Polydopamine-based SERS substrates for detection of food contaminants

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Polydopamine (PDA) is a biodegradable and biocompatible polymer obtained through the spontaneous autoxidation of dopamine in mildly alkaline aqueous solutions. Owing to its chemical analogy with natural melanin and its structural similarity to L-DOPA present in mussel adhesive proteins, PDA exhibits strong adhesion to a wide variety of substrates, tunable optical properties and excellent biocompatibility. These features have driven increasing interest in PDA for sensing application. Moreover, PDA can promote the in-situ nucleation and growth of metal nanoparticles, enabling the integration of plasmonic, antimicrobial, and photothermal functionalities within a single sensing platform.

Among current sensing challenges, food quality and safety monitoring are of paramount importance. Surface-enhanced Raman scattering (SERS) represents a powerful technique, providing fast, sensitive, and molecule-specific detection with minimal sample preparation. Beyond conventional noble-metal-based plasmonic substrates, dielectric materials have recently attracted significant attention for SERS applications due to their low optical losses, higher stability, reduced sensitivity to fabrication imperfections, and the presence of resonant modes that can be stronger and more robust than their metallic counterparts. Furthermore, dielectric antennas offer additional opportunities for chemical enhancement through tailored charge-transfer interactions with adsorbed analytes [1].

In this work, we explore an alternative SERS strategy based on the functionalization of non-plasmonic dielectric resonators with a thin PDA layer. Specifically, PDA coatings were applied to non-plasmonic T-rex substrates composed of core/shell SiO_2/TiO_2 micrometric spheres acting as dielectric resonators. The strong and universal adhesion of PDA enables uniform surface functionalization and enhances analyte–substrate interactions. The performance of the proposed substrates was evaluated using methylene blue as a model Raman probe, histamine as a representative food contaminant and thiram as a model pesticide, demonstrating their potential for sensitive detection [2].

Finally, to address the practical requirements of swab-based sampling, which demands both flexibility and mechanical robustness, we also investigated fully flexible SERS substrates based on bacterial cellulose functionalized with PDA and plasmonic gold and silver nanoparticles. These composite substrates combine the mechanical resistance and conformability of cellulose with the adhesive and functional properties of PDA and nanoparticles opening new perspectives for rapid, on-site food safety monitoring on complex and irregular surfaces.

References

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