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Gamma ray effects on optical properties of CoS nanoparticles

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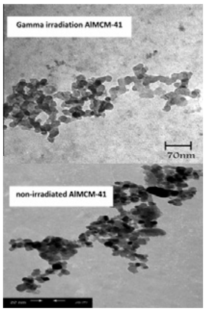
HIGHLIGHTS

- In the present investigation the AlMCM-41 was used as the host material, and CoS was selected as the guest molecule.
- The TEM images show average size of CoS NPs before and after neutron radiation about 20 and 70 nm, respectively.
- The results indicate host materials have important role in decrease of radiation defects (RDs).

GRAPHICAL ABSTRACT



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ABSTRACT

In this work, cobalt sulfide nanoparticles powder was synthesized in AlMCM-41 molecular sieve by using ion exchange method. The influence of gamma ray-radiation on the structural and optical properties of CoS/AlMCM-41 nanoparticles has been studied. Sample was irradiated by ^{60}Co and ^{137}Cs gamma ray source. The sample was characterized by X-ray diffraction (XRD), UV–Vis spectroscopy, scanning electron microscopy (SEM), FT-IR techniques and transmission electron microscopy (TEM). The XRD patterns show that nanoparticles size is increased after gamma radiation. The DRS results show that Co^{2+} ions produced after gamma radiation, located in tetrahedral sites in AlMCM-41. The results indicate host materials have important role in decrease of radiation defects (RDs). The gamma ray creates free radicals and forms new bonds in CoSAlMCM-41 sample.

Introduction

The discovery of highly ordered mesoporous materials has drawn considerable attention due to their structural characteristics such as uniform pore-size distribution, highly specific surface area, and pore volume. These materials are important for potential application in the field of large organic molecule adsorptions and catalytic transformations of bulky molecules [1,2]. The most extensively studied member of the mesoporous materials family has been MCM-41, which exhibits a hexagonal array of one-dimensional mesopores. These mesopores can be turned from 2 to 10 nm by choosing suitable structure-directing agents and synthesis conditions [2].

Pure siliceous materials have electrically neutral frameworks and consequently no Brønsted acidity, which limits the use of these materials as catalysts. Incorporation of trivalent atoms such as Al into the walls of MCM-41 creates Brønsted acid sites and allows the preparation of materials with different acid strengths which possess different catalytic and adsorptive properties [3–6]. However, incorporation of aluminum into the structure of MCM-41 materials via isomorphous substitution of aluminum for silicon, generate ion exchange sites in this mesoporous molecular sieves [7]. Therefore, cationic metals such as Co^{2+} can be incorporated into AlMCM-41 by ion exchange method [8,9]. Because of their high surface areas, regular pore channels, and large pore diameters (2–20 nm), ordered mesoporous materials, such as SBA-15 and

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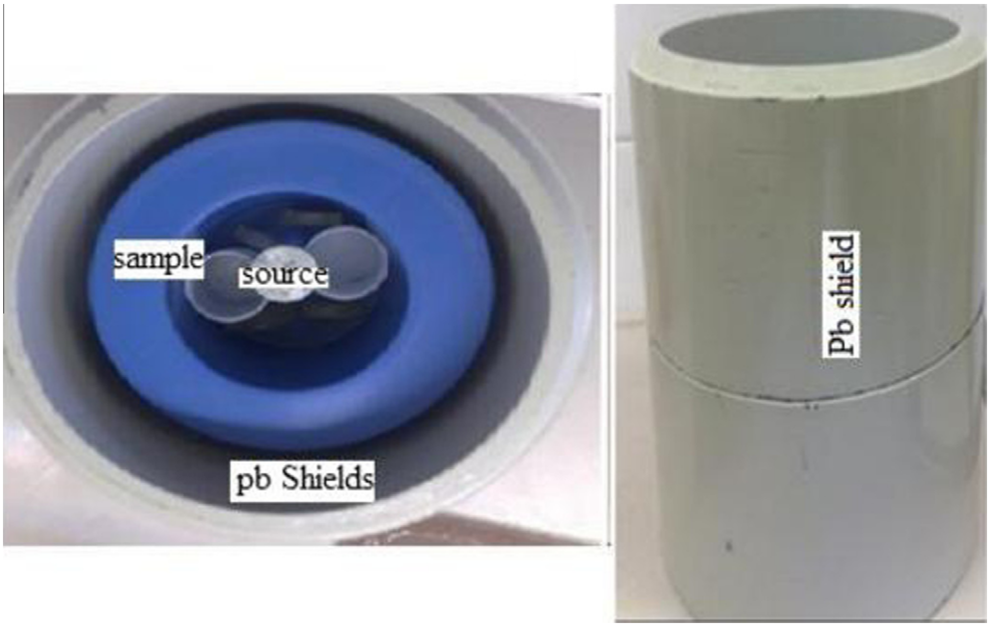

Fig. 1. Photograph of experimental setup.

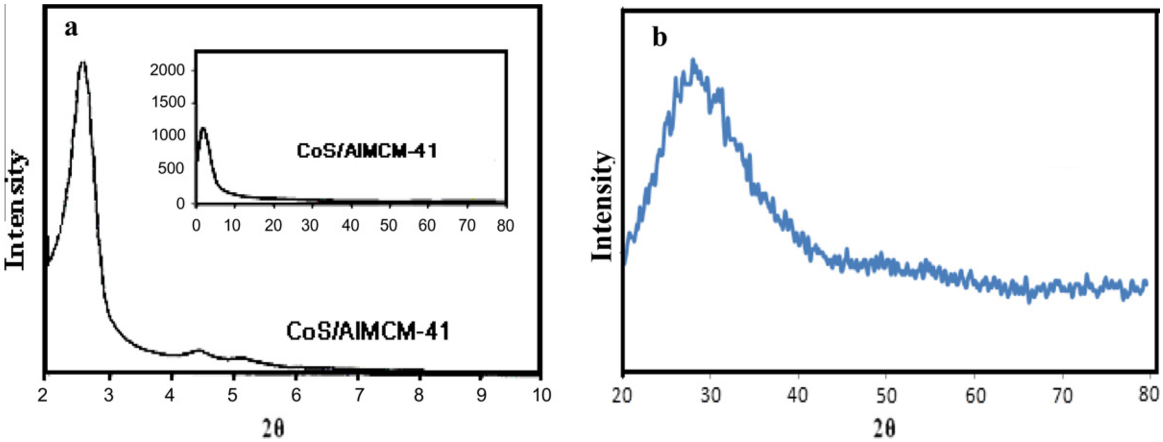

Fig. 2. X-ray diffraction patterns of: (a) non-irradiated and (b) gamma irradiated samples.

MCM-41, have been used as suitable scaffolds for the dispersion of semiconductor nanoparticles [10].

Permanent damage from irradiation to semiconductors is caused (either directly or indirectly) by collisions of the incident particles with the atoms in the crystal lattice. Atoms that are displaced from their original positions under irradiation are referred to as primary knock-on atoms (PKA). Depending on the absorbed energy, the PKA can generate a displacement cascade, which dissipates the initial energy to form a stable structure of defects. These defects degrade the transport properties of the charge carriers, particularly the minority carrier lifetime [11]. A number of articles have been published on investigating radiation defects (RDs) in semiconductors. In particular, the influence of different types of radiation including electrons, ions and neutrons on semiconductor properties were studied [12,13]. It was shown that irradiation with electrons of $E < 5$ MeV energy at room temperature gives rise to the formation of simple RDs in semiconductor. But the irradiation with gamma rays, protons and higher energy electrons produce more complex RDs. The RDs essentially influence electrical, optical and structural properties of the devices manufactured on its base.

The aim of this work is study of optical properties CoS semiconductor in AlMCM-41 host material under the influence of gamma radiation. The study was carried out in room temperature. CoS/AlMCM-41 nanocomposite was prepared by ion exchange method. To investigate gamma effects in CoSAlMCM-41 nano-composite, we described below some results that obtained from high-tech instruments such as XRD (X-ray diffraction), SEM (scanning electron microscopy), transmission electron microscopy (TEM), UV–Vis spectroscopy and FT-IR (Fourier transform infrared) for irradiated and non-irradiated samples.

Experimental procedure

Synthesis of AlMCM-41 material

The MCM-41 and AlMCM-41 materials were synthesized by a room temperature method with some modification in the described procedure in the literature [13].We used tetraethylorthosilicate (TEOS; Merck, 800658) as a source of silicon and hexadecyltrimethylammonium bromide (HDTMABr; BDH, 103912) as a surfactant template preparation of the mesoporous material. The molar composition of the reactant mixture is as follows: