

Optimized silver selenide quantum dots for surface-enhanced infrared absorption spectroscopy detecting venlafaxine

Guilherme F. Pinto^{a,b}, Patrick Krebs^b, Claudete F. Pereira^c, Giovannia A. L. Pereira^c, Érika Sousa^d, Vânia Calisto^d, Boris Mizaikoff^b, Goreti Pereira^d

^a*Department of Chemistry, University of Aveiro, Aveiro, Portugal.*

^b*Institute of Analytical and Bioanalytical Chemistry, Ulm University, Ulm, Germany*

^c*Department of Fundamental Chemistry, Federal University of Pernambuco, Recife, Brazil.*

^d*Department of Chemistry & CESAM, University of Aveiro, Aveiro, Portugal.*

E-mail: guilhermepinto@ua.pt

The presence of pharmaceutical residues in water resources has been increasingly recognized as a major problem for both public health and the environment. Due to their high stability and incomplete removal, these compounds have persisted in water bodies, accumulating in biota and thus compromising aquatic ecosystems. To combat this complex problem, remediation measures alone are not enough. Sensitive, robust analytical methods are also needed that can monitor these compounds at trace levels in a quick, practical, and simple manner.

Although well-established analytical methods (like HPLC-MS) are extremely accurate and reliable, their application in monitoring these compounds is often limited by complex equipment, the need for highly specialized technicians, high costs, and low compatibility with rapid analysis of possible contamination. In this context, it is necessary to seek other alternatives that can overcome these limitations, and surface-enhanced infrared absorption spectroscopy (SEIRA) has emerged as a promising approach, enabling the detection of low levels of analyte via molecular vibrational signals. Plasmonic nanostructures of noble metals, such as gold or silver, are generally required to serve as amplifiers of the analyte signals. Quite recently, silver chalcogenides have received considerable attention as SEIRA amplifiers because they exhibit distinctive surface and electronic properties that differ from those of conventional plasmonic metals, enabling strong local-field enhancement mechanisms.

In this study, silver selenide quantum dots (Ag₂Se QDs) were evaluated as SEIRA amplifiers for the detection of pharmaceutical contaminants, more specifically using venlafaxine, a widely prescribed antidepressant, as a model. The Ag₂Se QDs were synthesized in an aqueous medium through the interaction of silver and selenide precursors, as well as a reducing agent and a stabilizing agent to prevent agglomeration of quantum dots. Subsequently, QDs were purified to eliminate contributions from free residues, thereby enabling more accurate detection of the analyte. Two strategies for depositing the amplifiers and analyte onto the ATR crystal of the FTIR equipment were assessed: mix-deposition, in which the QDs and analyte were mixed prior to deposition onto the FTIR substrate; and layered deposition, in which a QD layer was first deposited and dried, followed by analyte deposition.

The results demonstrate a substantial enhancement of the infrared signal, reaching up to a 53-fold increase in specific spectral regions, thereby enabling the detection of venlafaxine at concentrations in the mg/L range. The integration of Ag₂Se QDs into FTIR-based analysis highlights their potential as effective SEIRA amplifiers. Overall, this work expands the range of nanomaterials available for vibrational signal enhancement and supports the development of more sustainable, accessible, and cost-effective analytical tools or monitoring pharmaceutical contaminants in aqueous environments.

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