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Article

Fabrication of a Greener TiO_2@Gum Arabic-Carbon Paste Electrode for the Electrochemical Detection of Pb^{2+} Ions in Plastic Toys

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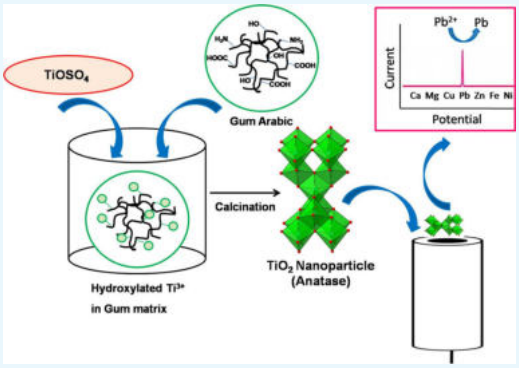
ABSTRACT: A novel greener methodology is reported for the synthesis of titanium dioxide (TiO_2) nanoparticles (NPs) using gum Arabic (*Acacia senegal*) and the characterization of the ensuing TiO_2 NPs by various techniques such as X-ray diffraction (XRD), Fourier transform infrared, Raman spectroscopy, scanning electron microscopy−energy dispersive X-ray, transmission electron microscopy (TEM), high resolution-TEM, and UV−visible spectroscopy. The XRD analysis confirmed the formation of TiO_2 NPs in the anatase phase with high crystal purity, while TEM confirmed the size to be 8.9 ± 1.5 nm with a spherical morphology. The electrode for the electrochemical detection of Pb^{2+} ions was modified by a carbon paste fabricated using the synthesized TiO_2 NPs. Compared to the bare electrode, the fabricated electrode exhibited improved electro−catalytic activity toward the reduction of Pb^{2+} ions. The detection limit, quantification limit, and the sensitivity of the developed electrode were observed by using differential pulse voltammetry to be 506 ppb, 1.68 ppm, and 0.52 ± 0.01 $\mu A\ \mu M^{-1}$, respectively. The constructed electrode was tested for the detection of lead content in plastic toys.



1. INTRODUCTION

Designing materials in nanoscale dimensions has attracted intense scientific interest because of their exponential potential in almost all fields of science. There are several chemical and physical methods currently employed for the synthesis of metal and metal oxide nanoparticles.[1−3] However, most of these methods are quite expensive, labor-intensive, involve high pressure and high energy requirements, and are potentially harmful to the environment and living organisms because of the release of toxic and hazardous chemicals.[4] Hence, there is considerable interest in developing alternative biosynthetic, inexpensive, environmentally friendly, and sustainable methods for the synthesis of nanoparticles for an ever-increasing number of applications.[5−12]

Diverse applications of TiO_2 have been documented mainly in the fields of photovoltaics, photocatalysis, and sensors.[5−9] TiO_2 nanoparticles (TiO_2 NPs) are widely used in the fabrication of gas sensors, which can detect various different gases including oxidative gases (O_2, NO_2) and reductive gases (H_2, CO, NH_3, H_2S, VOCs), organophosphorus, toxic organic solvents, and amperometric biosensors.[10−14] Heavy metal pollution is one of the most serious problems in the world and poses major threats to the health and well-being of millions of people and global ecosystems because of their dramatic increase from both anthropogenic and natural sources. Heavy metals such as lead (Pb) are hazardous pollutants because they affect human health even at very low concentrations and induce high toxicity and considerable carcinogenicity.[15] Pb is a cumulative poison that adversely affects infants, children up to 6 years of age, the fetus, and pregnant women.[16] Adults absorb about 10% of the Pb contained in food, whereas children absorb 4−5 times as much, and the gastrointestinal absorption of lead from ingested soil and dust by children has been calculated as high as 30%.[17] Low-level lead intoxication often leads to significant changes in behavior and mental development in young children.[18] Hence, it is important to detect and avoid exposure to Pb in our daily life as its presence is very common in our surroundings, being widely used for the production of lead storage batteries, solder, alloys, cable sheathing, pigments, rust inhibitors, ammunition, and glazes plastic stabilizers, among others.[19] Tetraethyl and tetramethyl lead were extensively used as an antiknocking agent in petrol, but their use has now been completely phased out in most of the developed world,[19] but lead salts are still used as pigments to impart bright colors to toys to attract

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