Novel ZnO-Imine composite for photochemical detection of metal cations

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Abstract

A novel zinc oxide tetrapod - imine (ZnO-Imine) composite was synthesized and explored as a photochemical sensor for the detection of environmentally relevant metal cations. The composite integrates the photocatalytic and optical responsiveness of ZnO nanoparticles with the selective chelating ability of an imine-based ligand, offering a synergistic platform for sensitive and selective ion detection. A comprehensive structural and morphological analysis was performed using scanning electron microscopy (SEM), high-resolution transmission electron microscopy (HR-TEM), and X-ray diffraction (XRD), confirming the crystalline nature and uniform dispersion of ZnO within the imine matrix. X-ray photoelectron spectroscopy (XPS) revealed effective coordination interactions between ZnO and the imine functional groups, supporting the formation of a stable hybrid interface. Optical properties of obtained composite were investigated by photoluminescence (PL) and diffuse reflectance spectroscopy. The composite formation was confirmed by Fourier transform infrared spectroscopy (FTIR).

In order to assess the viability of operating the proposed sensor within an aqueous environment, the contact angle was measured. The resulting composite exhibited superhydrophobic properties, with an angle of repose of 150°. The issue of hydrophobicity was addressed by coating the sensor chips with an ionomer, which permits the transmission of ions to the composite, thereby resulting in a hydrophilic surface. The contact angle of the final chip with water was measured at 70°.

Sensor testing was carried out in fluidic system integrated with fiber optic system for time-resolved photoluminescence (PL) measurements.

Selectivity tests demonstrated significant improvements in comparison with pure imine ligand. Sensitivity tests demonstrated distinct PL emission response to Cu^{2+}, Fe^{3+}, Cd^{2+}, and Cr^{3+}, which are in the list of toxic heavy-metal environmental pollutants. In turn, Cu^{2+}, Fe^{3+} ions are crucial macronutrients for plant growing.

These findings underscore the proposed sensor platform application for a real-time, non-invasive detection of metals in agriculture and environmental protection industry.

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