High-Order Mesoporous Sensors for Visual Recognition of Emerging Pollutants

Anupreet Kaur

[1]Basic and Applied Sciences Department,

[2]Punjabi University-Patiala, PUNJAB-NDIA

Email: [1]anu_chem06@yahoo.co.in

Abstract. Recently, the developments of high-ordered mesoporous monoliths (HOM) open different methodological avenues for changes especially beneficial in the field of sensor applications. Growing public awareness on the potential risk to humans of toxic chemicals in the environment has generated demand for new and improved methods for toxicity assessment and removal, rational means for health risk estimation. Mesoporous materials are highly desirable materials that have a large surface area, high porosity with a highly ordered pore structure with uniform mesopores, hydrophilic character and relatively good chemical and mechanical stability was fabricated and during this study as toxic metal sensor. Manipulation of micro-sized mesoporous monoliths at the nanoscale level has enabled the development of optochemical nanosensors that exhibit high strength, as well as recognition and signaling of a broad range of chemical species. The advanced functionality of manipulating chromophore probes into nanomaterials as sensing receptors has received attention in the design of chemical sensor arrays for responsive recognition of several species such as metal cations, and charged and neutral organic molecules. As customary, its blossoming was enabled to generate novel families of fascinating reproducible sensors exhibiting a high selectivity, low time consuming, and low cost.

Keywords: Mesoporous, Sensor, HOM, Emerging Pollutants.

1. Introduction

Because of global demand for rapid industrialization, urbanization, domestic activities, agricultural activities, fuel burning and geological and environmental changes are becoming increasingly prevalent. The contamination of fresh water systems has attracted considerable concern as a major environmental threat worldwide and associated with key environmental problems being faced by humanity. Water and environmental pollution caused because of various organic, inorganic and biological pollutants has increasingly become serious issue in the present scenario, which leads to the deterioration of quality of water resources because of the various pollutants[1]-[3]. The development of nanoscale structures and their integration into components, system and natural architectures such as monoliths and large scale devices is one of the most promising areas in the emerging field of nanotechnology. Ordered mesoporus monoliths offers great promises in industrial and environmental applications because of their large surface area, uniform pore size and controllable pore geometries. Since the discovery of the first broad mesoporous family denoted by M41S, amphilic-water systems have been used as the structure–directing agents to fabricate mesoscopically ordered materials over a wide range of synthesis conditions.

The importance of monitoring and conditioning of extremely toxic metal ions as well as emerging pollutants in the environment are unquestionable. Hence, the attractive means of improving monitoring of pollutants concentrations would be the use of simple, inexpensive, rapid responsive and portable sensors. A Sensor is a device that measures or detects a physical parameter and converts it into a signal, which is subsequently read by an observer or by an instrument. Sensors have high sensitivity and selectivity; they also provide on-line and real-time analysis, which has revolutionized and field of chemical analysis, particularly in the critical care analysis of blood and serum samples. Sensors with faster response times and higher selectivity are desired to monitor ultrace levels of various pollutants. For these and many other reasons, sensors are being developed based on several energy-transduction principles. The selective optical sensing is attracting strong interest due to the use of "low tech" spectroscopic instrumentation to detect relevant chemical species in various environmental samples. The field of optical chemical sensors has been a growing research area over the last three decades. Optical chemical sensors employ optical transduction techniques to generate analyte information. Optical sensors are the most effective because of their accurate detection of pollutants at low concentrations without equitable control of experimental environments or the use of sophisticated equipment. Manipulation of micro-sized mesoporous monoliths at the nanoscale level has enabled the development of optochemical nanosensors that exhibit high strength, as well as recognition and signaling of a broad range of chemical species. The advanced functionality of manipulating chromophore probes into nanomaterials as sensing receptors has received attention in the design of chemical sensor arrays for responsive recognition of several species such as metal cations [4]-[6], and charged and neutral organic molecules.

Porous monoliths architectures provide a very robust, open and tunable periodic scaffolds on the nanometer scale[7]. Nanometer-sized materials with engineered features including shape, size, composition and function play a leading role for their emerging applications in diverse areas[8]. In this review, we have discuses the highly ordered monoliths as sensors for various emerging pollutants from various environmental samples.

2. Review

Industry and municipalities use more than about 10% of the globally accessible runoff and generate a stream of wastewater, which flows or seeps into rivers, lakes, groundwater, or the coastal seas. These wastewater contain numerous chemical compounds in varying concentrations. In addition, a common problem in many industries is disposal of large volumes of waste water containing major classes of these organic compounds, which are mutagenic and carcinogenic, with high toxicological potentials. Water pollution with thousands of industrial and natural chemical compounds is one of the key environmental problems facing humanity and industrial today. Therefore, the development of a simple, fast technology for removal of, separation, and determination of organic contaminants in aquatic life is crucial issue.

Sol-gel is the most commonly used technology for the synthesis of various optical and electrochemical sensors for various pollutants. Sol-gel offers almost limitless possibilities for sensing substrates due to variety of physical properties that can be obtained by altering a number fabrication conditions and techniques. Sol-gel are extremely inert and compatible with numerous chemical agents, making their use as sensor matrix supports desirable. Highly ordered monoliths had been synthesized by sol-gel technology and the functionalized mesoporous molecular sieves of hexagonally highly packed channels such as MCM-41, HMS and SBS-15 materials were thus shown to be promising as new developing interest in nanostructured adsorbents for wastewater treatment. Functionalized mesoporous materials by grafting organosilane groups or cyclodextrin molecule exhibited various surface natures and organic molecule from the wastewater. These mesoporous materials were also used for the adsorption of organic dyes, organic compounds and also other pollutants. Monoliths for sensing of emerging pollutants were summarized in Table1.

Table 1: Monoliths for visual sensing of emerging pollutants.

Highly ordered Monoliths sensors	Target analyte	Matrices	Reference

Silicate monoliths and aluminosilicate Monoliths	Aniline	Waste water	9
Silicate monoliths	Cr(VI)	Waste water	10
Fm3m monoliths	Cd(II)	Environmental samples	11
Mesoporous cubic la3d aluminosilica monoliths	Cu(II), Cd(II), Hg(II)	Waste water as well as environmental samples	12
Mesoporous cubic la3d aluminosilica monoliths	Cd(II)	Waste water	13
Aluminosilica monoliths	Pd(II), Cu(II)	Waste water	14
N,N-bis(salicylidene)1,2-bis(2-aminophenylthio)ethane-silica monoliths	Pd(II)	Various waste water	15
2-nitroso-1-naphthol, Bis[N,N-bis(carboxymethyl)aminomethyl] flurorecein	Co(II)	Lithium batteries discharge wastage materials	16
MCM-41 and Cubic Fd3m monoliths	Cu(II)	Waste water samples	17
Mesoporous silica/metal oxide nanocomposites	Volatile organic compound	Air samples	18

3. Conclusion

Over the years, pollutants have been recognized to have serous effects on human health and the environment. This recognition has led to numerous studies that deal with the properties of various forms of emerging pollutants. Conventional technologies for the treatment of pollutants include precipitation, coagulation, reduction, membrane separation, ion exchange, and adsorption. Among these technologies, adsorption has been widely studied because it is easy to operate and cost-effective. The field of optical chemical sensors has been a growing research area over the last three decades. The key components in this sensing method are optical sensors that efficiently detect pollutants in terms of sensitivity and selectivity with real-time monitoring. Nanosensor design techniques are introduced as the best process and treatment practice that can be identified and evaluated for detecting trace amounts of pollutants. The key to designing optical nanosensors is the ability to immobilize chromophore probes with different functional characteristics, such as density, accessibility, and intrinsic mobility, onto the pore surfaces of these 3D mesoporous cage monoliths, which indicates an easy and reliable synthesis design.

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