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Self-assembly of silver nanoparticles as high active surface-enhanced Raman scattering substrate for rapid and trace analysis of uranyl(VI) ions

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Abstract

A facile surface-enhanced Raman scattering (SERS) substrate based on the self-assembly of silver nanoparticles on the modified silicon wafer was obtained, and for the first time, an advanced SERS analysis method basing on this as-prepared substrate was established for high sensitive and rapid detection of uranyl ions. Due to the weakened bond strength of O=U=O resulting from two kinds of adsorption of uranyl species (“strong” and “weak” adsorption) on the substrate, the ν_1 symmetric stretch vibration frequency of O=U=O shifted from 871 cm^{-1} (normal Raman) to 720 cm^{-1} and 826 cm^{-1} (SERS) along with significant Raman enhancement. Effects of the hydrolysis of uranyl ions on SERS were also investigated, and the SERS band at $\sim 826\text{ cm}^{-1}$ was first used to approximately define the constitution of uranyl species at trace quantity level. Besides, the SERS intensity was proportional to the variable concentrations of uranyl nitrate ranging from 10^{-7} to $10^{-3}\text{ mol}\cdot\text{L}^{-1}$ with an excellent linear relation ($R^2=0.998$), and the detection limit was $\sim 10^{-7}\text{ mol}\cdot\text{L}^{-1}$. Furthermore, the related SERS approach involves low-cost substrate fabrication, rapid and trace analysis simultaneously, and shows great potential applications for the field assays of uranyl ions in the nuclear fuel cycle and environmental monitoring.

Keywords: SERS, Uranyl(VI), Self-assembly, Adsorption mechanism, Trace analysis.

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