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Reduction of Pollutant Emission from Two-wheeler Automobiles using Nano-particle as a Catalyst

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Abstract

Today, one of the toughest challenges faced by the mankind is the increasing of pollution at an alarming rate. It is causing an environmental imbalance and contributing to increase in the green house effect. Automobile pollution is the major source of pollution. The majority of the environmental pollution is due to the two-wheeler automobiles due to their large number. There are two methods of control of pollution namely, pre-pollution control and post pollution control. This paper is based on the post pollution control method in two-wheeler automobiles using nano-particle as a catalyst. A study on nano-particle reveals that the ratio of surface area of nano-particle to the volume of the nano-particle is inversely proportional to the radius of the nano-particle. So, on decreasing the radius, this ratio is increased leading to an increased rate of reaction and the concentration of the pollutants is decreased. To achieve this objective, an innovative design of catalytic converter for two-wheeler automobiles is proposed using nano-particle as a catalyst. The proposed method is very effective in the prevention of environmental pollution contributed from two-wheeler automobiles. It involves the use of copper nano-particle which is cheaper than the platinum, palladium and rhodium nano-particles used in automobiles.

Keywords: Automobiles, catalytic converter, copper nano-particle.

Introduction

During the last twenty years, scientists have been looking towards nanotechnology for the answer to problems in medicine, computer science, ecology and even sports. Nanotechnology offers the promise for new solutions and product improvements to a variety of market sectors including materials, electronics, energy, bio-medical and consumer goods. A great deal of emphasis is placed on the real societal benefits around nanotechnology for energy efficiency, renewable resources, environmental remediation and pollution prevention. In particular, new and better techniques for pollution control are emerging as nano-particles push the limits and capabilities of technology. Environmental pollution by vehicles is caused due to tail-pipe exhaust emissions depending on changes in driving cycles, engine condition, fuel composition and air-fuel ratio. Malfunction of engine devices, especially fuel injection system, increases the emissions of the main exhaust components. Vehicular emissions consist of carbon dioxide, carbon monoxide, nitrogen oxide, hydrocarbons including lead, particulate matter etc. Inhaling of carbon monoxide hinders oxygen supply from blood into the tissues, as it combines with the Iron in hemoglobin, leading to variety of ailments, viz. Cancer[1]. Carbon dioxide causes environmental problems related to global warming. The past century has seen a dramatic increase in the atmospheric concentration of heat-trapping gasses, due to human activity. If this trend continues, scientists project that the earth's average surface temperature will increase between 2.5°F and 10.4°F by the year 2100. One of these important heat-trapping gasses is carbon dioxide (CO_2). Carbon mono-oxide (CO) is considered as toxic pollutant, whose effective reduction can be achieved by using catalytic converter[2].

Inhaling of carbon monoxide hinders oxygen supply from blood into the tissues, as it combines with the Iron in hemoglobin, leading to variety of ailments, viz. cancer. A huge amount of research and development activity has been devoted to nano-scale related technologies in recent years. The national science foundation projects nanotechnology related products will become a $1 trillion industry by 2015. Nano-scale technology is defined as any technology that deals with structures or features in the nanometer range or that are less than 100 nanometers, about one-thousandth the diameter of a human hair, and larger than about 1 nm, the scale of the atom or of small molecules. Below about 1 nm, the properties of materials become familiar and predictable, as this is the established domain of chemistry and atomic physics. It should be noted that nanotechnology is not just one, but many wide ranging technologies in many technical disciplines including but not limited to chemistry, biology, physics, material science, electronics and self-assembly. Nanotechnology is of significant interest because materials at this scale can exhibit novel properties that are different from the same substance's properties at the macro or even micro scales. Nanotechnology is already having a profound effect on a wide range of different sectors and applications, from medicine to packaging to environmental sensors and remediation[3]. Nano-structures have the ability to generate new features and perform new functions that are more efficient than or cannot be performed by larger structures and machines. Due to the small dimensions of nano-materials (figure-1), their physical/chemical properties (e.g. stability, hardness, conductivity, reactivity, optical sensitivity, melting point, etc.) can be manipulated to improve the overall properties of conventional materials.

At nanometer scales, the surface properties start becoming more dominant than the bulk material properties, generating unique material attributes and chemical reactions. Metal nano-particles are being considered for potential use in catalytic converters since the catalytic reactivity is significantly enhanced due to the increased surface area and altered electronic structure of the metal nano-particle. Coolants utilize nano-particles and nano-powders to increase the efficiency of heat transfer and potentially reduce the size of the automotive cooling equipment.

Methodology

In the past few years, considerable interest has been focused on metal nano-particles due to their special properties and potential applications in diverse fields. Among various metal particles, copper nano-particles have attracted considerable attention because of their catalytic, optical, and electrical conducting properties. Several methods were developed for the preparation of copper nano-particles, including thermal reduction, metal vapor synthesis, radiation methods, micro-emulsion techniques, laser ablation, mechanical attrition, and chemical reduction[4]. Nano-material-based catalysts are usually heterogeneous catalysts broken up into metal nano-particles in order to speed up the catalytic process. Metal nano-particles have a higher surface area so there is increased catalytic activity because more catalytic reactions can occur at the same time. Nano-particle catalysts can also be easily separated and recycled with more retention of catalytic activity than their bulk counterparts. These catalysts can play two different roles in catalytic processes: they can be the site of catalysis or they can act as a support for catalytic processes. They are typically used under mild conditions to prevent decomposition of the nano-particles at extreme conditions. A catalytic converter (figure-2) is a vehicle emissions control device which converts toxic byproducts of combustion in the exhaust of an internal combustion engine to less toxic substances by way of catalyzed chemical reactions. The specific reactions vary with the type of catalyst installed.

Most present-day vehicles that run on gasoline are fitted with a "three way" converter (figure-3), so named because it converts the three main pollutants in automobile exhaust: an oxidizing reaction converts carbon monoxide (CO) and unburned hydrocarbons (HC), and a reduction reaction converts oxides of nitrogen (NO_x) to produce carbon dioxide (CO_2), nitrogen (N_2), and water (H_2O). The first widespread introduction of catalytic converters was in the United States market, where 1975 model year gasoline-powered automobiles were so equipped to comply with tightening U.S. Environmental protection agency regulations on automobile exhaust emissions. These were "two-way" converters which combined carbon monoxide (CO) and unburned hydrocarbons (HC) to produce carbon dioxide (CO_2) and water (H_2O). Two-way catalytic converters of this type are now considered obsolete, having been supplanted except on lean burn engines by "three-way" converters which also reduce oxides of nitrogen[5,6,7].

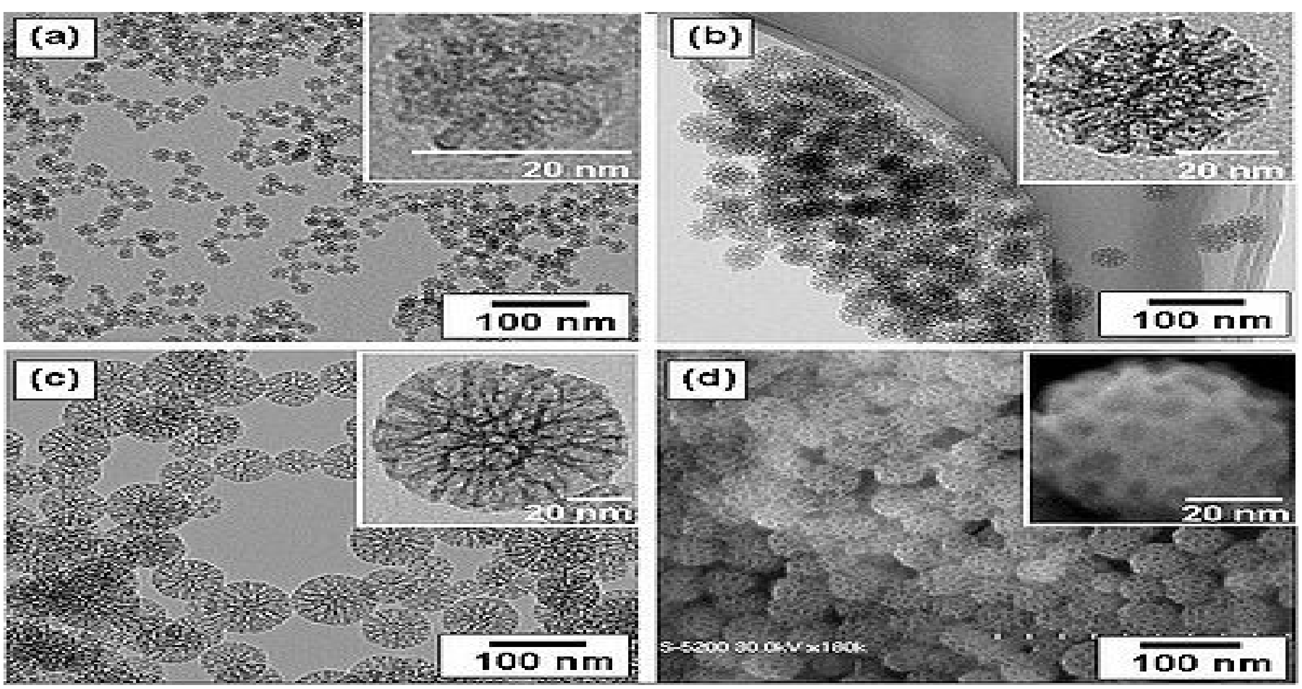

Figure 1
Nano-particles

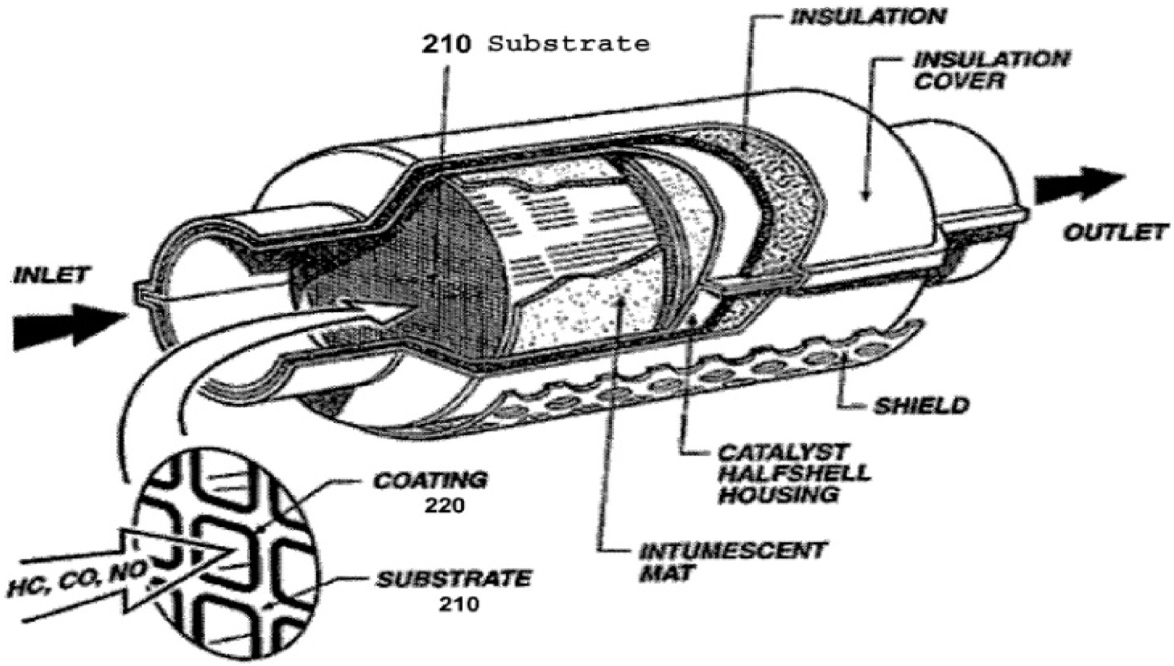

Figure 2
Catalytic converter

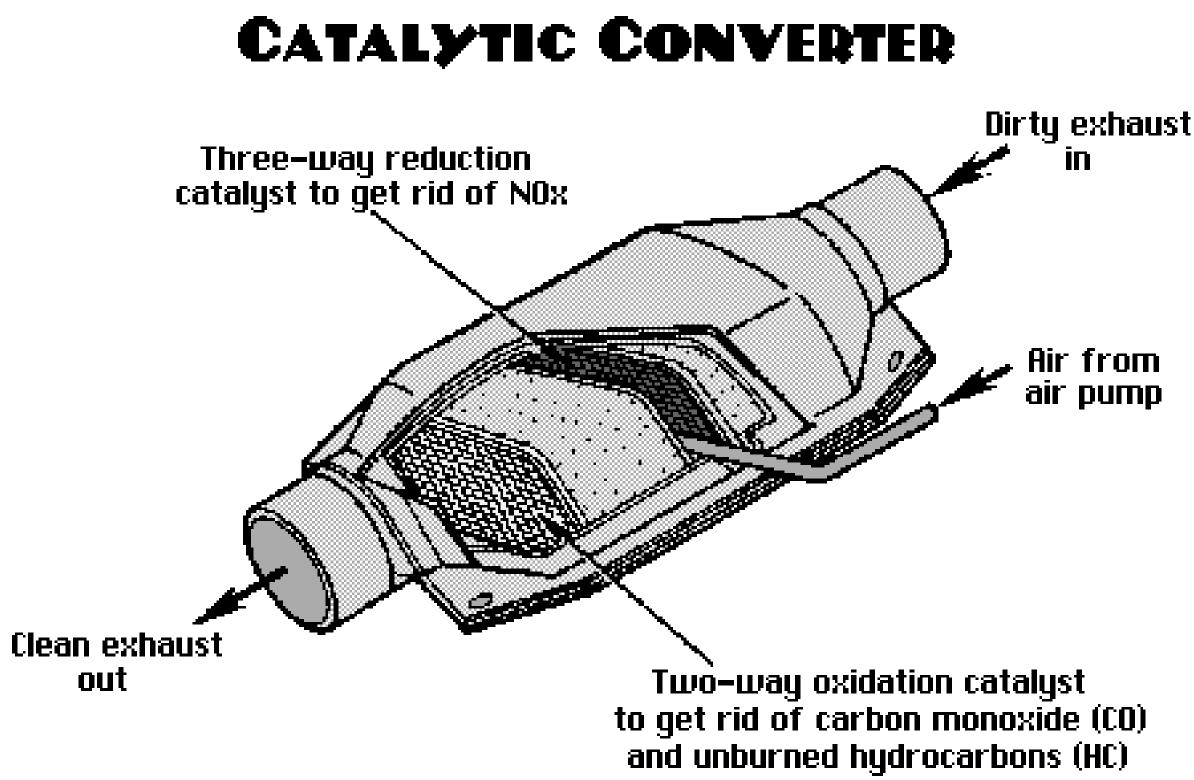

Figure 3
Working of catalytic converter

The main principle behind the working of catalytic converter is that the ratio of surface area of nano-particle to the volume of the nano-particle is inversely proportional to the radius of the nano-particle. So, on decreasing the radius, this ratio is increased leading to an increased rate of reaction and the concentration of the pollutants is decreased[8,9,10]. To achieve this objective, an innovative design of catalytic converter for two-wheeler automobiles is proposed using nano-particle as a catalyst. Mazda Motor Corporation has unveiled a new generation of catalytic converters that use 70 to 90 per cent less of the precious metals which help to purify exhaust emissions. The converters rely on nano-particles of the catalytic metal, each less than five nano-metres across, studded onto the surface of tiny ceramic spheres. The Japanese firm claims this is the first time 'a catalyst material has been achieved that features single, nano-sized precious metal particles embedded in fixed positions. Automotive catalysts use platinum, rhodium and palladium to speed up chemical reactions of pollutants such as nitrogen oxide, carbon monoxide and hydrocarbons, to create non-toxic emissions. By using nano-particles of the precious metals instead of large particles, less metal is needed to produce the same surface area over the ceramic base of the catalyst (figure-4).

This simple concept had not been utilized in the past because exhaust heat can make the nano-particles migrate over the surface of the ceramic bead, agglomerating into larger particles, explained Michael Zins, deputy director of the Fraunhofer Institute for Ceramic Technologies and Systems (IKTS) in Dresden, Germany. This reduces the overall surface area of the metal, cutting the converter's efficiency. Zins described the use of nano-particles to produce catalysts as a major development, and one that all automakers would like to copy. 'I am sure all other companies are working on the technology,' he said. Indeed, Mazda's claim comes just two months after rival Japanese automaker Nissan announced it had developed a nanotechnology-based catalyst that would cut its precious metals usage by 50 per cent. Nissan, which will share the technology with French partner Renault, intends to launch a new vehicle using the catalyst in late 2008 or early 2009. The chief benefit of the technology is cost savings, Zins said. Vehicle manufacturers use a large proportion of the world's annual platinum, rhodium and palladium output, and the development could eventually have a big impact on the prices of these metals. Less platinum and palladium in catalysts could also translate into health benefits. For example, ongoing research suggests that emissions of platinum-group metals from catalytic converters along US highways might be a root cause of an alarming rise in allergies and asthma. An automobile exhaust system (figure 5) comprises of various devices or parts of an automotive engine, which are used for discharging burned gases or steam. Exhaust systems consists of tubing, which are usually used for emitting out waste exhaust gases with the help of a controlled combustion taking place inside an automobile engine. All the burnt gases are exhaled from an engine using one or more exhaust pipes. These gases are expelled out through several devices like cylinder head, exhaust manifold, turbocharger, catalytic converter, muffler and silencer.

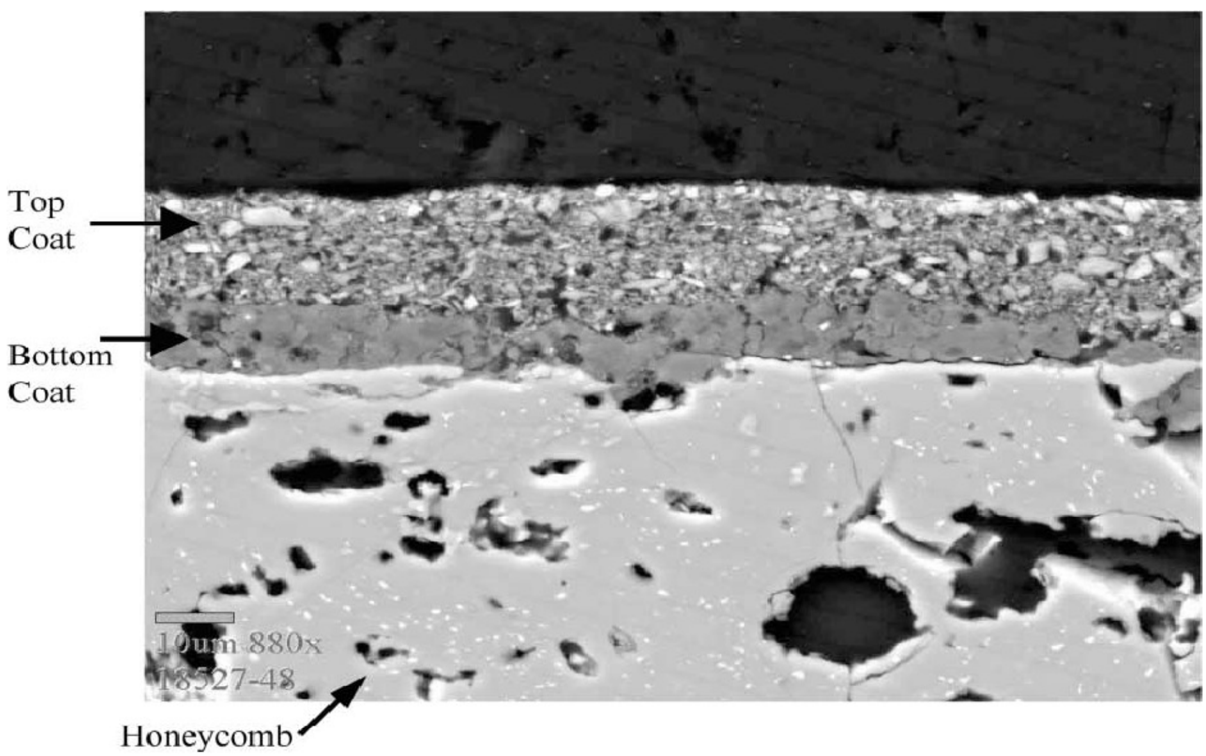

Figure 4
Coating of nano-particle catalyst

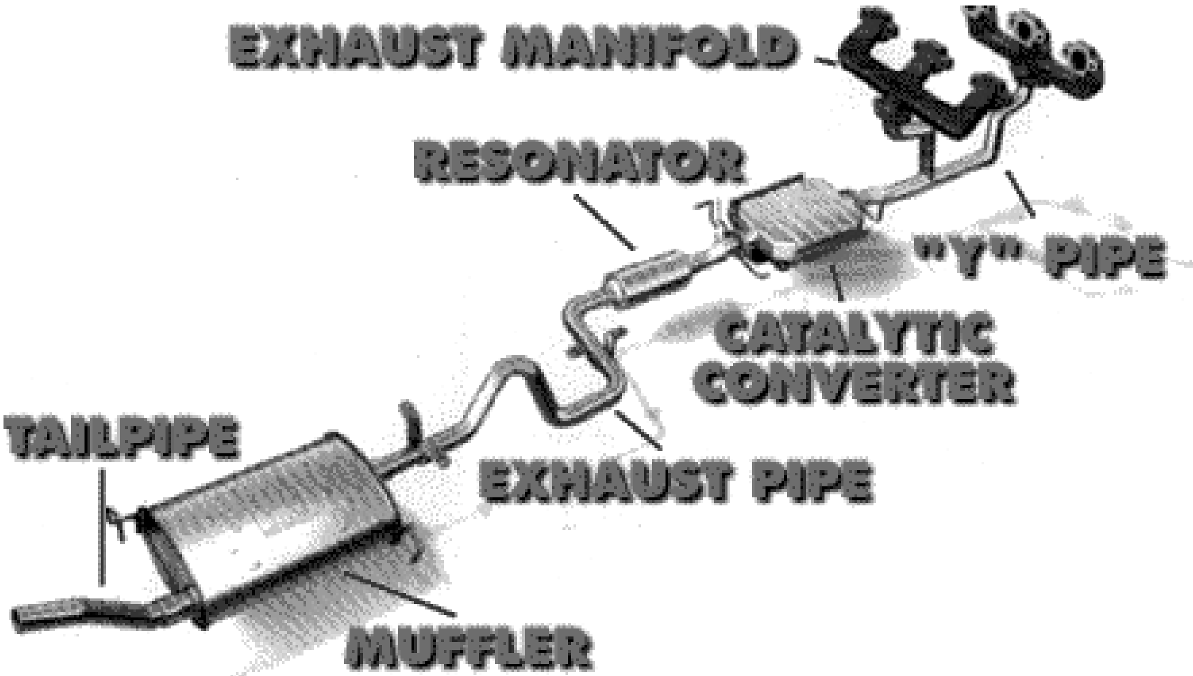

Figure 5
Automobile exhaust by using metal nano-particles

High surface area metal oxides are one of the main components of automotive exhaust catalysts. These metal oxide materials are utilized to physically and chemically enhance the performance of active precious metal particles as support material. These materials are designed to have large surface area, high oxygen exchange capacity, and high thermal stability. The traditional metal oxide materials are prepared through liquid phase precipitation reactions. Traditional liquid phase methods rely on natural crystallization process at or near room temperature conditions to form metal oxide particles. This process is extremely difficult to control. Also, the resulting materials do not maintain high surface area when they are exposed to the extreme temperatures and gas atmospheres present in automotive exhaust. Flame combustion techniques for producing nano-particles also exist. However, flame synthesis can only operate under oxidizing conditions, and at a lower temperature than the plasma based processes described in this invention. Both of these features introduce limitations in the array of materials that can be created. With this novel invention a new technique is introduced to generate metal oxide nano-particles for use as catalyst supports, preferably for use as automotive exhaust catalyst, using a microwave plasma torch. This technology involves passing solid or liquid phase precursor material carried as a wet or dry aerosol by a carrier gas through plasma created from Ar, He or other noble gases.

Results and Discussion

The catalyst increases the rate of reaction by adsorption of reactants in such a form that the activation energy for reaction is reduced far below its value in non-catalytic reaction. Copper metal is selected for the present work as it is cheaper than platinum, palladium and rhodium also it adsorbs the reactants molecule strongly enough to hold and active the reactants but not so strongly that the product can't breakaway also the diffusion of reactants and products into and out of the pore structure of copper took place efficiently. Due to this, the pollution level for the exhaust emission of S.I. engine has found to be reduced which is better with nano-sized catalytic converter. The idea behind the work is to create a structure that exposes the maximum surface area of catalyst to exhaust stream, also minimizing the amount of catalyst required. The exhaust gases pass through a bed of catalyst and the catalytic action takes place at surface of copper which is porous and the higher catalytic activity towards the oxidation of carbon mono-oxide and hydro-carbons could be due to the higher catalytic surface area of small nano-particles. Air pollution can be remediated using nanotechnology in several ways. One is through the use of nano-catalysts with increased surface area for gaseous reactions. Catalysts work by speeding up chemical reactions that transform harmful vapors from cars and industrial plants into harmless gases. Catalysts currently in use include a nano-fiber catalyst made of manganese oxide that removes volatile organic compounds from industrial smokestacks. Other methods are still in development. Nanotechnology's potential and promise have steadily been growing throughout the years. The world is quickly accepting and adapting to this new addition to the scientific toolbox. Although there are many obstacles to overcome in implementing this technology for common usage, science is constantly refining, developing, and making breakthroughs.

Conclusion

The catalyst increases the rate of reaction by adsorption of reactants in such a form that the activation energy for reaction is reduced far below its value in uncatalyzed reaction. Copper metal is selected for the present work as it is cheaper than platinum, palladium and rhodium also it adsorbs the reactants molecule strongly enough to hold and active the reactants but not so strongly that the product can't breakaway also the diffusion of reactants and products into and out of the pore structure of copper took place efficiently. Due to this, the pollution level for the exhaust emission of S.I. engine has found to be reduced which is better with nano-sized catalytic converter. Catalytic converters based on spray of copper nano-particle on copper sieve demonstrate superior performance. Nano-particle exhibit high temperature stability beyond that normally encounter in catalytic converter applications. The above work also opens a pathway for some future prospects such as exhaust gas recirculation model for reduction of NO_x concentration level which is already available and has to be incorporated with present catalytic converter model and tested against experiments. Catalytic converter based on spray of copper nano-particle on copper sieve demonstrates superior performance. Nano-particle exhibit high temperature stability beyond that normally encounter in catalytic converter applications.

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