Development of novel carbon based CO2 adsorbent nanocomposites for industrial applications

Project Objectives:

1) ***Broad Objectives***:

The growing needs of fossil fuel energy pose a great challenge in the control of CO_2 emissions in our atmosphere. The increasing atmospheric CO_2 concentration, mainly caused by fossil fuel combustion, has led to concerns about global warming. Most of the emissions of CO_2 to the atmosphere from the electricity generation and industrial sectors are currently in the form of flue gas from combustion.

As a result, innovations like carbon capture technology would allow us to maintain optimum CO_2 level. Among all the means to reduce its global emission, the geological sequestration and storage options of CO_2 are both environmentally and economically beneficial and thus have attracted worldwide attention among researchers. Currently, the most common method for carbon dioxide capture is gas absorption, being monoethanolamine (MEA) the most used solvent. Large scale removal of CO_2 from flue gas, synthesis gas and other industrial gases is commonly accomplished using amine-based absorption, which suffers from inherent regeneration cost and inefficiency. Amine-based absorption technology has been established for over 60 years in the chemical and oil industries, for removal of hydrogen sulphide and other acid gases from gas streams. However, the main concerns with MEA and other amine solvents are corrosion in the presence of O_2 and other impurities, high solvent degradation rates because of its reaction with SO_X and NO_2 and the large amounts of energy required for regeneration.

As an alternative method for CO_2 capture, adsorption can be considered to be one of the more promising methods, offering potential energy savings compared to absorbent systems, especially with respect to compression costs. Adsorption is considered to be competitive and viable method for CO_2 removal in comparison to other technologies. In addition to low cost, ideally an adsorption medium for CO_2 removal and recovery at ambient temperature and high pressure should combine (i) high CO_2

uptake, (ii) complete regeneration under mild condition, (iii) high thermal stability and (iv) favorable adsorption–desorption kinetics. Current research activity on CO_2 adsorption processes focused on oxides and mixed oxides, high surface area porous materials such as zeolites, carbon, metal-organic frame works (MOFs) etc. In terms of achieving high adsorption capacities, activated carbons (ACs) and zeolite-based molecular sieves have shown much promise. ACs generally give higher additional capacity at pressures greater than atmospheric compared to zeolites. Activated carbons have been widely used as carbon dioxide adsorbents due to their high surface area, which confers them high adsorption capacity. However, this high capacity of adsorption is limited at room temperatures.

Some metals (like zero valent iron) have been reported for the reduction of CO_2. Metal based complexes can be good adsorbent for CO_2 adsorption due to the affinity of metals towards polarized CO_2 molecules. Metal oxides are important heterogeneous catalysts and interaction of CO_2 with oxide surfaces is of great interest. There have been spectroscopy studies of CO_2 adsorption on hydroxylated metal oxide surfaces, including iron oxide and oxide-supported metal catalysts. The formation of adsorbed carbonates, bicarbonates and carboxylates, as well as bent CO_2 species, has been observed in some of the metal oxides (Fe_2O_3, Al_2O_3). But metal and metal oxides nanoparticles have greater tendency to agglomerate and therefore reduction in the performance.

Multi walled carbon nanotubes (MWNTs) due to their high surface area, high porosity and good mechanical strength can be used as gas adsorbent. These MWNTs provide suitable platform for the decoration of metal/metal oxide nanoparticles and avoid their agglomeration. Recently, graphene, the first two-dimensional atomic crystal, emerges as a conceptually new class of carbon material. Graphene, the newest form of carbon, is catching attention of material scientist due to its unusual and attractive properties. Metal/metal oxide nanoparticles decorated MWNTs/graphene nanocomposites utilize the physical adsorption of CO_2 in the pores and chemical bonding of CO_2 molecules with metal/metal oxide nanoparticles. Hence it is anticipated that more CO_2 adsorption can be achieved by these nanocomposites. These metal/metal oxide nanoparticles decorated MWNTs/graphene based nanocomposites can be used as CO_2 adsorbent at high pressures, especially for the storage of CO_2 coming out from thermal power plants and cement industries by compressing the exhaust with some means. The desorption of adsorbed CO_2 from metal/metal oxide nanoparticles decorated MWNTs/graphene based nanocomposites will be achieved by giving suitable thermal energy and can be tested under ambient conditions so that the desorbed CO_2 can be used for other purposes like food packaging, preparation of carbonated soft drinks and fire extinguishers.

The specific objectives are

1. *Synthesis of metal/metal oxide nanoparticles decorated carbon nanotubes/graphene nanocomposites by different techniques for the selective dispersion of metal/metal oxide nanoparticles on carbon nanotubes/graphene*
2. *Characterization of metal/metal oxide nanoparticles decorated carbon nanotubes/graphene nanocomposites*
3. *Investigation of CO_2 adsorption capacity in metal/metal oxide nanoparticles decorated carbon nanotubes/graphene nanocomposites at different pressures and temperatures*
4. *Investigation of CO_2 desorption capacity in these carbon based nanocomposite materials*
5. *Exploring the production of the appropriate material in sufficient quantities viability for commercial applications.*

Impact of the work programme

The rising concentration of CO_2 in the atmosphere is linked with global climate change. Since the time of the industrial revolution, the atmospheric CO_2 concentration has risen by about 35% to a value of 380 ppm and it is projected to continue to rise if anthropogenic sources remain unchecked. Fossil-fuel-burning power plants are the single-largest anthropogenic emission sources globally, accounting for approximately one-third of CO_2 emissions. Of the fossil-fuel plants, for a fixed amount of fuel feed, coal-fired plants emit significantly more CO_2 than natural gas plants. In addition cement industries also contributes for increasing concentration of CO_2 in our environment. Thus by finding the appropriate CO_2 adsorbent, we can reduce the increasing problem of global warming.

The present project proposal therefore is aimed at developing an efficient, cost effective carbon dioxide adsorbent media using different carbon nanostructures (carbon nanotubes and graphene) and metal/metal oxide nanoparticles. It also includes the large scale production of CO_2 adsorbent for their direct use in industrial exhaust.

Milestones to be achieved during project duration:

1. *Establishing reproducible CO_2 adsorption capacity in carbon based nanocomposite materials.*
2. *Investigation of CO_2 desorption capacity in carbon based nanocomposite materials*
3. *Exploring the production of the appropriate material in sufficient quantities viability for commercial applications.*

National Status of work done on similar area/topic

There are fewer groups in India who are examining the different methods of CO_2 adsorption. The important groups are NEERI, IIT Bombay and IIT Kharagpur.

International Status of work done on similar area/topic

The Kyoto Protocol is a protocol to the United Nations Framework Convention on Climate Change (UNFCCC or FCCC), aimed at fighting global warming. The Protocol was initially adopted on 11 December 1997 in Kyoto, Japan and entered into force on 16 February 2005. Under the Protocol, 37 industrialized countries commit themselves to a reduction of four greenhouse gases (GHG) (carbon dioxide, methane, nitrous oxide, sulphur hexafluoride) and two groups of gases (hydrofluorocarbons and perfluorocarbons) produced by them, and all member countries give general commitments. As the result of this protocol, different countries started research and development programme for carbon capture and storage. Last year at the summit on carbon capture in Copenhagen, different countries have decided to control the CO_2 emission. Some of the major institutes involved in the present work are Georgia Institute of Technology-Atlanta, Facult´e Polytechnique de Mons-Belgium, University of California-Los Angeles, Graduate School of the Chinese Academy of Sciences-Changchun etc. Till now none of the research has come to up to the level of the commercial requirement to cut the CO_2 emission in environment.

Project Duration: Two years

Budget: 27 lakhs

Salary (1 JRF) (Rs. 4 lakhs)

Consumables (2.5 + 2.5 = 5 lakhs)

Contingencies (1 + 1 = 2 lakhs)

Equipment (Sievert's facility with Turbo molecular pumping system; furnaces; pressure transducers; vacuum oven) :- 16 lakhs

Name & Designation of Principal Investigator:

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