Nanoparticles application in Air and Environment Purification

Submitted in complete fulfilment of the course project of

ECE1006 – Introduction to NanoScience and Nanotechnology

In

Bachelor of Technology

By

Gautam Chettiar (19BEC0368)
Swarnim Kulshreshtha (19BEC0449)
Ansh Jignesh Patel (19BEC0364)

Under the guidance of

Prof. Mangaiyarkasari R.

CNR

VIT, Vellore

ACKNOWLEDGEMENTS

This project consumed a certain amount of work, research and dedication. Still, implementation would not have been possible if we did not have the support of many individuals including my mentor as well as my team leader. Therefore, we would like to extend our sincere gratitude to all of them.

First of all, we are thankful to Prof. Mangaiyarkasari R. for her logistical support and for providing necessary guidance concerning the implementation of the project.

Without the superior knowledge and experience of the technical staff, the project would have lacked in quality of outcomes, and thus their support has been very essential towards this work. We are very grateful to Vellore Institute of Technology for allowing us to pursue this project in this renowned company which helped us gain great knowledge towards my field and gave us quite an experience that will be useful for our work in the future.

Nevertheless, we express our gratitude towards our families and colleagues for their kind co-operation, constant support and encouragement which helped us in the completion of this project.

~ ***Our Team***

Gautam Chettiar

Swarnim Kulshreshtha

Ansh Jignesh Patel

Contents of the Project

Objective

The objective of our project “Nanoparticles application in Air and Environment Purification” is to find and assess conventional as well as non-conventional methods of purifying the various pathogens and impurities present in the air and the environment as a whole, look at previous attempts made by renowned scientist and the past implementations in order to curb the issue at hand

The project also aims at finding alternative methods to curb the toxicity in the air, using methods of NanoScience and the technology we have access to using particles’ property at the nano scale.

Also the project takes partial, if not complete inspiration from the current pandemic situation, plus at the current air purity levels at various cities throughout the world which fall in the ‘very poor’ or even ‘hazardous’ index in terms of air purity levels, and has very practical uses and an in-depth study can be used to recreate and produce products which will be relevant in the future and is industry as well as user friendly.

Literature Survey

[1] Susceptibility constants of Escherichia coli and Bacillus Subtilis to silver and copper nanoparticles

[2] KY Yoon, JH Byeon, JH Park, J Hwang - Science of the Total Environment, 2007 – Elsevier

[3] Manganese Oxide in heterogenous photo catalysts- by Simon Ristig, Niklas Chibura and Jennifer Strunk

[4]Protecting healthcare workers during COVID-19 pandemic with nanotechnology: A protocol for a new device from Egypt

MK Ahmed, M Afifi, V Uskoković - Journal of infection and public health, 2020 – Elsevier

[5] J. Yang, Y. Zheng, X. Gou, K. Pu, Z. Chen, Q. Guo, et al.*Prevalence of co morbidities in the novel Wuhan corona virus (COVID-19) infection: a systematic review and meta-analysis*

[6] Nanotechnology for the Energy Challenge; edited by Javier García-Martínez; with a foreword by Ernest J. Moniz

[7] Post-combustion carbon dioxide capture: Evolution towards utilization of nanomaterials

Low Carbon Economy (LCE) Research Group, School of Chemical Engineering, Engineering Campus, University

Sains Malaysia, 14300 NibongTebal, Pulau Pinang, Malaysia

[8] Nanotechnology for Carbon Dioxide Capture- researchgate citation

[9] Nanowerk -WILEY-VCH VERLAG explains the use of manganese oxide for air purification

[10] Synthetic 'gene-like' crystals for carbon dioxide capture- by understanding nano

[11] Mesostructured Manganese Oxide. Gold Nanoparticle Composites for Extensive Air Purification-Researchgate citation

[12] Low-cost catalyst prepares to take on power-plant emissions by Charles Lyman and Herman

Nanotechnology as a Measure against COVID-19

Precursors and Approach

- An important note to be made before starting the approach to prevent COVID is first know a little bit about it and what has been tried in order to hamper its spread.
- The virus size is 0.1 microns or 100 nanometers, hence it is really small.

The virus can be transferred via touch, indirect contact, and people within an infected person’s proximity are also prone to the risk.

The virus can also get airborne on water droplets that get ejected from the mouth while talking, coughing etc.

As of now there is no foolproof cure for COVID, there are in use immunity shots and prescribed diets and supplements, hence prevention being the primary goal.

And the best prevention is social distancing, and wearing masks at all times, but a recent research showed that even the N-95 masks aren’t really effective against COVID due to its small size, hence here comes the role of nano particles.

Copper Oxide Nanoparticles

- Copper Oxide nanoparticles are very active and they come from an ancient concept of using metals to sterilize surfaces.

- If the nanoparticles of CuO are sprayed finely all over the traditional mask, then when the virus comes in contact with them, due to their high reactivity, they will directly kill the virus.

- Even normal copper can be used for this, the entire process if done in mass is inexpensive

- Even if deactivated particles are used, then if it is applied on masks, it can decrease the pore size and be able to restrict its pore diameter to 0.1 microns.

Nanoparticles Fiber Materials

- One potential alternative is using the nano-particle fabric in High Efficiency Particulate Air (HEPA) filters found in heating and air conditioning units. This would allow the nanoparticles to deactivate viruses that circulate through the ventilation systems found in offices, shopping centers, public buildings, and even hospitals and care homes.

- Anson Nano-Biotechnology (ZhuHai) Co.Ltd. is developing masks using patented nano-silver technology. According to studies, nano-silver fabric lining the masks can help protect users against viruses and bacteria so that the nanoparticles continuously release ions, which are able to kill viruses and bacteria. Following the Corona virus outbreak, a special policy was put in place and antibacterial and antiviral usage of masks have to be inspected and approved by Guangdong's Drug Administration and Administration of Market Regulation of Zhuhai. It is very likely that this will come in handy if COVID doesn't start flat-lining anytime soon.

Masks using Polylactic-Acid

The primary route of SARS-CoV-2 transmission from human to human is through inhalation of respiratory droplets.

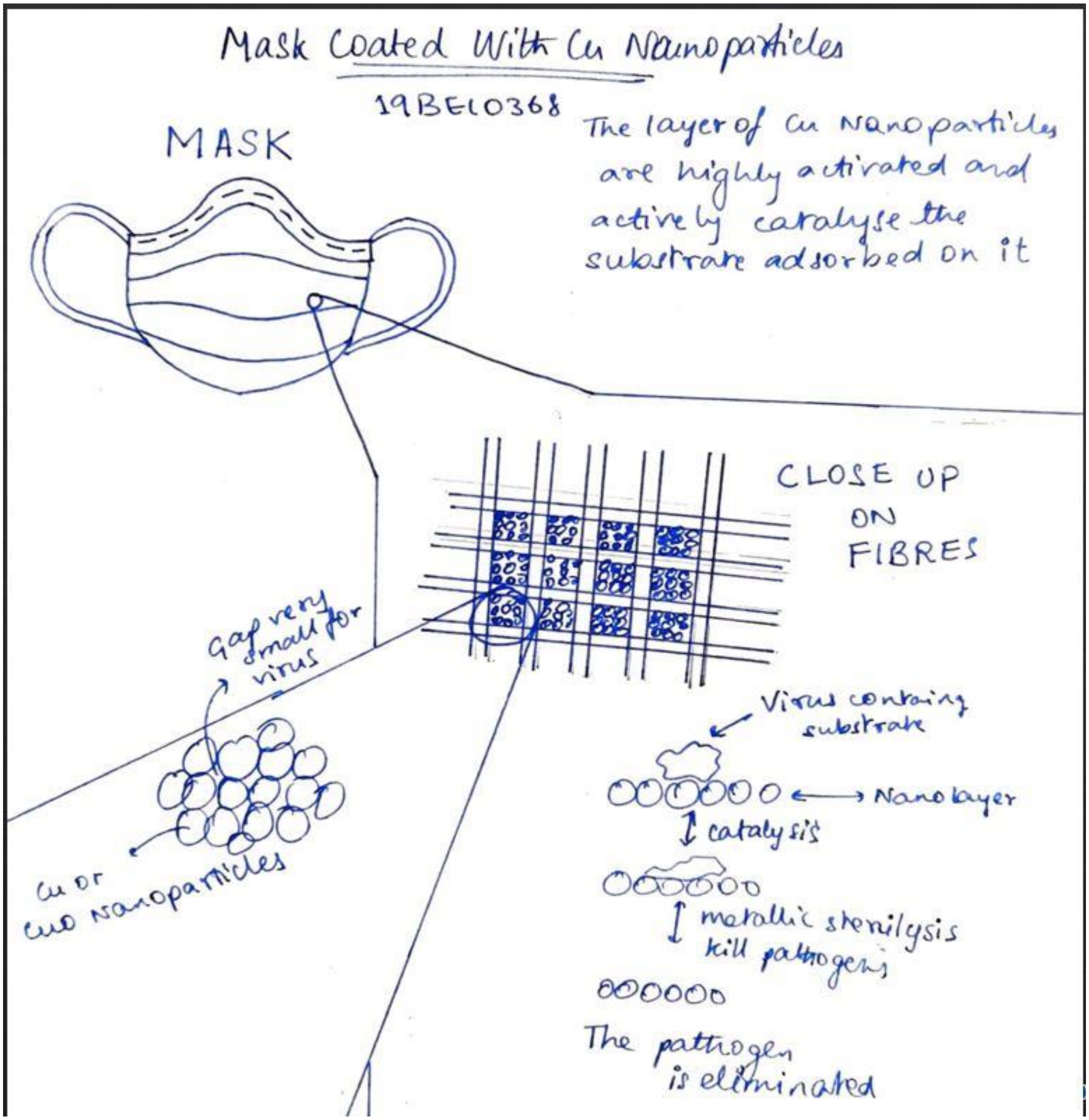
However, the current generations of protective respirator masks in use are noted for their imperfect design and there is a need to develop their more advanced analogues, with higher blockage efficiency and the ability to deactivate the trapped bacteria and viruses.

It is likely that one such design will be inspired by nanotechnologies. Here we describe a new design from Egypt, utilizing a reusable, recyclable, customizable, antimicrobial and antiviral respirator facial mask feasible for mass production.

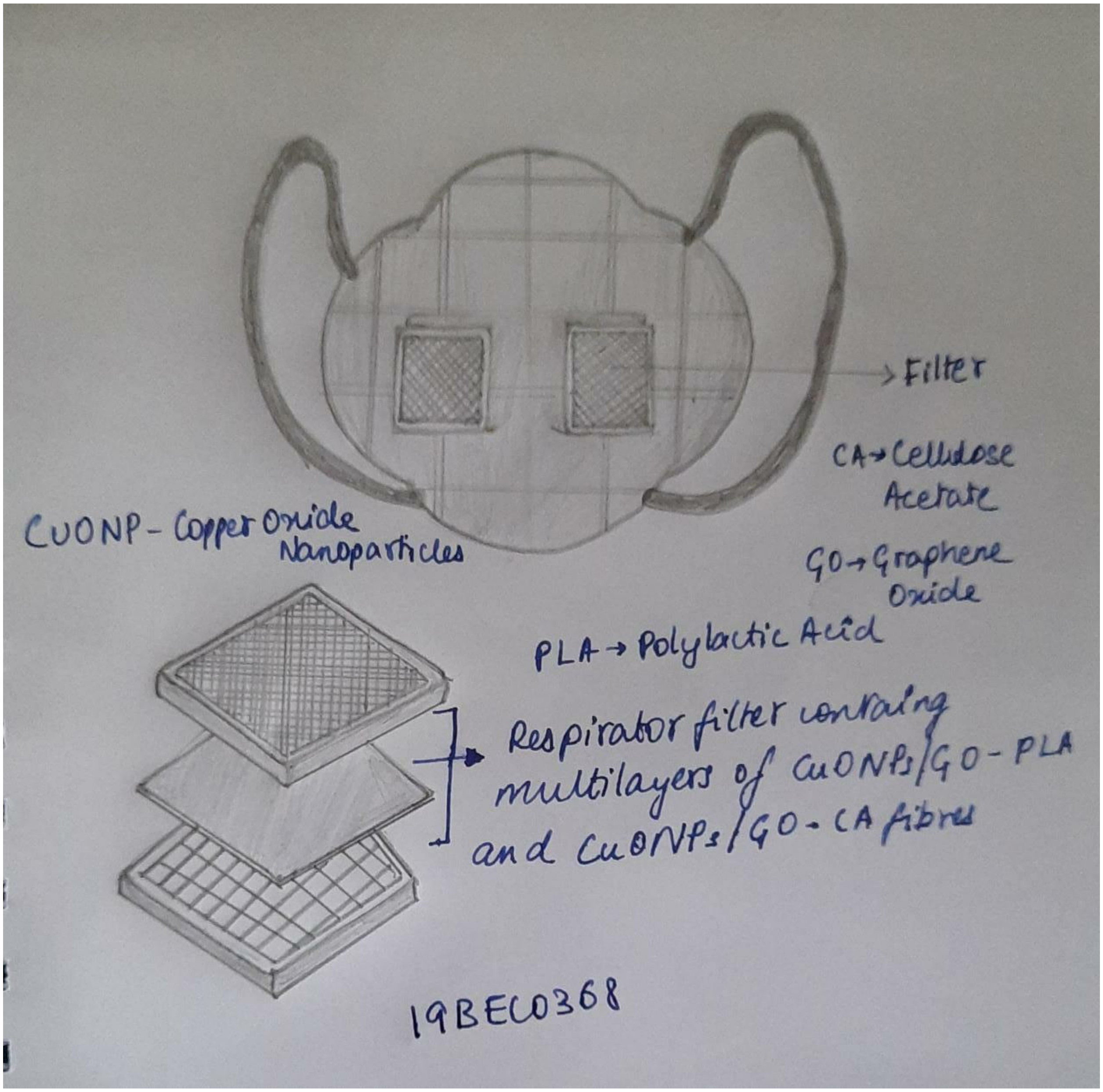
The novel design is based on the filtration system composed of a nanofibrous matrix of Polylactic acid and cellulose acetate containing copper oxide nanoparticles and Graphene oxide nanosheets and produced using the electrospinning technique.

Simultaneously, the flat pattern fabricated from a thermoplastic composite material is used to provide a solid fit with the facial anatomy.

Diagram Representation



New Mask Theory



Conclusion

Nanoparticles are the future, and can play a very vital role in COVID prevention and treatment.

Nanotechnology for Carbon dioxide capture

Precursors and Approach

Air contamination is one of the major issues that the world is facing today, also this problem is growing at an exponential rate with each passing year. This ultimately leads to severe harmful effects on our health and also the environment of the earth. At present the air present around us is full of various chemicals such chlorofluorocarbons, hydrocarbons and nitrogen oxides. Therefore, the development of nanotechnology plays an important role for monitoring and cleaning of air in the environment.

Many extensive research works have been carrying out under the field of nanotechnology to improve the constraints of existing technology.Nanomaterials have shown their potentials in CO_2 capture with its high surface area and adjustable properties and characteristics. Many limitations in existing technology were found improvable by nanomaterials.

Therefore, this part of the review focuses broadly on the application of nanotechnology for cabon dioxide capture.

◈ *Use of nano-porous membranes to remove carbon dioxide from air*

Traditional membrane approach for CO2 capture

A new type of membrane is developed recently which has carbon nanotubes (CNTs) forming the nano-pores.

Carbon dioxide (CO_2) molecules flow through the nanotubes to a storage tank, and the rest of the exhaust stream continues out the smokestack of factories.

Carbon nanotubes, unlike other nano-pores, have a very smooth inside surface. Therefore, after molecules enter the openings of these nanotubes, they encounter less resistance and move through more efficiently.

Development of such nanomaterials - Recently there has been a development of structures called metal-organic frameworks (MOFs). These structures take their name from the fact that metal molecules and organic molecules are connected in a framework.

These metal-organic frameworks (MOFs) contain pores that offer an easy way to store gases that are otherwise hard to store. Further, the researchers have designed MOFs with pores that are just the right size to let carbon dioxide molecules in. Therefore, cavities inside the MOFs provide space to store the carbon dioxide.

Advanced membrane approach for CO2 capture

In contrast, polymeric and other gas-permeable membranes often possess features which are nano. As mentioned above, there are several approaches to using membranes for CO2 capture, among them facilitated and other dual-functional membranes, supported enzyme membranes and supported ionic liquids on polymeric supports. In general, membrane approaches are less than ideal for classic coal-fired power plant CO2 capture, however, because the flue gas is a low pressure stream and hence the driving force for an efficient membrane separation is very low. Nevertheless, a brief summary of facilitated membrane approaches for CO2 capture is provided here.

Facilitated membranes utilize a chemical reaction between some part of the membrane and CO2 in order to enhance permeability through the membrane. Concurrently, the active phase of the membrane is selected such that it reacts with CO2 and does not react with any other gases present on the feed side, such as nitrogen or oxygen in the case of flue gas. This adds significantly to the selectivity for CO2 over any other gases present in the feed stream. Any gas other than CO2 can only pass through the membrane via diffusion. A recently described facilitated membrane schematic is provided. In this example, an amine functionality is added to the polymeric backbone. The amine reacts with CO_2 and water to form a bicarbonate anion. The bicarbonate anion then releases the CO_2 via the reverse reaction, and thus it effectively transports the CO_2 to the permeate side of the membrane.

Ionic liquids (ILs) supported on polymeric membranes can also serve as the active phase for selective CO_2 capture technology. CO_2 has been shown to be very soluble in several ILs, and thus the mechanism of CO_2 capture combines the high capacity of physical sorbents with the ease of use available via membrane technology. Current limitations to this emerging technology are the same as those mentioned above for facilitated membranes, plus an issue with absorption kinetics. That is, absorption rates are rather slow owing to the relatively high viscosity of ILs.

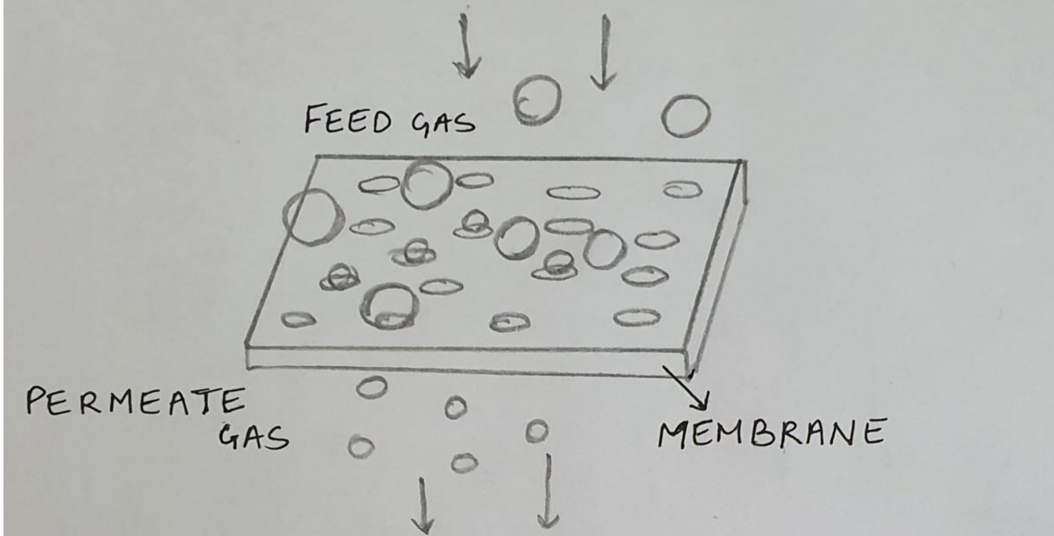
High-Temperature CO_2 Adsorbents

Two adsorbent systems with nano characteristics have been developed recently. One is perovskite-like (BCY) compound whose structure changes upon CO_2 adsorption at 700-1000 degree Celsius. Desorption occurs reversibly at 1400 degree Celsius in air. Unfortunately, these temperatures are extreme even for pre-combustion CO_2 capture.

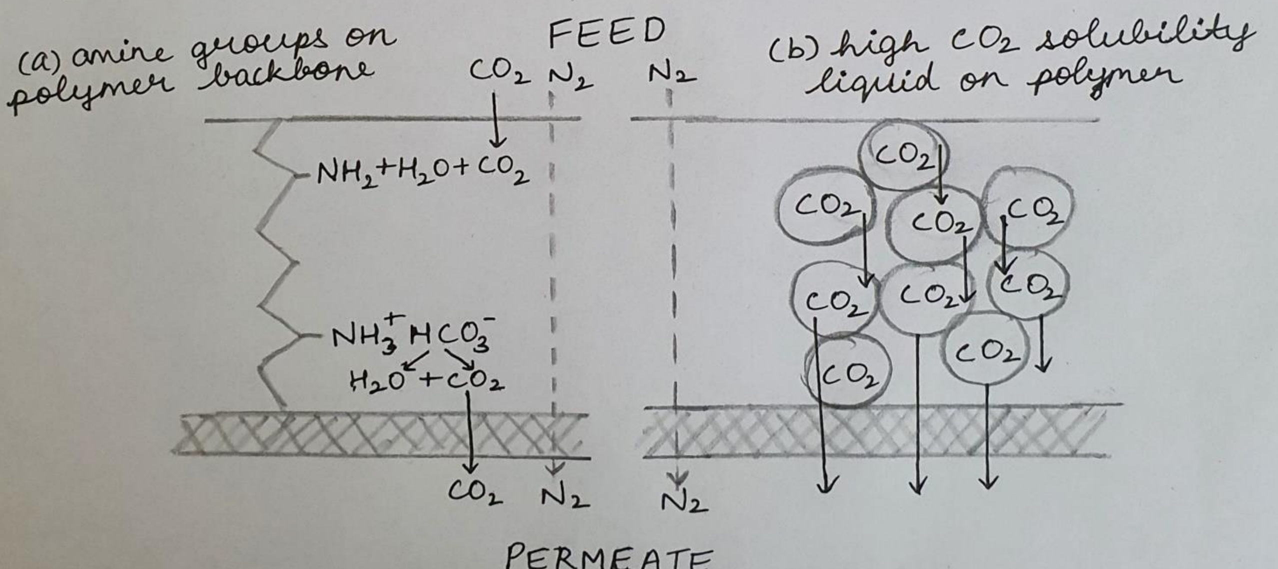
Likewise, nanocrystalline lithium, sodium and potassium-doped lithium zirconates from the Chen group adsorb CO_2 at 575 degree Celsius or so and require at least 600 degree Celsius for desorption.

Diagram Representation

① -19BEC0364



②



(a) an amine functionality attached to polymer backbone

(b) a high CO_2 solubility liquid trapped inside pores of polymeric membrane

Gold Nanoparticles in Manganese Oxide Cleans VOCs from Air

Precursors and Approach

Let's understand about what are VOCs first —

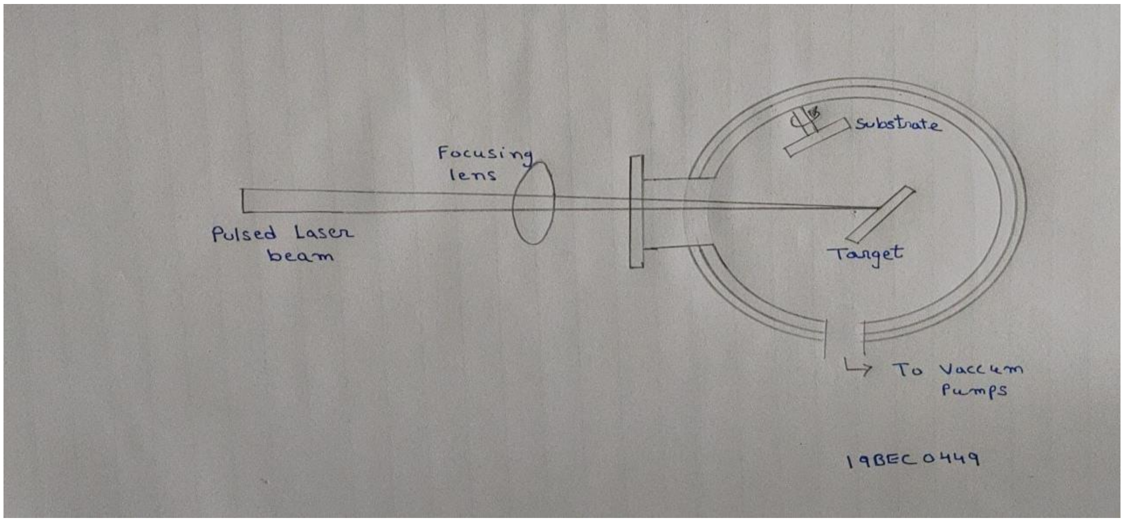
- VOCs stands for **volatile organic compounds**, some of which are very dangerous to the environment. Common examples of VOCs that may be present in our daily lives are: benzene, ethylene glycol, formaldehyde, methylene chloride, tetrachloroethylene, toluene, xylene etc.
- Some of these are even present in our environment which can impose serious threat problems. VOCs often cause eye, nose, and throat irritation, nausea, and can also damage the liver, kidney, and central nervous system.
- To remove them is therefore a challenge and also a need for humans. Here we use gold nanoparticles.
- Japanese researchers have now developed a new material that very effectively removes VOCs as well as nitrogen- and sulfur oxides from air at room temperature.

- According to their report, their system involves a highly porous manganese oxide with gold nanoparticles grown into it.
- This material has a very large inner surface area of the porous manganese oxide, which is higher than all previously known manganese oxide compounds.
- This large surface area offers the volatile molecules a large number of adsorption sites. Moreover, the adsorbed pollutants are very effectively broken down. There is clearly plenty of oxygen available for oxidation processes within the manganese oxide lattice.
- Degradation on the surface is highly effective because free radicals are present there. Presumably, oxygen from air dissociates on the gold surface to replace the consumed oxygen atoms in the lattice structure.

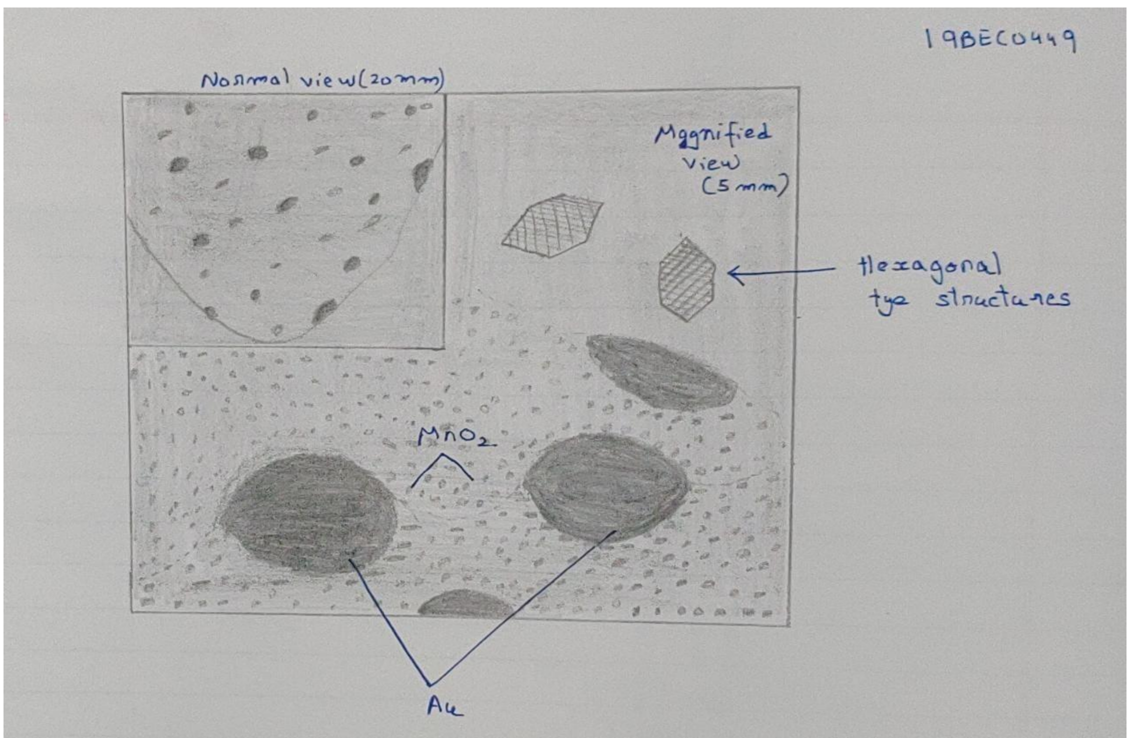
Formation of the material

- The gold is first deposited onto the manganese oxide by means of **vacuum-UV laser ablation**.
- In this technique, a gold surface is irradiated with a special laser, which dislodges gold particles through evaporation. These gold particles have unusually high energy, which allows them to drive relatively deep into the surface of the manganese oxide.

Schematic diagram(formation)



Schematic diagram(operation)

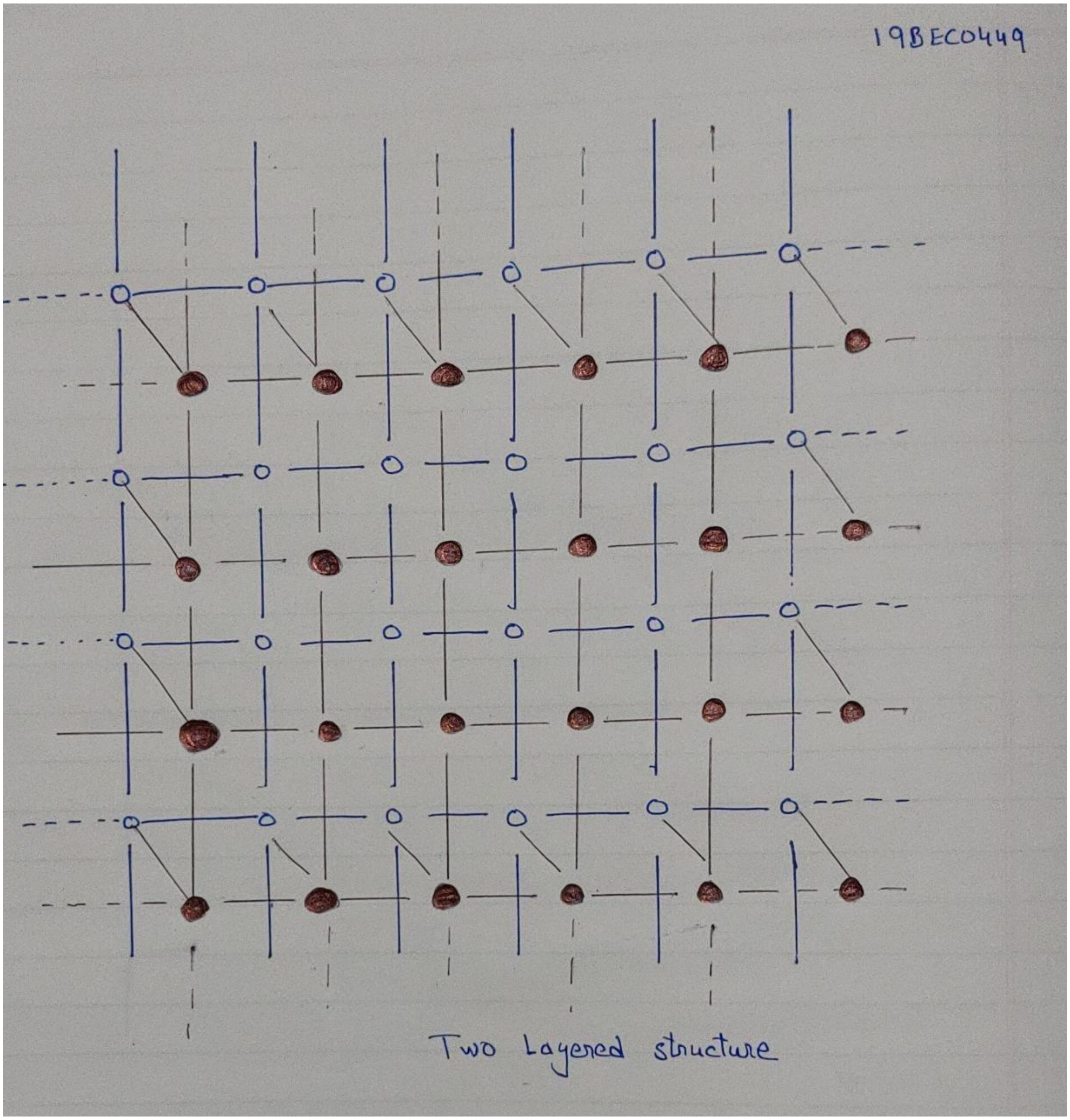


Here the Au particles act as a site for adsorption (providing surface area) and MnO_2 reacts with the VOCs to form simpler compounds which are harmless and releases in the atmosphere.

Synthetic 'gene-like' crystals for greenhouse gases

- To capture heat-trapping carbon dioxide emissions, which contribute to global warming, rising sea levels and the increased acidity of oceans, scientists at ULCA have developed a gene like crystal which claims to trap a large amount of greenhouse gases (like CO2) from the atmosphere.
- So just like a DNA which has a unique sequence for every human being which is why our faces are different, these synthetically generated nanoparticles too have a sequence which could be altered according to the conditions required.
- Scientists call it as a synthetic gene.
- These synthetic nanostructures can also be modified in such a way that would help to convert gases and liquids like carbon dioxide to fuel, or water to hydrogen. But this is under research

Schematic diagram



Low-cost catalyst prepares to take on power-plant emissions

- *Recent developments on catalysts that convert the harmful nitrogen oxides emitted from coal- and gas-fired power plants to nitrogen and water vapor are done.*

- *Unlike other conventional methods of converting nitrogen oxides (NOx), the low-cost nanoparticle-based catalysts do not use ammonia.*

- *NOx is a generic term for nitrogen oxide (NO) and nitrogen dioxide (NO2). The oxides, which are responsible for smog and acid rain, are produced when nitrogen and oxygen react in the air during combustion, especially at high temperatures. Therefore, it becomes necessary to trap this gas.*

- *To obtain the desired microstructure, researchers sequentially impregnated an alumina support with aqueous solutions of platinum and rhodium chlorides. Then they applied a series of thermal treatments to convert the metal chlorides into active bimetallic nanoparticles.*

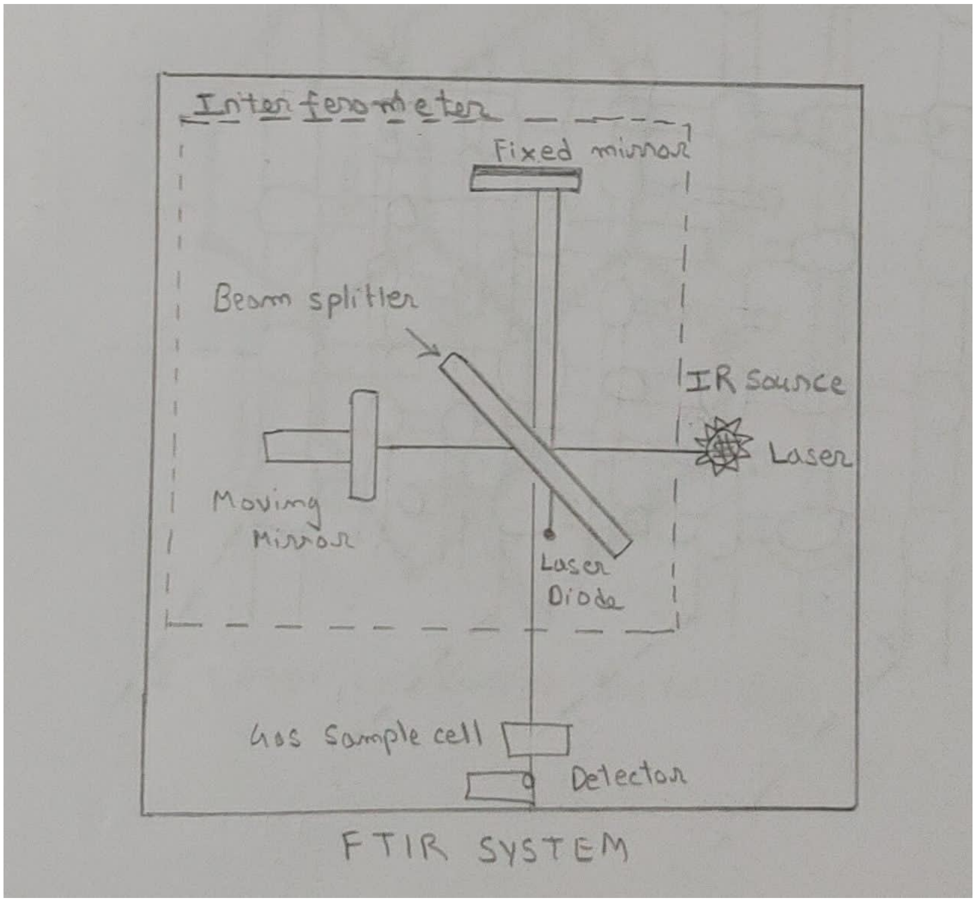
- *This procedure was chosen so that the desired microstructure would be achieved under reaction conditions*

- *In-situ Fourier transform infrared (FTIR) spectroscopy technique used to monitor the reaction.*

- *Lets first see what is FTIR spectroscopy*

Fourier transform infrared (FTIR) spectroscopy

- *FTIR method is used to obtain the infrared spectrum of transmission or absorption of a fuel sample. FTIR identifies the presence of organic and inorganic compounds in the sample.*
- *Depending on the infrared absorption frequency range 600–4000 cm^{-1}, the specific molecular groups prevailing in the sample will be determined through spectrum data in the automated software of spectroscopy.*
- *Here, this technique is only used to determine which substance should be added in what quantities for a perfect nanostructure.*



- *It revealed that the N-O chemical bond in a catalyst containing 5-percent rhodium was broken as soon as the molecule made contact with the nanoparticle. In a catalyst of 10-percent rhodium, however, the NO molecules tended to adhere to clusters of rhodium atoms present on the surface, which could potentially inhibit the desired reaction.*

- *At the end of experiment, two substances, Rhodium and Cobalt came out to be effective.*

- *Though Rhodium (5% only) gave a much higher activity and produced better results, but Cobalt (also about 5%) is* *more practical to use because it is about 10 times cheaper than rhodium, so large quantities could be used, the researchers said.*

INFERENCE

- From our project whose title is, "Nanoparticles application in Air and Environment Purification", we understood the relation and working of different chemical substance and the process in which they are implemented for different purification purposes. Different materials like gold, manganese, cobalt, rhodium etc. and their related compounds were covered in this project and their real-life significance was examined.

- One such application which drew out attention was the implementation of big air purifiers installed in AIIMS Delhi to purify nearby air and regulate the PM levels; keeping the patients safe.

- Not only just AIIMS, the other five in Delhi where the systems are installed are Sarai Kale Khan, Anand Vihar, Kashmere Gate, ITO and IIT Delhi.

- This system has been designed by the National Environmental Engineering Research Institute (NEERI) along with the Indian Institute of Technology Bombay (IIT-B).

- The purpose of this system is to tackle carbon monoxide, nitrogen oxide and hydrocarbons. The system has potential to reduce carbon monoxide and particulate emission by 40 per cent to 60 per cent in 20 to 30 meter radius during peak hours of traffic.