel cells can be an alternative source of power, and one active area of research and development is in microbial fuel cells (MFCs). In this type of cell, microbes are utilized to generate hydrogen that can be used as a source of fuel. Carbon buckypaper can be readily made from either a commercial source of carbon nanotubes (CNTs) or using graphene-based materials. These can then be characterized with the nano tools described previously and made into electrode substrates for the microbes (either on its own or also doped with metallic NPs). Then, the efficiency of these cells can be evaluated.

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One-Pot Synthesis of Substituted Pyridine

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Abstract

The studies on application of magnetically separable substituted nano ferrites towards the multicomponent one-pot synthesis of heterocyclic compounds were thoroughly investigated. The present study gives an efficient method for the one-pot three-component synthesis of poly substituted pyridine derivatives by the cyclo-condensation of aromaticaldehyde, malononitrile and substituted phenols in the presence of magnetically recoverable nano copper ferrite catalyst. This method involve simproved advantages like low percentage of catalyst used, lesser reaction times, higher yields ,magnetic recoverability and reuse of the catalyst, which makes it an environmentally benign process.

I.introduction

Multi-component reactions play a significant role in the organic synthesis particularly in the synthesis of medicinally potent heterocyclic compounds. It involves a simple workup procedure for the synthesis of medicinally privileged scaffolds by the combination of two or more components in a single step process. Thereby it offers a great advantage over convergent, combinatorial and multistep synthesis.

The poly substituted pyridine moiety has been identified as key constituent in many naturally occurring and synthetic biological active pharmaceuticals. Among these pyridine derivatives of 2-amino-pyridine-3,5-dicarbonitrile skeleton have great importance as medicinally active compounds like antiprion, antibacterial, anti-biofilm, anti-infective, anticancer and anti-hepatitis-B. Penta-substituted pyridine moiety is a medicinally privileged scaffold useful in the potassium channel opening for the treatment of urinary incontinence and the treatment for Creutzfeldt-Jakob disease, Parkinson disease, Hypoxia, Asthma, kidney disease and Epilepsy. The importance of this class of compounds can be understood by the number of patents filed in recent years.

Due to vast range of biologically active poly substituted pyridine frameworks, they attract much attention in their synthesis. A number of procedures were carried out for the synthesis of poly-substituted pyridine derivatives using various synthetic procedures such as Diels-Alder reaction of 3-siloxy-1-aza-1,3-butadiene with 6-alkyl-3,5-dichloro-2H-1,4-oxazin-2-one with different types of acetylenic compounds, [4+2] cycloaddition of oximinosulphonates,Vilsmeier-Haackreaction α-hydroxy ketene dithioacetals, Ruthenium-catalysed cyclo- isomerisation of 3-azadienynes and 6 π-azaelectrocyclization of azatrienes which limit with conventional multi-step process, low yield and challenging work up procedures.

Afterward a first convenient and interesting synthetic methodology reported for the one- pot synthesis of poly-substituted pyridine derivatives by the cyclocondensation of aromatic aldehyde, malononitrile and thiophenol using Et3N or 1, 4-diazabicyclo[2,2,2]-octane [DABCO] as catalyst. Then a few MCR methods have been reported for the one-pot synthesis of poly substituted pyridine derivatives by the three component condensation of aromatic aldehyde, malononitrile and thiophenol in presence of various catalysts like K2CO3 under reflux, Ionic liquid 1-n-butyl-3-methylimidazolium hydroxide, Nano crystalline MgO, Ammonium hydroxide,TBAH [tetra butyl ammonium hydroxide] and Piperdine. The above reported methods have their own importance and merits. But these methods limit in their longer reaction times, low yields, use of toxic chemicals

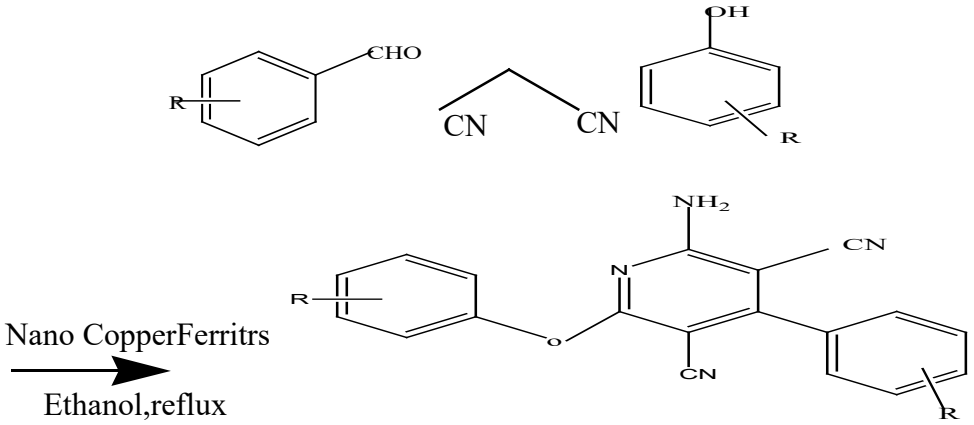
and non- recoverability of the catalyst. Hence there is a necessity to develop newer, greener, effective and environmental friendly methods of synthesis of poly substituted pyridine derivatives. It is further observed that in the above reported methods thiophenol has been used as a reactant but substituted phenolic derivatives such as 2-amino-6-phenoxy-pyridine-3, 5- dicarbonitrile derivatives have not been reported.

Nano copper ferrite has earlier been used as magnetically separable catalyst for several organic synthetic reactions such as asymmetric hydrosilylation of ketones, synthesis of diaryl or aryl alkyl sulfides via cross coupling process under ligand free conditions, synthesis of substituted benzoxazoles via Ullmann-type coupling under ligand free conditions, cross- coupling of aryl halides with diphenyl diselenide, green one-pot three component synthesis of spirooxindoles, multicomponent synthesis of 1,4-di substituted 1,2,3-triazoles in tap water and synthesis 1,4 dihydro pyridines involving aromatic aldehyde, ethylacetoacetate and ammonium acetate.

As a part of our ongoing research towards the synthesis of biologically active heterocyclic compounds using magnetically separable nano catalysts, keeping environmental friendly methods in mind, here we are reporting an efficient improved procedure for one-pot multi- component synthesis of some new poly substituted pyridine derivatives by condensation of aromatic aldehyde, malononitrile and substituted phenols using nano copper ferrite as a catalyst. This methodology involves high catalytic activity of the catalyst, its magnetic recoverability and reuse for five cycles without any noticeable loss of its catalytic activity.

2.Plausible mechanism for the scheme of the reaction:

A plausible mechanism had been proposed for the catalytic activity of the reaction. It can be predicted from the mechanism that it follows a base catalyzed pathway. The reaction is initiated by ferrite-mediated Knovenagel condensation of aldehyde and malononitrile, generating cinnamonitrile(1), which reacts with another molecule of malononitrile producing dihydropyridine intermediate (2). Then there are two possibilities to oxidize dihydropyridine to pyridines (3), one is aerobic oxidation of dihydropyridine, which plays a minor role limited by the solubility of oxygen in reaction solvent [ethanol] and the other is an efficient path,which involves hydrogen transfer from the dihydropyridine intermediate (2) to the Knovenagel intermediate (1). This step causes the involvement of an extra equivalent of aldehyde and malononitrile to get quick good yield of the product.



2-Amino-6-phenoxy-4-phenylpyridine-3,5-dicarbonitrile

3.Experimental:

All chemicals were purchased from the commercial sources and liquid aromatic aldehydes and liquid aromatic phenols are purified by distillation prior to use. XRD spectra were recorded

on PANalytical-XPert pro diffractometer and the average crystallite size was determined from the corresponding XRD data. The microstructural morphology was studied with a Scanning Electron Microscope (SEM) model JEOL–JSM 6610 LV. FTIR spectra were recorded on BRUKER ALPHA FT-IR with Opus 6.1 version. Magnetization M [H] measurements were made using a commercial vibrating sample magnetometer (VSM) model BHV-50 of Riken Denshi Co. Ltd. Japan. Specific surface area (SBET) of samples was determined by BET surface area analyzer (Nova 2000 series, Quanta chrome Instruments, UK). 1H NMR spectra were recorded on the Bruker-Avance 300-MHz spectrometer in CDCl3. The chemical shift values were reported on the δ scale in parts per million (ppm), downfield from tetramethylsilane (TMS) as an internal standard. The mass spectrum was recorded using a Perkin-Elmer PE SCIEX-API 2000, equipped with ESI source used online with a HPLC system after the ultraviolet (UV) detector. Silica gelused for column chromatography was purchased from ACME Chemical Company. All reactions were monitored by thin layer chromatography (TLC) on pre-coated silica gel 60 F254 (Merck) and spots were visualized with UV light.

4.General procedure for the synthesis of poly substituted pyridine derivatives:

The one-pot synthesis of poly substituted pyridine derivatives was carried out in a 250 mL round bottomed flask and fixed with a reflux condenser in an oil bath with temperature control and refluxed. About 500 mg of the catalyst was taken and activated at 500 ^{o}C for 2 h and cooled to room temperature before the experiment. Aromatic aldehyde (5 mmol) and malononitrile (10 mmol) were mixed together along with the catalyst and 5 mL of ethanol then the contents are stirred for 15 min at 50 ^{o}C. Afterwards the substituted phenol (5 mmol) was added to the reaction mixture and refluxed. The completion of the reaction was monitored by TLC (n-hexane: ethyl acetate 2:1) and the products were isolated by removing the catalyst magnetically from the reaction mixture. All the products were identified by FTIR, 1H NMR and mass spectra of representative compounds and compared.

5.Results and Discussion:

5.1 Effect of catalysts on the synthesis of pyridine derivatives:

As mentioned in introduction part, several catalysts have been reported for the synthesis of poly substituted pyridine derivatives by the cyclocondensation of aromatic aldehyde, malononitrile and thiophenol in presence of various catalysts have been presented. The reaction time, temperature of the reaction and yield of the corresponding product in presence of nano copper ferrite catalyst has been presented. It is observed fromthe literature that the synthesis of substituted pyridines with substituted phenols in presence of nano copper ferrite has not been reported earlier.

5.2 Effect of solvent on the synthesis of poly substituted pyridine derivatives:

Investigation of the reaction medium for the process revealed that solvents played an important role in the reaction under investigation. The results are summarized. It was found that polar solvents such as CH_3OH, CH_3CN and C_2H_5OH were much better than non-polar solvents. Trace amounts of yield observed when H_2O was used as solvent, presumably due to the aggregation of the hydrophobic catalyst. Although methanol was effective, low yield was obtained when the catalyst was reused. We therefore selected ethanol as solvent. The effect of solvent was checked by the system

5.3 Effect of temperature on the synthesis of poly substituted pyridine derivatives:

The reaction temperature has a notable effect on the proposed reaction. The reaction was examined for temperature effect in presence of ethanol as solvent at different temperatures ranging

from r.t. to 50 °C. The results are reported in Table. It is clear that at lower temperatures, even if the time was increased, only low percentage of yields were obtained. Hence, consequently we chose 50 °C as the optimal temperature for the reaction.

Table:Effect of temperature on the synthesis of poly substituted pyridine derivatives

S.No.	Time, min	Temp, °C	Product	Yield, %
1	120	R.T.	(4a)	30
2	75	40	(4a)	65
3	45	50	(4a)	95

5.4 Recycling of the catalyst:

Catalyst reusability is of major concern in heterogeneous catalysis. Catalyst recycling was achieved by fixing the catalyst magnetically at the bottom of the flask with a strong magnet, after which the solution was taken off with a pipette, the solid washed thrice with ethyl acetate and the fresh substrate dissolved in the same solvent was introduced into the flask, allowing the reaction to proceed for the next run. The catalyst was consecutively reused five times without any noticeable loss of its catalytic activity. The catalyst is highly magnetic and the saturation magnetization value is found to be 35.56 emu/g, which is much higher than other reported magnetic catalysts. Therefore, it could be easily and almost completely separated by an external magnet which is of a great advantage for a heterogeneous catalyst.

6.Conclusion:

We have reported an efficient and environmentally benign method for the synthesis of poly substituted pyridine derivatives using nano copper ferrite as catalyst. This method offers several advantages including high yield, short reaction times and ease of separation and recyclability of the catalyst.

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