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Short communication

Surfactant assisted sonochemical synthesis of hollow structured zinc phosphate nanoparticles and their application as nanocarrier

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HIGHLIGHTS

- Novel hollow zinc phosphate nanospheres were fabricated without template.
- The formation mechanism for the hollow nanospheres was studied.
- Synthesized hollow nanospheres thermally stable and having large surface area.
- The hollow nanospheres exhibited excellent loading capacity for imidazole.

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ABSTRACT

This work reports, the facile surfactant assisted sonochemical route for the synthesis of hollow zinc phosphate nanoparticles. The prepared material was analyzed by Fourier transform infrared, X-ray diffraction, Brunauer–Emmett–Teller nitrogen adsorption/desorption isotherms, field emission scanning electron microscopy, transmission electron microscopy and thermo gravimetric analysis confirm the successive formation of well-organized hollow spherical structure of zinc phosphate. The diameter and the shell thickness of the hollow particles are typically in the range of 20–40 nm and 5–7 nm respectively. The specific surface area and the total pore volume of the synthesized hollow zinc phosphate nanoparticles were found to be 100.15 m^2/g and 0.1384 cm^3/g respectively. A possible growth mechanism for the formation of hollow zinc phosphate nanospherical structures has been proposed, which is considered to be a sonochemically induced a surfactant vesicle-template formation. The prepared hollow zinc phosphate nanoparticles exhibits a sustained release behavior about 76.5 wt.% and 5.7 wt.% of the total loaded imidazole into the solution after 50 h at pH 6 and 10 respectively. The imidazole loaded hollow zinc phosphate nanoparticles can be potentially applied as a corrosion inhibitor in paint formulation.

1. Introduction

The hollow inorganic nanoparticles have unique physical and chemical properties such as low density, high specific surface area, better permeability and encapsulation of guest molecules [1–3]. Due to that, this morphology have received a great attention in recent years due to their wide variety of applications, which include the delivery and controlled release of drugs, dyes or inks; as catalysts and catalyst supports; as photonic materials; encapsulation and protection of biological macromolecules and fillers for composites [4,5]. There are various methods available for the preparation of inorganic materials with hollow spherical structure, such as hydrothermal technology [6]; emulsion droplets/micelles phase separation procedure [7]; kinetically controlled template-free synthesis method [8]; and sacrificial core technique [9].

Zinc phosphate (ZP), is a non-toxic and one of the most important multifunctional metal phosphate for its interesting properties and wide applications in various fields. ZP is widely used as anticorrosive pigment because it can provide the physical barrier; can block both, anodic and cathodic corrosion reactions on metal; can inhibit anodic acidification reaction; and phosphatize the metal substrate and form complexes with the binder [10–13]. The drying property and adhesion of paint film to the metal substrate can be improved in the presence of ZP [14]. ZP is well known to have a high affinity for living organisms and is therefore expected to be useful as white pigments in cosmetics [15]. Due to its low solubility in water/biological environment and biocompatibility, ZP is widely used as dental cement [16,17]. ZP has excellent catalytic properties in hydrocarbon conversion process, such as dehydration/dehydrogenation of sec-butanol and

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methanol conversion [17,18]. ZP is also one kind of commonly used luminescent host material, ZP doped or co-doped with rare earth metal such as Eu^{3+}, Tb^{3+} and Tm^{3+} shows excellent luminescent properties [19].

To the best of our knowledge, the preparation of hollow zinc phosphate nanoparticles (HZPn) via sonochemical method has not yet been reported. In the present work, we have combined the action of ultrasonic radiation with surfactant to synthesize HZPn. These nanoparticles were investigated for maximum loading and release behavior of imidazole.

2. Materials and methods

2.1. Chemicals

Zinc nitrate hexahydrate ($Zn(NO_3)_2\ 6H_2O$) and Diammonium hydrogen phosphate ($(NH_4)_2HPO_4$) precursor were purchased from S. D. Fine Chemicals Ltd., Mumbai, India. Sodium lauryl sulfate (SDS) was obtained from SD Fine Chemicals Ltd. Mumbai. Ammonia solution 25% was obtained from S. D. Fine Chemicals Ltd., Mumbai, India. Absolute ethanol was obtained from Changshu Yangyuan Chemicals, China. Distilled water prepared using Millipore apparatus was used during all the experimental runs.

2.2. Method of preparation of hollow zinc phosphate nanoparticles

In a typical procedure, a 100 mL of 33.4 mM of ($Zn(NO_3)_2{\cdot}6H_2O$) and 100 mL of 20 mM of $(NH_4)_2HPO_4$ solutions were prepared separately. The pH of the reaction was maintained to about 8.5 using the ammonia solution (25–28%). SDS (1.0 wt.%), which was used as surfactant, was added into the ($Zn(NO_3)_2{\cdot}6H_2O$) solution before the reaction. The prepared aqueous solution of $(NH_4)_2HPO_4$ was then added drop wise to the prepared aqueous solution of ($Zn(NO_3)_2{\cdot}6H_2O$ in the presence ultrasonic irradiation (ACE horn, 22 kHz frequency at 40% amplitude) at 5–10 °C for 30 min. After complete addition of $(NH_4)_2HPO_4$, the irradiation was continued for a further 30 min., which results into a formation of dense white precipitate of HZPn. The precipitate was collected by centrifugation and washed repeatedly with water and ethanol. After complete washing, the product was dried at 40 °C for 12 h in a suitable oven.

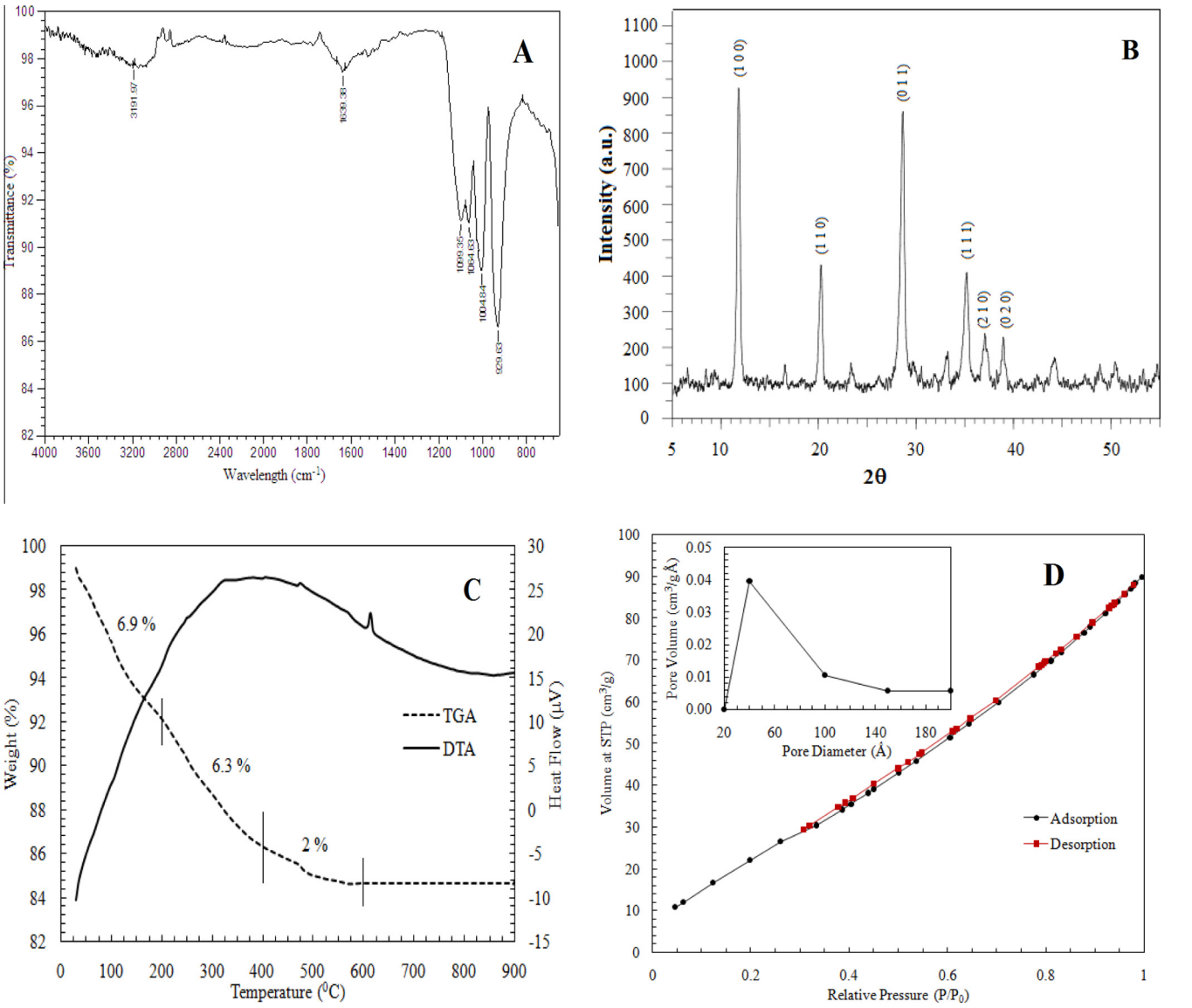

Fig. 1. (A) FT-IR spectra of the hollow zinc phosphate nanoparticles. (B) Powder XRD patterns of hollow zinc phosphate nanoparticles. (C) TG/DTA curves of hollow zinc phosphate nanoparticles. (D) N_2 adsorption–desorption isotherms of hollow zinc phosphate nanoparticles.