BENEFITS AND CHALLENGES OF METAL NANOPARTICLES : AS A GREEN CATALYST

Dr. Kanay Barik, Dr. Rajiv Kumar, Babli Shil, Sandeep Patra.
Jamshedpur, India

ABSTRACT

Introduction - Catalyst is an effective approach which allows functioning of raw ingredients that can effectively produce great value. With the emerging miniature size technology there is an enhanced demand for catalysts specifically focusing on nano based catalysts that has a potential to improve efficiency, environment friendly, cost effectiveness and consume less energy. This type of catalyst is easily substituted and acts as an alternative resource for a variety of chemical transformations.

Objective - The purpose of this study is to explore the properties of Nanoparticles which make them functionalism as a catalyst. Additionally, determine green nanoparticles in Catalysis Application along with the benefits and challenges associated with them.

Methodology - The paper choses secondary research approach to accomplish this research which is based on collecting information from already existing similar studies. This research design takes place to explore the topic of the research i.e metal nanoparticles from the lens of green catalyst and its utility and real world through exploring the existing data from electronic resources such as websites, research journals and others.

Results - The finding indicated that nanosized catalysts extracted from nanoparticles embedded with green synthesis approach have several benefits because of its characteristics like surface area, strength, stability, environment friendly, cost effective, and durable nature. Despite the number of benefits there are some challenges to producing a catalyst because of advanced technologies and other structuring complexities.

Keywords : Green catalyst, Metal Nanoparticles, metal nanoparticles in catalysis application.

1. INTRODUCTION

Nanometallic elements are developed by metal and alloy which are nanocrystalline grains having dimension ranges from 5 to 100 nm [1]. Nanotechnology is identified as a synthesising and formulating of various nanosized elements by manipulating their physical and chemical characteristics at nanoscale level. The technology works in a dynamic manner because it provides special features to the element such as its dimension, surface area, interface effect, and

quantum properties that make the element peculiar in its physical and chemical characteristics and making the ingredient highly reactive [2, 5]. This change in properties at a nano level takes place from bulk metal to its nanosized element having distinct energy which becomes more inclusively in its energy level under its miniature size as shown in (Figure 1). These features make the nanomaterial widely applicable in diverse domains covering biology, therapeutics, pharmacy, engineering, environment sustainability and so on [3, 4].

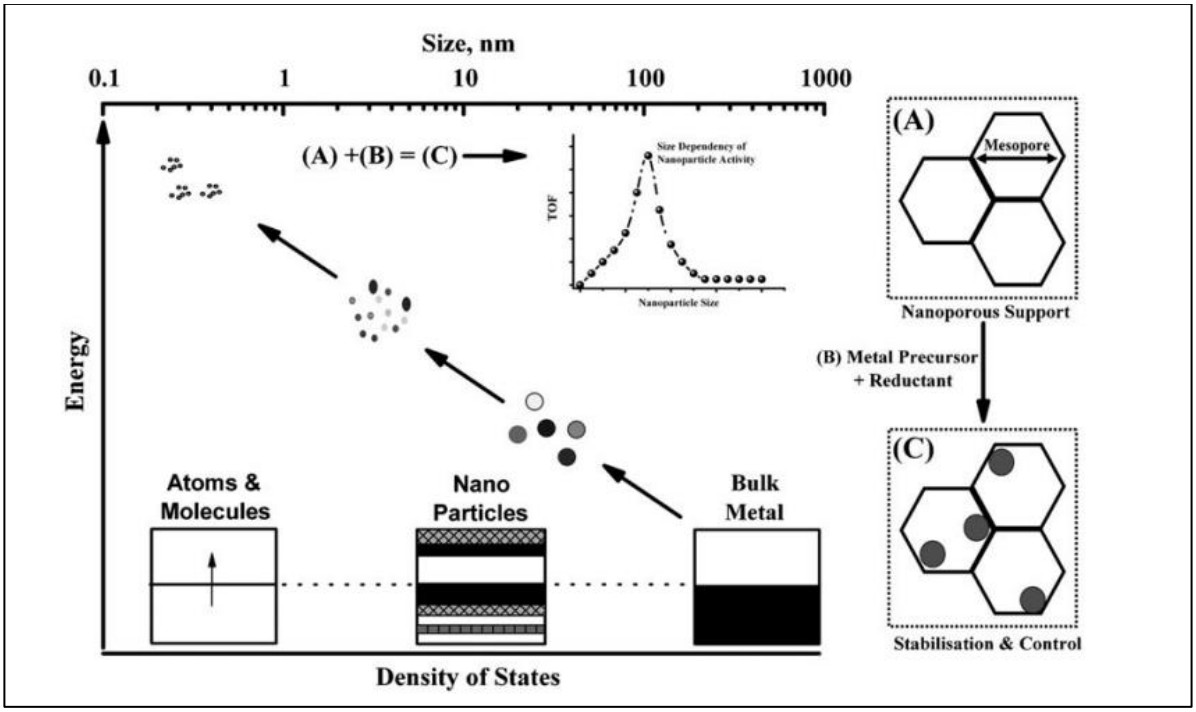

Figure 1: Relation between nanoparticle size, energy, and how catalyst activity works [10].

Nano particles are assumed to be utilised for catalysis because of their large surface area in comparison to bulk metal and these NP catalysts utilised on metal surface [6]. Catalyst is an effective approach which allows functioning of raw ingredients that can effectively produce great value. Catalysts are called heterogeneous catalysis when they are at an interface where reactant and catalyst are in distinct domains [7]. That development of catalysts specifically emphasising on sustainable catalysts is identified as a challenging role in material science. The significance of green catalyst is enhanced because of its environment friendly and reusable approach that declines waste disposal and catalytic ingredients are assumed to be indispensable.

1.1 Background

Catalysis is a prominent discipline in science and industry where catalysts are employed in multiple perspectives with the intention to transform chemically in d]iverse drives such as petrochemistry, pharmaceutical, environment remediation and so on [8]. With the emerging miniature size technology there is an enhanced demand for catalysts specifically focusing on nano based catalysts that has a potential to improve efficiency, environment friendly, cost

effectiveness and consume less energy. This type of catalyst is easily substituted and acts as an alternative resource for a variety of chemical transformations. Broadly catalysts can be categorised as homogeneous, heterogeneous, and biocatalyst. Under the reaction, where reactant and catalyst both are available in physical state are called homogeneous catalysts. Heterogeneous catalyst is opposite to homogeneous catalyst where reactant and catalyst are available in different phases [9]. Nano-based catalysts act as a bridge between homogeneous and heterogeneous catalysts and explore the significance of both the techniques.

2. LITERATURE REVIEWS

Nanoparticles formulated by metal have obtained enormous attention in the last few years because of their excellent characteristics, their shape, size and dimensional properties which make them applicable in diverse domains. The catalyst characteristics of nanoparticles rely on its physical and chemical properties, the strategies used to synthesise in a monitoring manner and exploring the performance. The study [8] explores the formation of metal nanoparticles emphasising on its correlation between its performance and physical-chemical characteristics. The research highlighted hollow interiors of nanoparticles and their capabilities based on the shape size and other dimensions. Moreover, the review also provides how surface morphology is associated with catalytic performance. Another study [9] spotted green synthesis technique and its utility for the synthesis of a number of metallic nanoparticles. The research also explores catalytic capabilities of most usually function nanoparticles. Future examine the challenges that are subjected to the industrial world in order to formulate metal nanoparticles as effective catalysts. Metal nanoparticles are widely utilised as a catalysis. The intention of the article [10] is to review how metallic nanoparticles are prepared and used as a catalysis by putting emphasis on a sustainable development approach. The natural synthesis that is used as metal oxides nano elements that are extracted from microorganisms and plants are highly preferred because of its eco-friendly and cost effective approach. Metal oxide nanoparticles play a critical role in the health sector as they are recognised as an agent which expands half life and therapeutic index because of certain immunogenic properties.

This research [11] explores several metal oxide such as titanium, iron, zinc, and copper from the perspective of biosynthesis and its utility in the pharmaceutical industry along with energy and environment utility. The characteristics of any catalyst are long life, low energy consumption and all these features depend on the dimension of the ingredients, its electronics structure and chemical stability. The miniature size of nanoparticles has excellent surface power that makes metallic ingredients to use in energy efficient, enhanced catalyst capacity, productivity recycling and recovery potential and cost effective [12]. Green catalyst as a nanoparticle has a potential to subdue the waste contamination which creates a challenging role in global warming and also assist in producing an environmentally friendly approach. The study [13] highlights the recent advancement taking place in the nanotechnology world where hybrid approach i.e amalgamation of organic and inorganic nanoparticles act as a source for immobilising carrier of the catalyst

functioning. It was illustrated in this work along with certain examples regarding how nanoparticles based on organic ingredients act as an effective catalyst for environment friendly synthesis.

Xu Y in his work [14] briefly discusses advancement in metal based nanoparticles that play a significant role in formulation of catalyst as well as colloidal synthetic techniques which are used for the formation of nanostructure is the focus of this research. The study also highlights some physicochemical characteristics that play a significant and vital role for constructing nanomaterial and the catalytic application from a future viewpoint.

2.1 Research Question

1. Explore the properties of Nanoparticles which make them functionalism as a catalyst?
2. Determine metal nanoparticles in Catalysis Application?
3. Identify the challenges and advantages of green catalyst ?

2.3 Importance of the Study

Nanoparticles formulated by metal have obtained enormous attention in the last few years because of their excellent characteristics, their shape, size and dimensional properties which make them applicable in diverse domains. The miniature size of nanoparticles has excellent surface power that makes metallic ingredients to use in energy efficient, enhanced catalyst capacity, productivity recycling and recovery potential and cost effective. Thus to explore how metal NP works as a catalyst and its application is the intention of this research. Moreover, how MNP incorporation with organic ingredients to synthesise effectively for producing qualitative application is another significance of this research. Hence, the importance of the research is to look beyond different perspectives from MNP and its utility as a green catalyst. Further the significance and challenges associated with green catalyst technologies in the present scenario.

2.4 Research Objectives

- Explore the properties of Nanoparticles which make them functionalism as a catalyst.
- Determine green nanoparticles in Catalysis Application.
- Identify the challenges and advantages of green catalyst.

2.5 Scope and Limitation

The scope of the research is looking beyond the green NP in catalytic utilities along with incorporation of metallic and bimetallic nanostructures. Hence the study compiled itself around a sustainable and green catalytic approach while excluding some other components like the technique used for producing metal nanoparticles as catalyst rather than green catalyst is comprehensively explored. Thus this became the limitation of the research.

3. RESEARCH METHODOLOGY

The paper choses secondary research approach to accomplish this research which is based on collecting information from already existing similar studies. The main intention is to select a secondary approach to enhance the understanding regarding the topic and see all the appropriate advancement that take place in the present world regarding the theme of the research as to enhance awareness and profound knowledge regarding the subject. This research design takes place to explore the topic of the research i.e metal nanoparticles from the lens of green catalyst and its utility and real world through exploring the existing data from electronic resources such as websites, research journals and others. After collecting data from electronic media, the study manually identifies the literature that must meet the inclusion criteria (journal published only in English language and should have specific keywords or title related to the theme).

4. ANALYSIS OF THE STUDY

Question 1 - Explore the properties of Nanoparticles which make them functionalism as a catalyst?

Catalysis is vital because of its significant features that are catalysts to provide rapidness to the chemical reaction and decreasing energy consumption during transition state by dominant reaction route with the help of appropriate synthesis. Nano catalysis are crucially utilised because they enhance sustainable processes without humming the environment and having economic feasibility[8]. Nanocatalystic approaches provide swift and specific chemical transformation by generating effective products through convenient catalyst separation and recovery. Catalyst embraces excellent revival rate because of fundamental features like reducing pollutant and hazardous waste, cost effectiveness, and efficiency. All these take place when catalysts are involved as a green catalyst.

Metal nanoparticles contain transition metal nanoparticles or deposited metallic groups on a large surface area that ranges from 150- 1200 metre square per gram. Usually, the metal loading of the supported metal catalytic particle comes under the range of 0.5 to 10% of their weight and nanoparticles having the size of 1 to 30 nanometer. This indicates that metallic nanoparticles possess certain chemical and physical characteristics which act on single metal and bulk metal surfaces whose dimension is larger in size around <100 nm [10]. Specifically the reactivity of metal catalyst is heterogeneous in nature which is based on the dimension of specific metal deposited on the surface layer of the carrier, whereas the surface metal can only participate in the chemical reaction. For instance gold NP on alumina whose dimension is less than four nm particle depicts extreme transformation due to ethylene glycol oxidation, however the diameter of gold NP enhances beyond 5nm and falls up in the transformation of about 40%. This indicates that nanocatalyst works in a very sensitive manner because it highly depends on the dimension of the particle which is influenced by other types of supporters [11]. Several oxidic supporting elements such as alumina, silica, ceria and so on, along with a number of carbon materials that

function as a supporter for metallic nanoparticles. One thing should be kept in mind that the supported material must possess robust interaction between metal and support element, having high surface area and incidence of active site that can contribute to the reaction process.
The catalytic characteristic of NP can be influenced by a second metal which is also known as a bimetallic catalyst. This bimetallic catalyst leads to alloys with distinct electronic and structural characteristics. Some of the incidence that are used for the formation of by metallic NP for electrocatalytic applications Pt-Ni, where as bimetallic ingredient can be effectively used for reforming hydrocarbons Au-Ni, some by metallic ingredient are effectively utilised in eliminating sulphur from refineries such as Co-Mo and Ni-Mo. Number of bimetallic ingredients (Au, Pd, Rh, Ru, Ni and Ag) are effectively utilised in diverse domains from automobiles to purification of fossil fuel, for hydrogenation, oxidation and so on [12]. MNP that possess catalytic characteristics are illustrated in the below table.

Metal NP	Catalyst
Platinum–Antimony Tin Oxide NP	"Cathode catalysis for direct methanol fuel cells via an oxygen reduction reaction"
Tin Oxide Nanoparticles	"Catalysts for the reduction and photodegradation of organic compounds"
TiO_2 NP	"TiO2 nanoparticles and photocatalytic performance measured under a medium-pressure mercury UV lamp"
Gold Nanoparticles	"Gold nanoparticles help to create an active catalyst for the reduction of nitroarenes in an aqueous medium when placed on top of nanocrystalline magnesium oxide"
Silver Nanoparticles	"Silver nanoparticles can be used as chemically stable nanoparticles with no environmentally harmful effects on microbes under anaerobic conditions"

Table : Metal NP and their catalyst features [9]

Green synthesis technique of nanoparticles is based on the fundamentals of formulating NP which consists of non hazardous chemicals, renewable or reusable ingredients, and environment friendly solvent. The vital steps in the formation of NP based on green synthesis approach embraces nontoxic solvent medium, harmless reducing agent, and eco stabilising agent. The

utilisation of plant waves material has obtained enormous attention because of its easy availability, biodegradability feature, and nontoxic extraction procedure. Some of the biosynthesis ingredients that are used to formulate nanoparticles and act as a catalyst [12].

The synthesis procedure of green catalyst can be at present an alternative resource to provide a sustainable approach in the material science world and assist to accomplish high yield products. Organic materials that either extract from plants or microorganisms assist to formulate environment friendly metallic NP including AU, AG, PB, and so on. These NP are subjected to distinct substrates involving carbon nanotubes protein such as Soybeans, poly-l-lysine in order to formulate bio-inspired hybrids ingredients. Research [13] indicates that the architecture of nanocatalysts for the development of hydrogen gas relay on ethanol and alumina supported program metal nanocatalysts assure high yield hydrogen gas in a much more protective manner. This indicates catalytic manipulation of green bio fuel such as ethanol which is an environmentally sustainable approach to develop hydrogen gas. Magnetic nanocatalysts are emerging technology in material science because they possess several characteristics like reusable nano catalyst, cost effectiveness, enhanced reactivity, selectivity, highly stable, and reasonable recyclability. Some of the plant extraction that can be utilised as green catalyst along with nanoparticles are descripted in the below table.

Plant	Nanoparticle	Morphology	Dimension	Application
Honey	Au, Pt	Spherical	2.2 nm	Therapeutic, catalyst
Ayurvedic arishtams	Au	Spherical	15-23nm	Catalyst
Phoenix dactylifera	Pd	Spherical	5-21nm	Biomedical and Catalyst
Egg yolk	Pt	Spherical	7-50 nm	Pharma and Catalyst
Orange Peel	Au, Pt	Spherical, nanowires	10-35 nm	Antibacterial, Catalyst

Table : Organic extraction and Nanoparticles and its utility as catalyst[15]

Question 2 - Determine metal nanoparticles in Catalysis Application?

MNP vitally performs a meaningful role catalysis design and utility. Mainly because of its high surface area and rapid reaction activity which enhance product yield and quality. The designing of nanoparticles can be broadly categorised into noble metals like Au, Ag, Pt and others which

are also called supported metal NP and non metal which are also known as bimetallic ingredients such as Fe, Cu, Ni, Co. For instance, a study reflects the catalytic feature of carbon monoxide in the availability of gold nanoparticles deposited on a metal oxide. They indicate that the clusters formulated by the nanoparticle are in the dimension of 1 to 3 nanometers which are designed essentially for catalysis of carbon monoxide under oxidation reaction and had a positive influence on the performance of catalytic activities [12].

Nanostructures of gold obtain enormous interest because they have excellent catalytic properties. One of the research indicates that the alloy of gold (Au) and silver (Ag) synthesised as a catalyst with dimensions of 6 to 9 nanometres through graphene oxide sheets (rGO) depicting tremendous results in reducing 4 nitrophenol. Prominently nitroarenes are identified as the most useful object released from industrial and agricultural areas. This pollutant by the use of a catalyst can be decomposed into non-toxic elements such as the amino arena as shown in figure. Another example of gold NP is Au nanorod is an prominent nano component that displays localised surface plasmon resonance and has vital utility in photothermal therapy, molecular imaging, and gene delivery.

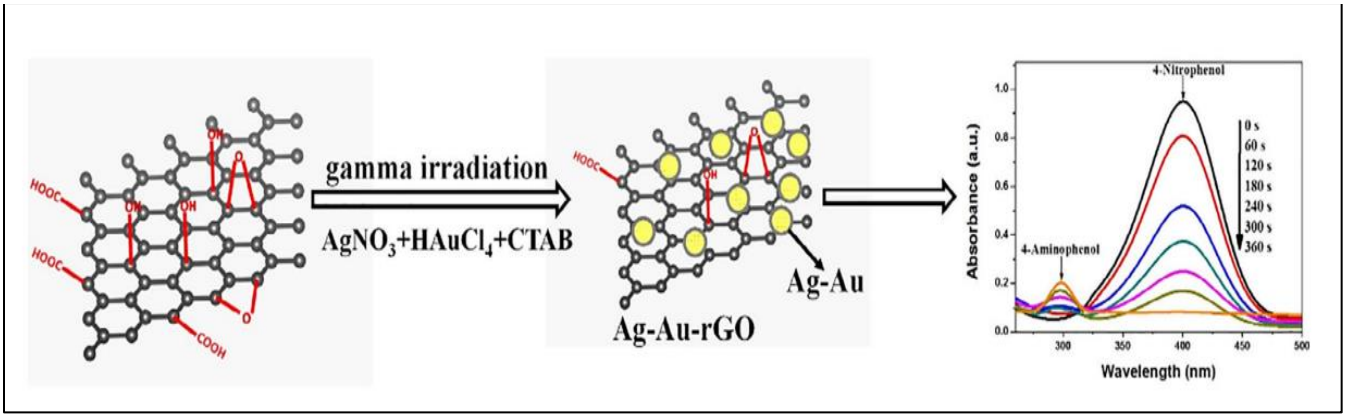

Figure: Alloy of Au and Ag [13]

Eucalyptus globulus is a plant extracted ingredient which can be used as a synthesis zinc oxide to produce nanoparticles. The approach UV-Visible analysis is used to explore the synthesised and nanoparticles and it illustrates the peak was obtained at 361 nanometers for zinc oxide nanoparticles. Evaluation indicates catalytic activity that takes place in deforming methylene blue and methyl orange with utmost degradation efficiency up to 98%. Another example for green catalyst preparation is the manufacture of Ce-doped titanium dioxide nanoparticles. The dimension of Ce-doped is around 5 nm which was dispersed on the surface of porous glass beads. These nanocomposite structures depicted tremendous photo-catalytic features for the visible light degradation of methyl orange and rhodamine. The organic synthesis procedure and photocatalytic activity intensify the characteristics of TiO2 nanoparticles and are effectively used for removal of organic pollutants [13].

Platinum supported nano components are also widely utilised in a diverse arena involving electrocatalytic oxidation for fuel cells because of its high dispersibility and catalytic activities. Metallic platinum has been used for construction of a number of nanoparticles, iron oxide, which produce a stabilised and active catalyst for the oxidation of alcohol, carbon monoxide vitamin and so on. Moreover MNP comprising Pb, Pt, Au illustrate effective activity and stability toward the selective oxidation of alcohol under distinct circumstances [11]. Other than metal supported nanoparticles there are several non metal supported particles such as Fe, Cu, Ni and others widely started because of their catalytic features and large convenience and accessibility. The properties that are subjected under the catalytic functioning of these elements based on their sensitivity, stability, and sustainability that play an active role in heterogeneous catalytic applications [14]. The association of magnetic Fe NP that can be processed into graphene, CNT, 2D substances, are also developed to impact their catalytic properties effectively. It may be extracted that organic synthesised as well as metal supported nanoparticles have broadly functioned in numerous industrial procedures and have diverse applications such as environment remediation, water splitting, biomedical and so on.

5. RESULTS

The findings of the research indicate that with enormous progress in the green synthesis and features of catalytic ingredients proceed towards emerging strategies to enhance the nanocomponents characteristics. This improves the industrial amenability of catalysts for instance by enhancing their atomic efficiency, permitting the replacement of toxic modifiers, extending their life span, and ensuring the recyclability. Most impactful factor for the transformation of catalytic technology into industrial utility is its durability; the advancement in nanostructuring plays a significant and vital role in delivering solutions to issues like stability in the framework of catalytic material that improves durability.

There are several benefits and challenges subjected to producing a catalyst because of advanced technologies and other structuring complexity such as there is a complication in decoupling the catalyst under the influence of distinct parameters of nanocatalyst such as dimension, electronic, morphology, and support that makes it extremely challenging to obtain a molecular level understanding of catalyst. However metal nanocatalysts with manipulative shape and size can function as excellent model catalysts, though their atomic structure is not appropriately described as a homogeneous catalyst [16].

Additives can extremely operate to intensify the sensitivity of an industrial catalyst providing its manipulative size and surroundings of surface metal rearrange the electronic characteristics associated with the formulation of desired product. For instance lindlar catalyst is effectively utilised for hydrogenation of alkyne [17]. Nevertheless, it is associated with two concerns while using the modifiers there toxicity and extremely low metal used responsible for producing outcome catalysts. Meanwhile, with a number of efforts to explore nontoxic surface modifiers,

ligands linked purposely to metal surfaces produce high activity and sensitivity. In catalysts, obtaining support from nanoparticles exploited strategies involving optimising the interconnected strength between the active phase and the carrier through careful production; declining the mobility by tailoring the energy landscape of the active phase or carrier's surface; managing the integrated features of supported nanoparticles. Because robust metal supports incorporation influences to improve catalystics stability through intensifying the interfacial linking strength [18].

6. CONCLUSION

This study tries to provide applications of metal nanoparticles as a catalyst from distinct dimensions along with how the characteristic of MNP can be accelerated by binding green synthesis activities. The synthesis procedure of green catalyst can be at present an alternative resource to provide a sustainable approach in the material science world and assist to accomplish high yield products. Organic materials that either extract from plants or microorganisms assist to formulate environment friendly metallic NP.

Eventually it may be extracted from this study, that nanosized catalysts extracted from nanoparticles embedded with green synthesis approach have several benefits because of its characteristics like surface area, strength, stability, environment friendly, cost effective, and durable nature. It was also identified that the catalytic rate intensifies directly with the number of catalytic sides exposed to the reaction as it yields a faster rate of reaction in a large area and is responsible for higher catalytic activities. Another benefit of nanosized catalysts is the insolubility of the catalyst in the reaction solution which assists convenient separation and reutilisation of nanoparticles as a nanocatalyst. Although except for several advantages, there are certain studies that also indicate complications associated with the use of nanocatalysts. There is also one of the emerging domains which highlighted the influence of Nano composition of metal free catalyst which are not covered in this research. This indicates that future analysis is required to comprehensively explore the nanocatalyst and its application arena from distinct domains.

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