

Surface Enhanced Raman Spectroscopy for Secure Banknote Authentication

A modern banknote carries an average of twenty security features. Automated sorting already leans on machine-readable luminescent, infrared and magnetic inks to check authenticity at speed [1]. Surface Enhanced Raman Spectroscopy (SERS) is being explored as a highly sensitive and unique way of providing a chemical fingerprint embedded in a product's surface. The materials used to generate the SERS response are hard to detect without specific knowledge, and almost impossible to reproduce.

How SERS Gives a Molecule Its Fingerprint

Raman spectroscopy alone produces a weak signal, since only a tiny fraction of scattered photons carry vibrational information about a molecule. SERS solves this by bringing the molecule close to a nanostructured noble-metal surface, typically gold or silver, where localised surface plasmon resonance concentrates the incident light into an intense electromagnetic field. At the "hot spots" where this field is strongest, Raman scattering can be enhanced by many orders of magnitude relative to normal Raman, turning a faint effect into a readable spectrum [2].

A security-grade SERS tag typically pairs a plasmonic core (gold or silver) with a Raman reporter molecule and a protective shell. In one well-established design, a nanometre-scale Au or Ag core carries the reporter and sits inside a thin glass shell, which gives the particle mechanical and chemical stability and stops it clumping together in solution [3]. Each reporter produces its own set of narrow, well-resolved peaks, so a library of tags can be built with very little spectral overlap between them.

Why the Effect Suits Currency Security

Three properties make SERS particularly well suited to document and currency authentication rather than just a laboratory curiosity.

1. **Specificity:** A Raman spectrum is a vibrational fingerprint, so a genuine reporter molecule is very hard to fake by eye or with a generic pigment; a reader either sees the correct set of peaks, or it does not.
2. **Encoding capacity:** The enhancement depends on nanoparticle size, shape, aggregation state and reporter choice, all of which are difficult to reverse-engineer, SERS-based labels sit within a broader family of chemical physically unclonable functions, security features whose exact physical structure arises from an uncontrolled, effectively random fabrication step and therefore cannot be cloned even by someone with access to the same starting materials [4]. Combining several gap-enhanced Raman reporters in a single label has been used to build anticounterfeiting tags of this kind, where the physically unclonable structure itself, not just the chemistry, forms part of the security feature [5].
3. **Compatibility with paper and ink:** Excitation in the near-infrared avoids much of the native fluorescence background from paper substrates and printing inks that would

otherwise swamp a Raman signal, which matters for a note that has already been printed, folded, and circulated.

Engineering Tags for Covert, High-Speed Reading

SERS tags are made deliberately silent at certain laser wavelengths, so that a tag is unlikely to be picked up by a generic handheld Raman device. In the reported examples, gold nanorods, in some cases coated with a thin silica shell, are attached to a glass-encapsulated tag and act as plasmon absorbers that selectively block one excitation wavelength while leaving another largely unaffected. Silica-coated nanorods were shown to cut the signal at one wavelength relative to another by roughly eight-fold [6].

Detecting genuine SERS taggants in a printed marking on a banknote moving past a Raman spectrometer at speeds of 10 m/s or more, as in a note-sorting machine. Excitation sits in the near-infrared, roughly 750 to 1400 nm, with sub-millisecond integration times, and a statistical F-test is used to classify each note as genuine, counterfeit, or set aside for further forensic analysis [7].

Gold or Silver?

The published literature does not point to a single "correct" metal. Silver nanoparticles functionalised with aryl diazonium salts have been formulated into SERS security inks and printed by handwriting and inkjet, specifically to address the tendency of thiol-anchored reporters to desorb and degrade under laser exposure over time [8]. Gold-based gap-enhanced Raman tags have separately been engineered into security inks and imaged under 780 nm excitation, with the metallic shell geometry tuned for signal density and long-term stability [9]. In an adjacent anticounterfeiting application, roughly 10ng of gold nanoparticle tags deposited on a pharmaceutical tablet produced a distinguishable SERS signal after a single second of 785 nm irradiation [10]. Gold tends to be favoured where chemical stability under ambient conditions and longer excitation wavelengths matter, while silver often gives a stronger raw enhancement at shorter wavelengths; the right choice depends on the excitation source, the reporter chemistry, and how the tag will be packaged.

Why Choose Nikalyte SERS Substrates for This Kind of Research

Nikalyte gold and silver SERS substrates are fabricated in vacuum using a gas aggregation technique, producing ultra-pure, hydrocarbon-free nanoparticles rather than chemically synthesised colloids [11]. For anyone working on fingerprint-based authentication chemistry, a clean metal surface with no ligand background makes it far easier to see a reporter molecule's true Raman signature rather than an artefact of the synthesis route. Our substrates amplify Raman signals by 10^3 to 10^9 compared with standard Raman methods, enabling detection down to parts-per-billion levels [11]. Gold performs well at 785 and 830 nm, silver gives stronger enhancement at shorter wavelengths, and both have been validated at 532, 785 and 830 nm on Agilent Resolve and Wasatch Photonics instruments, a range that overlaps well with the near-infrared window used in the security literature above.

Nikalyte substrates are analytical substrates, not finished security taggants, which is exactly what makes them useful at the research stage: screening candidate Raman reporters, comparing how gold and silver cores respond to the same molecule, characterising a security ink's spectrum before it goes into a formulation, or benchmarking a Raman reader's sensitivity against a well-characterised, reproducible surface. For requirements outside the standard substrate range, our R&D team can discuss bespoke SERS coatings.

Conclusion

SERS has moved well beyond the laboratory bench for anti-counterfeiting work generally, and the same physics, chemical specificity, huge encoding capacity through nanoparticle and reporter combinations, and compatibility with fast, non-destructive optical readout, is exactly what a security-conscious application like currency needs. The patent literature shows that the two hardest engineering problems, keeping a tag covert against common handheld readers and reading it reliably on a note moving at several metres per second, have each been addressed in principle. What remains, as with most SERS applications moving from bench to field, are the practical questions: batch-to-batch reproducibility of nanoparticle synthesis, long-term photostability of the reporter under repeated laser exposure, the cost of adding a further layer to an already crowded security stack, and the standardisation needed before central banks or note printers would commit to it at scale. None of these are unique to currency; they are the same reproducibility and stability challenges that SERS researchers work through in every other application area, from forensic trace analysis to pharmaceutical authentication. That shared groundwork is precisely why research-grade tools matter. Every reporter molecule characterised, every gold-versus-silver comparison run, and every reproducibility study carried out on a substrate feeds into whether this technology is ready for a banknote. [Nikalyte SERS](#) substrates are built to support exactly that stage of the work.

[Explore Nikalyte SERS substrates](#) or [shop SERS substrates now](#).

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