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Development of electrochemical sensor based on layered double hydroxide as a marker of environmental toxin

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ABSTRACT

Zinc/vanadium layered double hydroxide (LDH) was prepared and its functional relationships with thiourea were investigated in order to develop a sensor for the recognition of this toxin. Sensor technology is one of the major recognition methods and has shown potential applications in environmental monitoring, but issues of sensitivity, selectivity, and high cost related to this technology still need to be resolved in order to allow their more extensive use. Our study therefore focused on the development of a low-cost selective and sensitive thiourea sensor. This was developed using LDH where its sensing potential was investigated by a simple *I–V* technique. The developed sensor exhibited high sensitivity (1.004 μA μM cm^{-2}), lower limit of detection (8.4 μM) and wide range of linear dynamics (10–500 μM). The selectivity was studied using different interfering agents and it was found that the developed sensor is more selective toward thiourea. The sensor behavior was further optimized using buffers of different pH.

Introduction

Toxic chemicals and biochemicals have gained much importance due to their lethal effect on human health and living organisms [1–3]. Industrial activity contributes significantly to the accumulation of toxic compounds by releasing them into the environment. Thus there is an urgent need to maintain a continuous check on health damaging pollutants in water and the environment. Therefore the discovery and detoxification of hazardous chemicals are essential for the safety of living organisms, as well as required for industrial purposes [4–6].

Different tools and methods have been applied to search for toxic organic pollutants, but none of these has been fully satisfactory on the basis of its performance and high cost [7–12]. Nowadays sensor technology has a major role in keeping the environment and water safe and usable for living organisms. Thus to maintain a safe ecosystem on the planet, it is necessary to develop easy, trustworthy, and low-cost sensors to identify lethal chemicals in water. Various chromatographic and spectroscopic techniques have lost favor because of complications and sluggishness in their application for hazardous chemicals. Electrochemical sensors have displayed excellent properties such as rapid operation, response and recognition, thus playing an important role in revealing unsafe compounds [13,14]. The size, structure and properties of electrode materials control the sensitivity and selectivity of electrochemical sensors [15,16].

Nanomaterials have unique and varied applications as regards human health and the environment [17–20]. They have received considerable attention due to their exceptional properties, distinctive performance and extensive range of applications in various fields, especially in human health and environmental applications [21–24]. These widespread applications are basically made possible by the meticulous shape and high surface area of the nanomaterials. LDH is an anionic clay with the general formula $[M(II)1-xM(III)x(OH)_2]x+Az-x/z{\cdot}nH_2O$. It contains cationic layers and anions inside hydrotalcite-like layers, which is why LDH is called a two-dimensional layered nanostructure. The anions inside LDH layers are exchangeable and can be replaced by other anionic molecules. LDH has been widely used as a carrier and in catalysis, drug delivery, sunscreen materials, etc. [25–28].

In this investigation, LDH based on vanadium and zinc was prepared and structurally characterized by XRD and FTIR. It was

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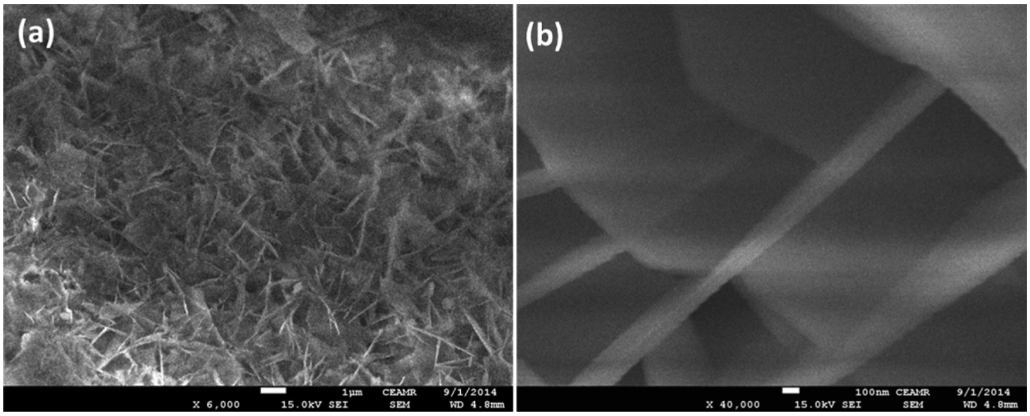


Fig. 1. FESEM images at (a) low magnification and (b) high magnification for LDH.

studied for its sensing potential and the sensor behavior was further optimized by using various interfering agents and buffers of different pH. The developed cheap and sensitive sensor explored the applicability of LDH as a toxin marker for applications in the area of water resources and health monitoring.

Experimental

Synthesis of LDH

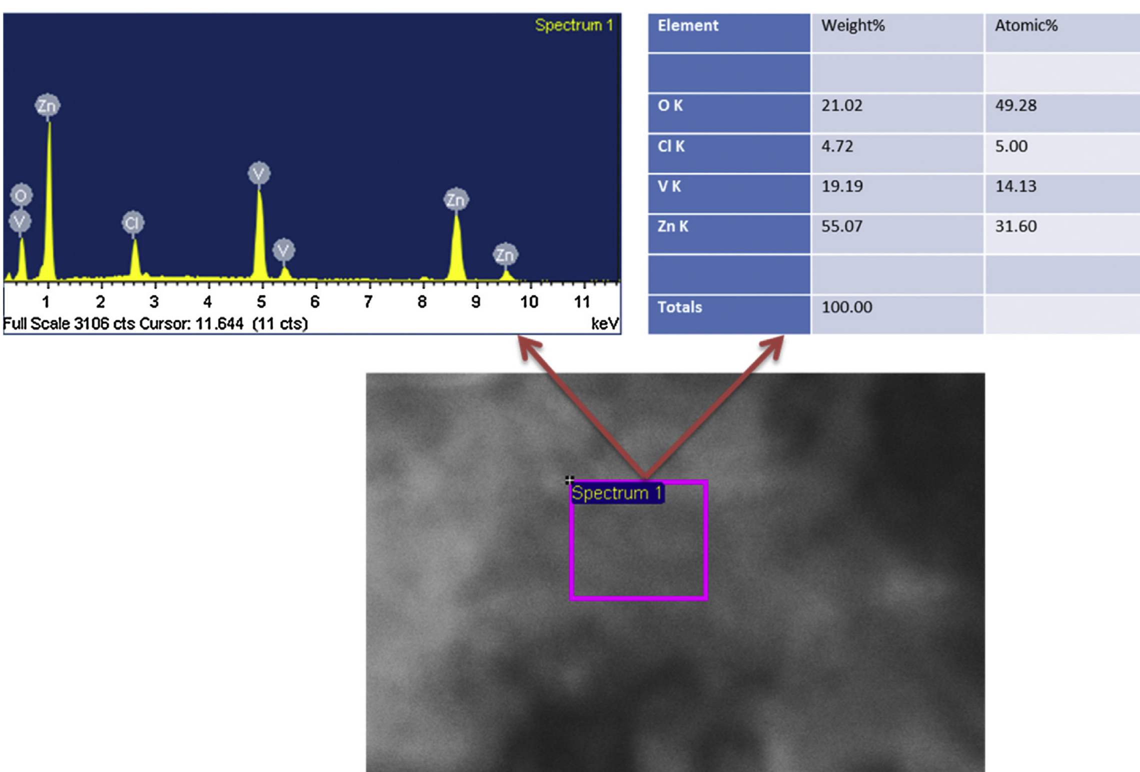
$ZnCl_2$ and VCl_3 (3:1 molar ratio) solutions were prepared by dissolving metal salts in water with constant stirring for about 30 min at room temperature. NaOH solution was then added to the metal salts solutions to adjust the pH (9.0) of the solution and stirred overnight at room temperature. The solution was processed through a centrifuge to clean it and dried in an oven at 60 °C. The product was ground and used for characterization and sensing applications [25].

Characterization

The morphology of LDH was analyzed by field emission scanning electron microscope (JSM-7600F, JEOL, Japan). The compositional analysis was studied by energy dispersive spectroscopy (EDS). The structure of LDH was examined by XRD using ARL Service XRD and FT-IR spectrometer. Keithley electrometer was used for the toxin detection.

Fabrication of sensor

The sensor was fabricated by surface modification of silver electrode (AgE). The silver electrode was first polished with alumina slurry (0.05 μm), rinsed thoroughly with deionized water and then ultrasonicated with a 1:1 mixture of deionized water and ethanol, followed by sonication with deionized water and air drying of the electrodes. 10.0 mg of LDH was added to 10.0 μL of 0.01% nafion (3:1 w/v ratio) and dispersed well. The dispersed



Element	Weight%	Atomic%
O K	21.02	49.28
Cl K	4.72	5.00
V K	19.19	14.13
Zn K	55.07	31.60
Totals	100.00	

Fig. 2. EDS analysis of LDH.