Fe_3O_4 Nanohybrids Modified with Pt, Ag and Au for Surface-Enhanced Molecular Spectroscopy

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Introduction

- Magnetite-based nanohybrids combine magnetic functionality with enhanced molecular spectroscopy, providing multifunctional platforms for chemical and biological analysis.
- Fe_3O_4 modified with noble metals (Au, Ag, Pt) acts as effective substrates for surface-enhanced Raman scattering (SERS) and surface-enhanced infrared absorption (SEIRA).
- Thymine and glycine are used as model biomolecules to probe adsorption behaviour, molecular orientation and signal enhancement on the nanohybrid surfaces.

Aim

- Compare Fe_3O_4–Pt, Fe_3O_4–Ag and Fe_3O_4–Au as multifunctional SERS/SEIRA substrates for molecular detection.
- Identify the role of metal type in signal enhancement, molecular orientation and interfacial binding.
- Clarify the relative contributions of electromagnetic enhancement and chemical adsorption for each system.
- Demonstrate the potential of Fe_3O_4-based nanohybrids as versatile platforms for molecular identification and biosensing.

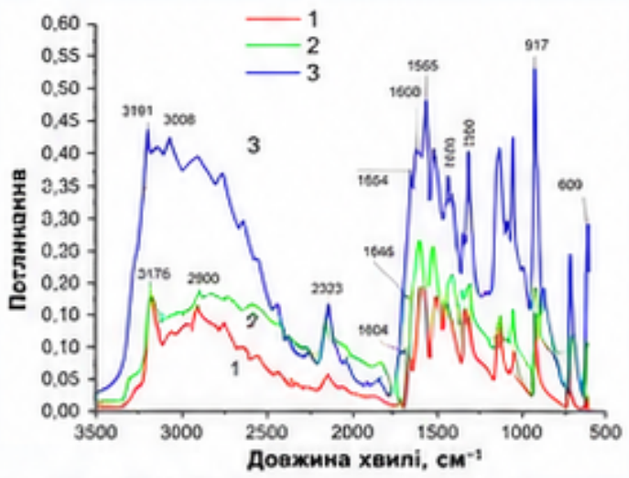
Materials & Methods

- **Synthesis:** Fe_3O_4–Ag and Fe_3O_4–Au nanohybrids prepared by chemical precipitation; Fe_3O_4–Pt systems prepared by rotational corrosion dispersion.
- **Characterization:** XRD, SEM/TEM, UV–Vis, FTIR and Raman spectroscopy.
- **Electrical measurements:** used for Pt-containing samples to examine dielectric behaviour and conductivity.
- **Samples:** nanohybrids studied with model molecules glycine and thymine from aqueous solutions.
- **Data analysis:** comparison of vibrational spectra to identify adsorption sites, molecular orientation and enhancement mechanisms.

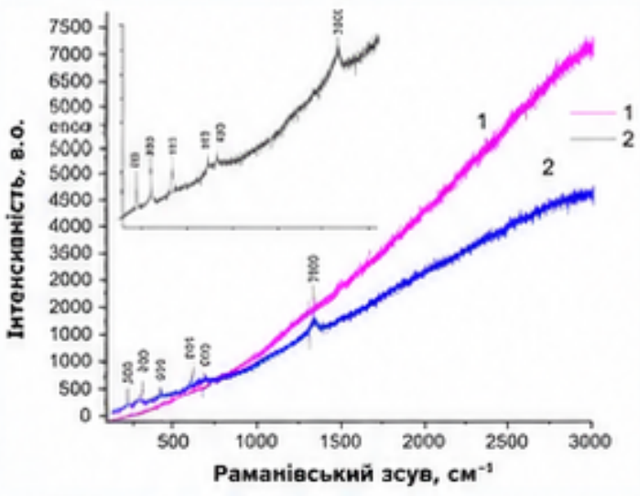
Results and Discussion

Real published figures and micrographs are used below.

Fe_3O_4–Au / Glycine



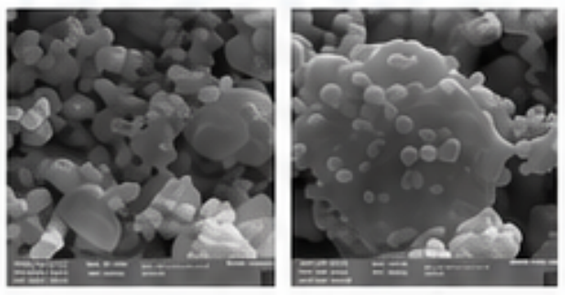
FTIR: Gly, Gly/Fe_3O_4 and Gly/Fe_3O_4–Au (SEIRA) [1]



Raman/SERS: glycine on Fe_3O_4–Au [1]

- Au decoration significantly enhanced the vibrational response of glycine on Fe_3O_4.
- Glycine adsorption is dominated by the carboxylate group, with involvement of COO^-, CH and NH_3^+ moieties.
- Both SEIRA and SERS spectra show pronounced signal enhancement and changes in band intensities, indicating molecular orientation on Au sites.
- The enhancement arises from electromagnetic effects of Au nanoparticles combined with chemical adsorption.
- The Fe_3O_4–Au platform is an effective SERS/SEIRA substrate for glycine detection while retaining magnetic properties for potential separation and preconcentration.

Fe_3O_4–Ag / Thymine



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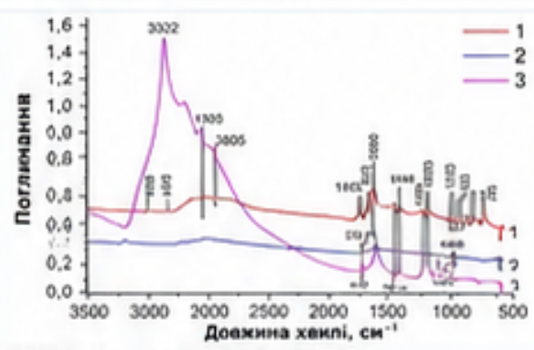
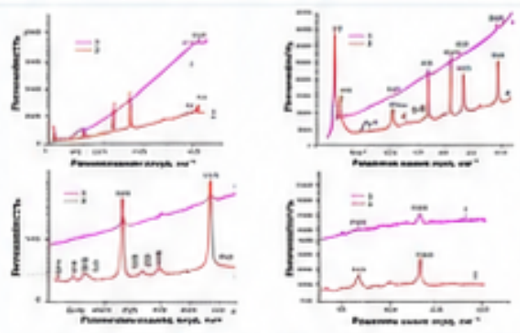
SEM morphology of Fe_3O_4 / Fe_3O_4–Ag [2]



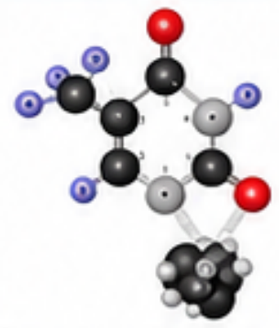
FTIR/SEIRA: thymine on Fe_3O_4–Ag [2]



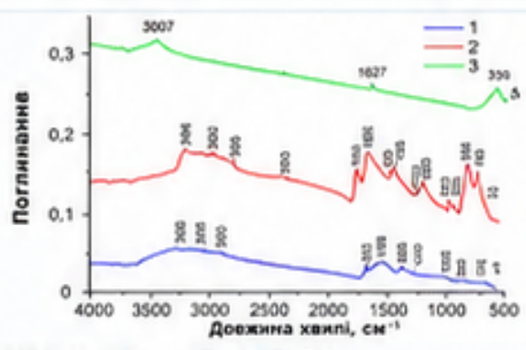
Raman/SERS: thymine on Fe_3O_4–Ag [2]

- Fe_3O_4–Ag nanohybrids support sensitive detection of thymine by SEIRA and SERS.
- Thymine coordinates predominantly through nitrogen an atoms on Ag-containing surfaces (partial N3 coordination).
- Spectral changes indicate both electromagnetic enhancement and chemical interaction with Ag sites.
- The Fe_3O_4–Ag system represents a novel and effective multifunctional substrate for thymine detection, combining high sensitivity with magnetic functionality.

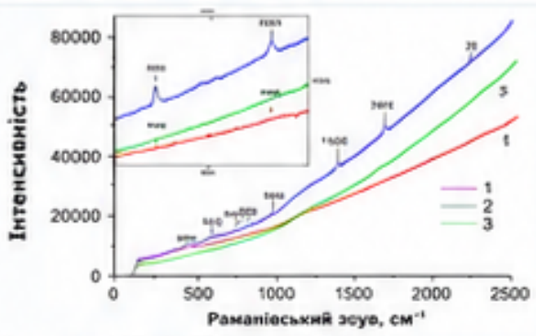
Fe_3O_4–Pt / Thymine



Published interaction scheme: thymine with Fe_3O_4–Pt [3]



FTIR/SEIRA: thymine on Fe_3O_4–Pt [3]



Raman/SERS: thymine on Fe_3O_4–Pt [3]

- Pt-containing nanohybrids provide measurable SEIRA and SERS enhancement for thymine detection.
- Chemical adsorption is particularly strong; thymine coordinates mainly through carbonyl (C=O) groups and, to a lesser extent, N1.
- Additional absorption bands near ~744 and ~830 cm^{-1} are attributed to combined vibrational modes and possible Pt–N / Pt–O contributions.
- Electrical measurements revealed Pt-dependent changes in dielectric behaviour and conductivity of the nanohybrids.
- Both electromagnetic enhancement and chemical interaction contribute, with chemical effects being especially important for Pt-containing systems.

Comparison of Fe_3O_4–M nanohybrids

Property	Fe_3O_4–Au	Fe_3O_4–Ag	Fe_3O_4–Pt
Preparation method	Chemical precipitation	Chemical precipitation	Rotational corrosion dispersion
Model analyte	Glycine	Thymine	Thymine
Dominant interaction	Carboxylate groups (COO^-), CH, NH_3^+	Nitrogen coordination (mainly N3)	Carbonyl groups (C=O), partly N1
Spectroscopic role	SEIRA and SERS enhancement	SEIRA and SERS enhancement	SEIRA and SERS enhancement
Distinctive feature	Effective glycine detection; strong enhancement	Novel substrate for thymine detection	Strong chemical adsorption; bands at ~744 and ~830 cm^{-1}; changes in dielectric behaviour and conductivity

Conclusions

- Metal modification enhances vibrational signals while the Fe_3O_4 component retains magnetic functionality.
- Au-containing nanohybrids are effective SERS/SEIRA substrates for glycine detection, with adsorption dominated by carboxylate groups.
- Ag- and Pt-containing nanohybrids are effective for thymine detection, with different coordination modes (N on Ag; C=O and partially N1 on Pt).
- Both electromagnetic enhancement and chemical adsorption contribute to signal enhancement; chemical effects are especially important for Pt-containing systems.
- Fe_3O_4-based nanohybrids are promising multifunctional substrates for molecular identification and biosensing.

References

[1] Rallev M., Fesenko O., Yaremkevych A., Lavrynenko O. Fe_3O_4–Au nanohybrids as novel SEIRA and SERS substrate for Glycine detection. Mol. Cryst. Liq. Cryst. 2024, 768(3), 89–100. DOI: 10.1080/15421406.2023.2260077.

[2] Rallev M. et al. Fe_3O_4–Ag nanohybrids as novel SEIRA and SERS substrate for thymine detection. Mol. Cryst. Liq. Cryst. 2025, 768(1), 179–190. DOI: 10.1080/15421406.2024.2434336.

[3] Rallev M. et al. Magneto-Plasmonic Fe_3O_4–Pt nanohybrid for SEIRA and SERS-based thymine sensing. Mol. Cryst. Liq. Cryst. 2026. DOI: 10.1080/15421406.2026.2619526.