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Porous Nanomaterials for Energy, Environment and Biomedical Applications

Asim Bhaumik*

Department of Materials Science, Indian Association for the Cultivation of Science, India

***Corresponding author:** Asim Bhaumik, Senior Professor, Department of Materials Science, Indian Association for the Cultivation of Science, India, Tel: 91-3324734971; E-mail: msab@iacs.res.in

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Introduction

In this editorial, I would like to summarize the recent developments in one of the major areas of materials science and nanomaterials that is very important to readers of this journal and relevant scientific community. Design and synthesis of novel microporous and mesoporous materials [1] are of particular interest to materials science community round the globe due to their unique surface, structural, and chemical properties compared to their nonporous counterpart. These porous nanomaterials can be synthesized by using inorganic, organic or organic-inorganic hybrid framework building units/metal ions with or without using template molecules as structure directing agents. Typically these porous nanostructures have pore dimension roughly in the range 0.4-100 nm. Historically the field has been developed from synthetic Al-rich zeolites, followed by high silica zeolites and then metallosilicates [2,3], followed by aluminophosphates [4] mesoporous silica and related wide range of mesoporous materials with a large variation of framework compositions [5,6]. Development of periodic mesoporous organosilicas (PMOs) [7], mesoporous carbons [8], metal organic frameworks (MOFs) [9], zeolitic imidazolate frameworks (ZIFs) [10], porous organic polymers (POPs) [11] and covalent organic frameworks (COFs) [12] have added further dimensions to the family of porous nanomaterials. All these materials, especially those having periodicity of pores showed high potentials for fabricating versatile nanostructures: their pore topologies, sizes and surfaces can be tuned according to the respective requirements.

Another member in this category of porous nanomaterials is porous metal phosphates/phosphonates [13]. General mechanism for the synthesis of mesoporous inorganic materials, in which interactions are exerted between the inorganic species and individual organic molecules of the surfactant/template in a cooperative nucleation process, can be applied for the synthesis of mesoporous metal phosphates/phosphonates. Today these metal phosphates/ phosphonates can act as active solid catalysts for various acid-base catalysis, redox catalysis and photocatalytic processes.

Today these materials are intensively studied in several application areas of energy, environment and biomedical research. This includes metal ion adsorption, ion-exchange, sensor, gas storage (H_2, CO_2, CH_4), eco-friendly catalysis (liquid and gas phase), energy storage, optoelectronics, drug delivery [14] so on and so forth. With the depletion of fossil fuel based petroleum sources, succeeding changes in the economic system of the world and also the environmental pollution associated with the increase in greenhouse gases due to the burning of petroleum diesel and fossil fuels have prompted the researchers to explore the biofuels as a renewable energy resource. Due to their exceptional surface area and possibility of designing several solid acids based on these porous nanomaterials they are often extensively employed as heterogeneous catalyst for biodiesel production. Typically these materials have huge potential to be explored as catalyst for the conversion of biomass to biofuels, which could contribute significantly for the sustainable supply of energy in future [15].

Due to advancement of human civilization, activities like deforestation, burning of fossil fuel and waste, industrial plants have polluted the air by emitting large amount of CO_2, affecting the natural eco-balance in the atmosphere. Large concentration of CO_2 is causing the greenhouse effect, responsible for global warming. Hence, storage of CO_2 by means of physical adsorption can be an effective method to reduce the pollution. Physisorption at these porous material surfaces is very lucrative and promising due to their high surface area/porous texture, and N-rich basic framework sites, which can offer stronger dipolar interaction with CO_2 molecules [16]. In this context these MOFs, ZIFs, POPs, COFs, porous carbons, BCN graphene analogues etc. can contribute significantly through CO_2 capture and storage from flue gas mixtures under ambient conditions.

Another area which needs particular attention is the chemical fixation CO_2 to value added fine chemicals by using these porous nanomaterials as heterogeneous catalyst. Successful utilization of CO_2 as C1 source for various chemical reactions by using these catalysts is one of the frontline areas of materials science research today [17]. Synthesis of a wide range of commodity chemicals like methanol, formic acid, urea, esters, dimethyl carbonate, cyclic carbonates as well as carboxylation of alkynes and alkenes, formylation of amines etc. [18] can be successfully carried out using CO_2 as reagent over several metal supported porous nanomaterials or related organocatalysts and the research in this area is going to expand tremendously over the years to come.

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