Biosensors

B. Tech.

Course No.: EEL 3050

L-T-P [C]: 3–0–2 [4]

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ELECTRICAL ENGINEERING

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Lecture 13 dated 5th Sep. 2024

Surface-Enhanced Raman Spectroscopy
or
Surface-Enhanced Raman Scattering (SERS)

- a surface-sensitive technique that enhances Raman scattering by molecules adsorbed on rough metal surfaces or by nanostructures
- the enhancement factor can be as much as 10^{10} to 10^{11},
- the technique may detect single molecules

SERS

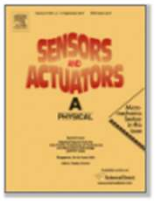
- The exact mechanism of the enhancement effect of SERS is still a matter of debate
- There are two primary theories and while their mechanisms differ substantially, distinguishing them experimentally
- the electromagnetic theory proposes **the excitation of localized surface plasmons**, while
- the chemical theory proposes the **formation of charge-transfer complexes.** It is based on **resonance Raman spectroscopy**, in which the frequency coincidence (or resonance) of the incident photon energy & electron transition greatly **enhances Raman scattering intensity**.

3. Nano-structure array for *Surface Enhanced Raman Spectroscopy*

ELSEVIER

Sensors and Actuators A: Physical

Volume 139, Issues 1–2, 12 September 2007, Pages 36-41

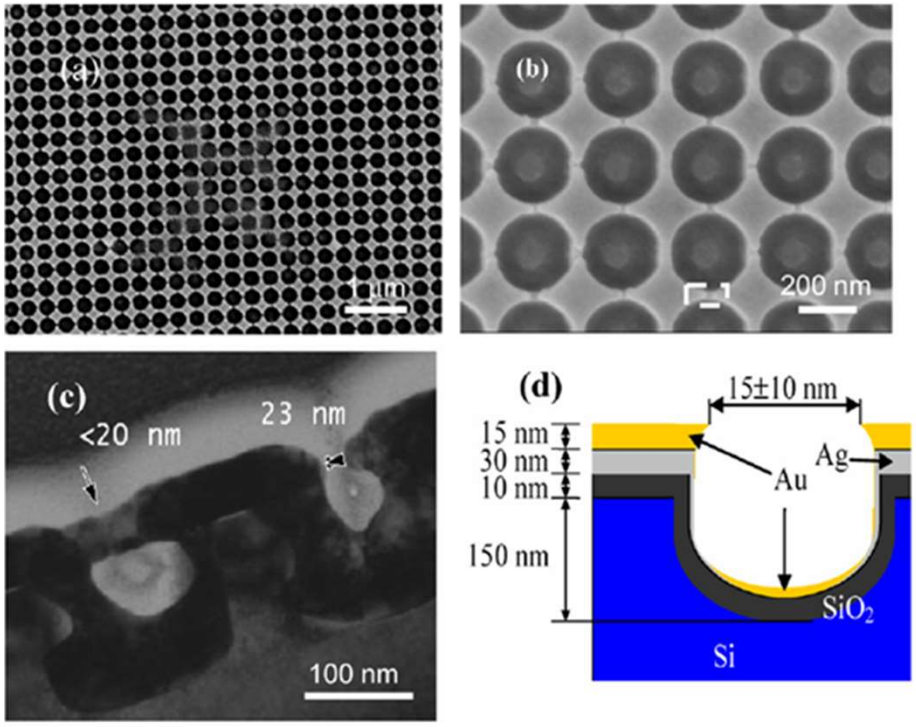


3D arrays of SERS substrate for ultrasensitive molecular detection

R.Z. Tan [a], A. Agarwal [a], N. Balasubramanian [a], D.L. Kwong [a], Y. Jiang [b], E. Widjaja [b], M. Garland [b]

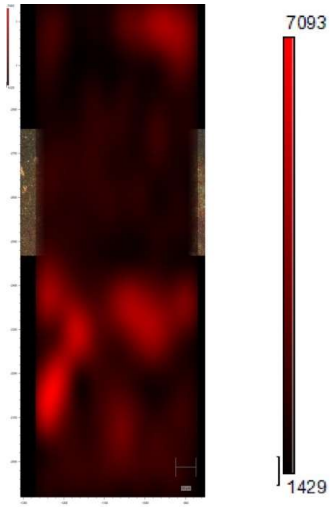
Suitable for *trace level detection* of:

- **Biological warfare,**
- **Bio-markers,**
- **Explosives, etc.**



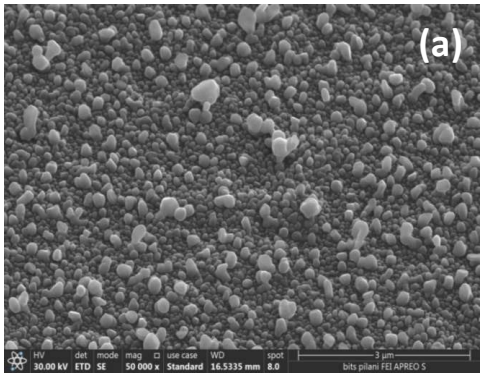
SERS substrates

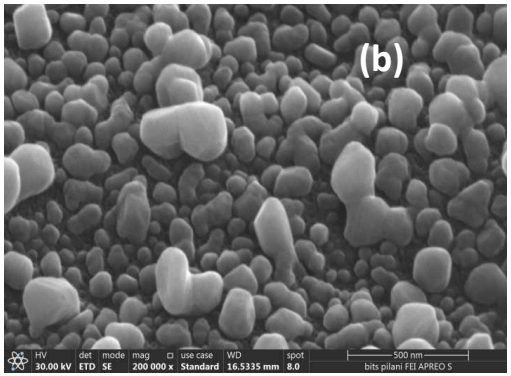
Bio-sample analysis on SERS substrate



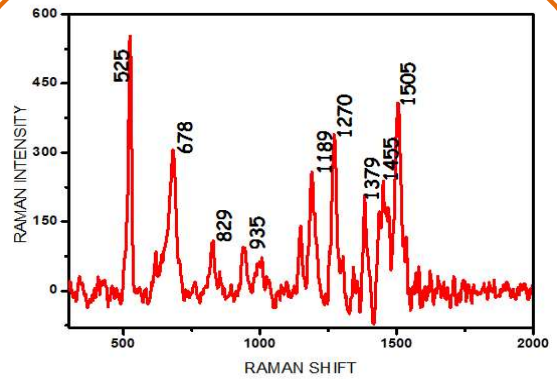
1.5mm x 0.5mm

Raman Mapping of SERS substrate for Rhodamine B (10 µM, 785 nm) at 620 cm-1



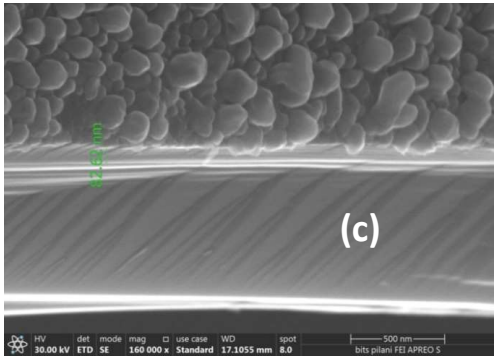


FESEM images of Si SERS substrate surface (a to b)



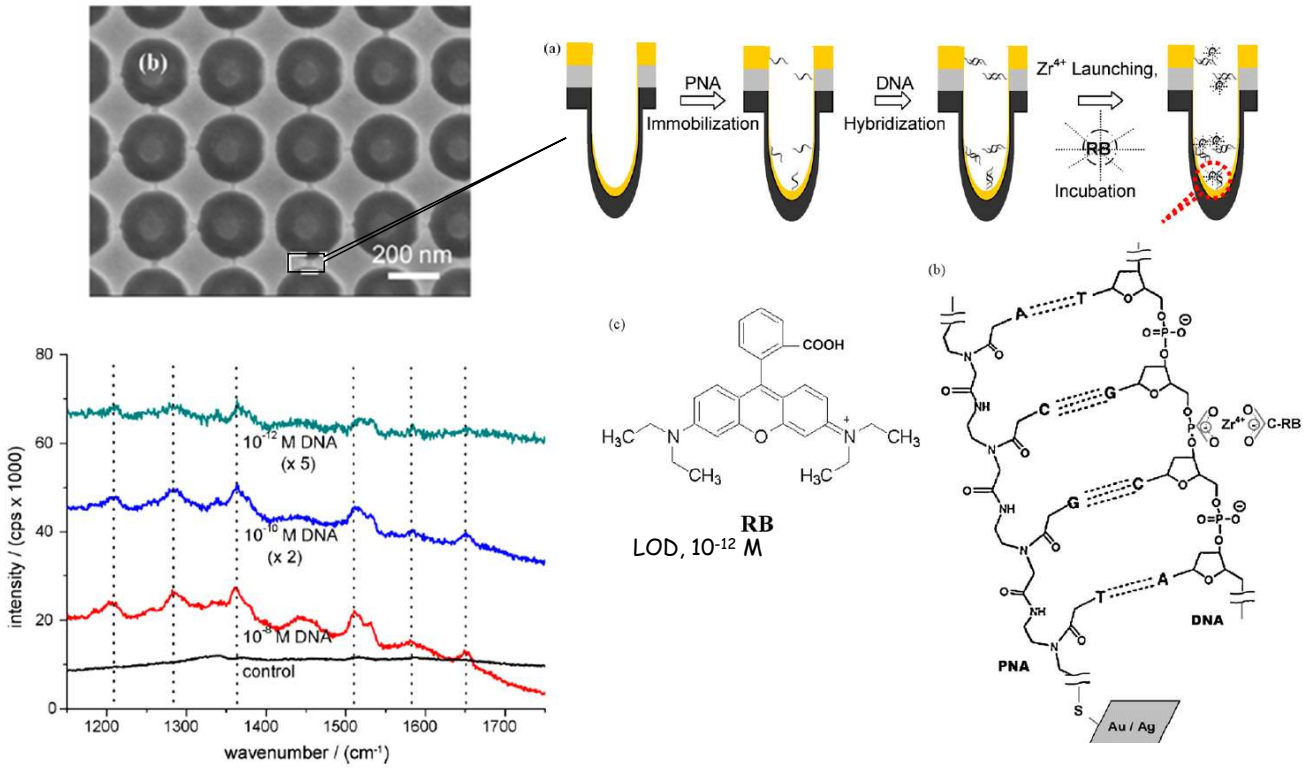
ER-PR-HER-2+ TISSUE SAMPLE

Bio-sample analysis of breast cancer tissue cells



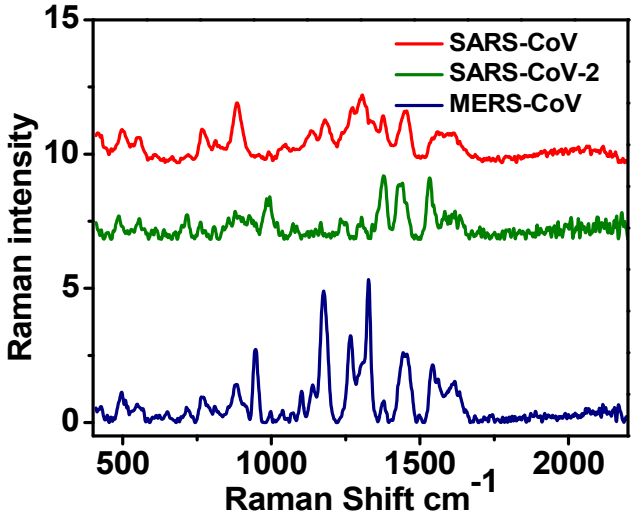
Cross-sectional view

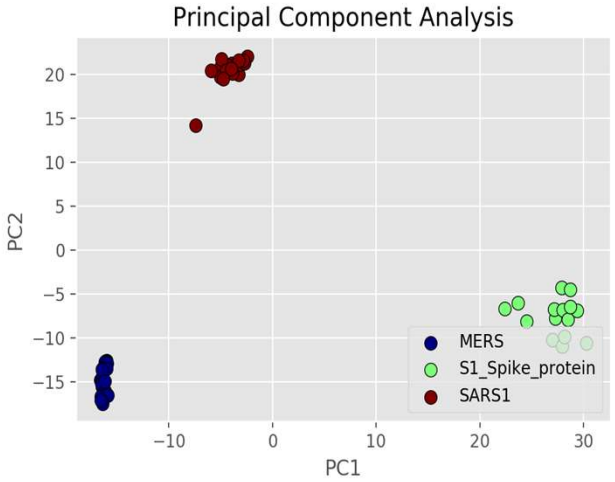
DNA detection



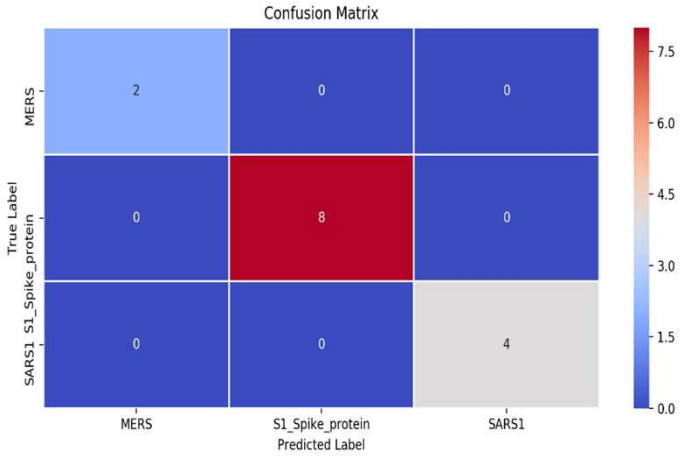
C. Fang, **Ajay Agarwal,** et al., **Biosensors and Bioelectronics,** 24 (2008) 216–221

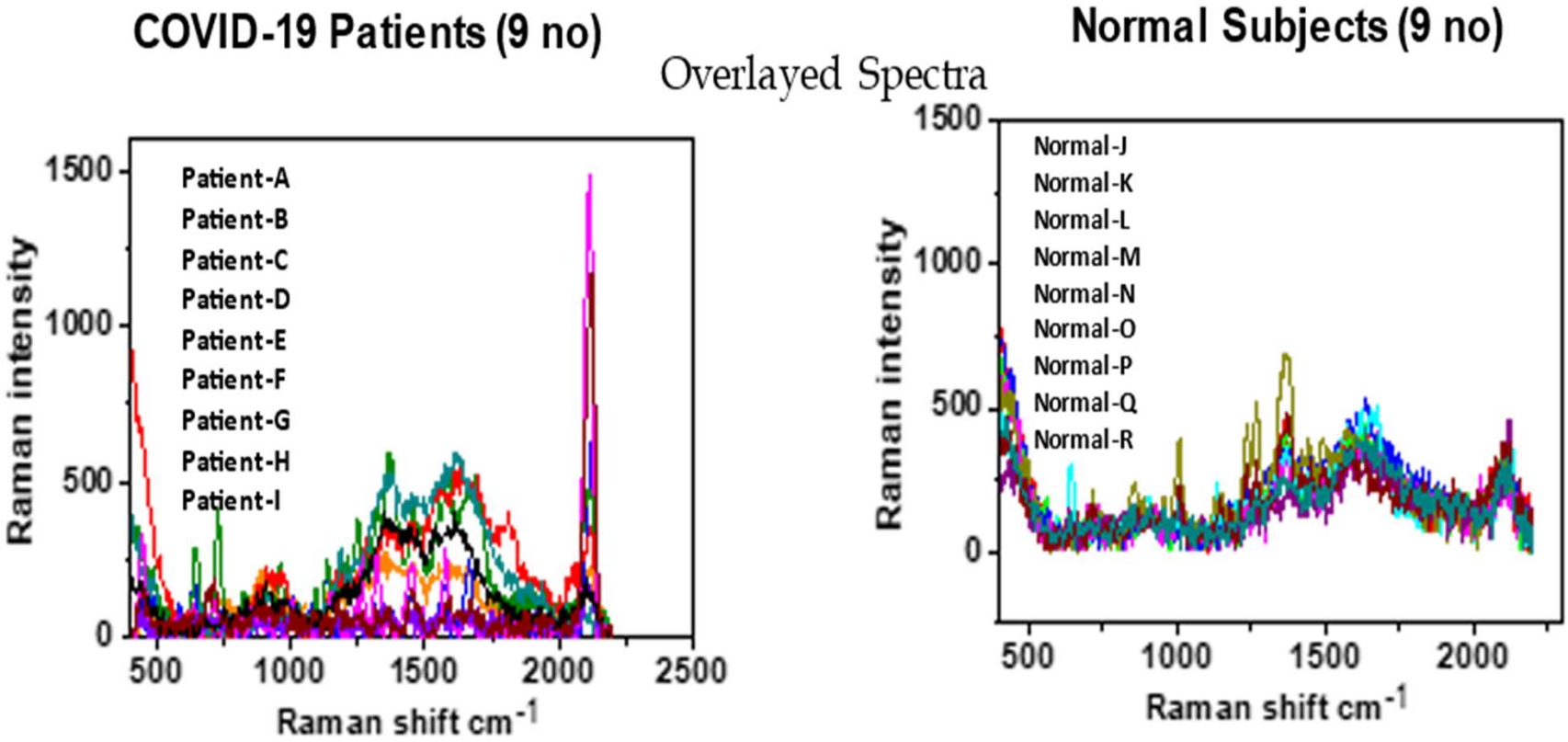
Differentiation of Raman fingerprints of three different Corona virus Spike Protein (SARS-CoV-2, SARS-CoV, MERS-CoV) by PCA & SVM





Wavenumber cm^{-1}	Peak assignment
883	CH2 protein assignment
937	Side chain vibration of Proline
1176	C-H bending tryrosine
1327	Amide III



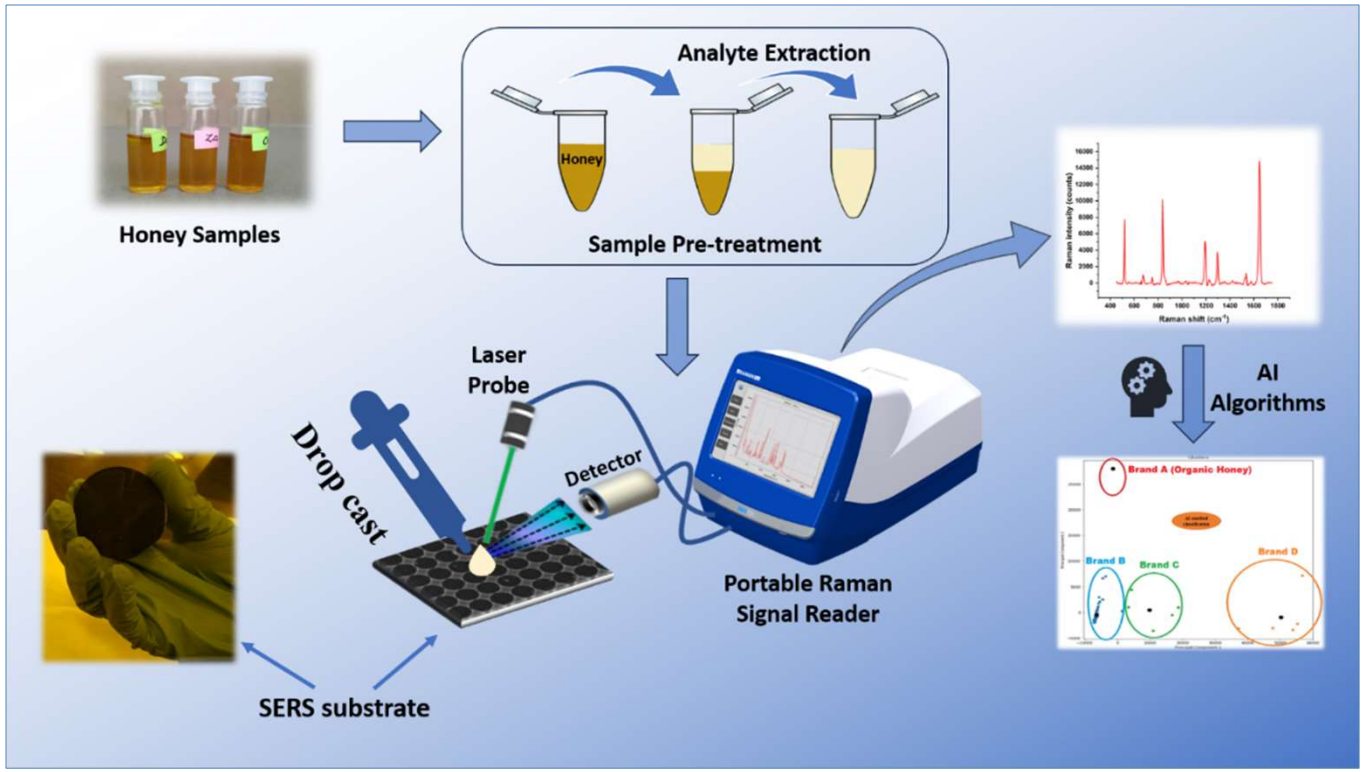


Raman spectra, taken using SERS active substrates, of COVID-19 patients' and normal subjects' saliva

Varsha K, … , **Ajay Agarwal**, S Singh, Kaustabh K Maiti, A non-invasive ultrasensitive diagnostic …, Journal of Photochemistry and Photobiology B: Biology, 2022, 112545.

Nanosensor for the Classification of Organic Honey

- **Indian Honey market is valued at INR 2330 Crores (2022) and expected to reach INR 3880 Crores by 2028 (8.4 % CAGR).**

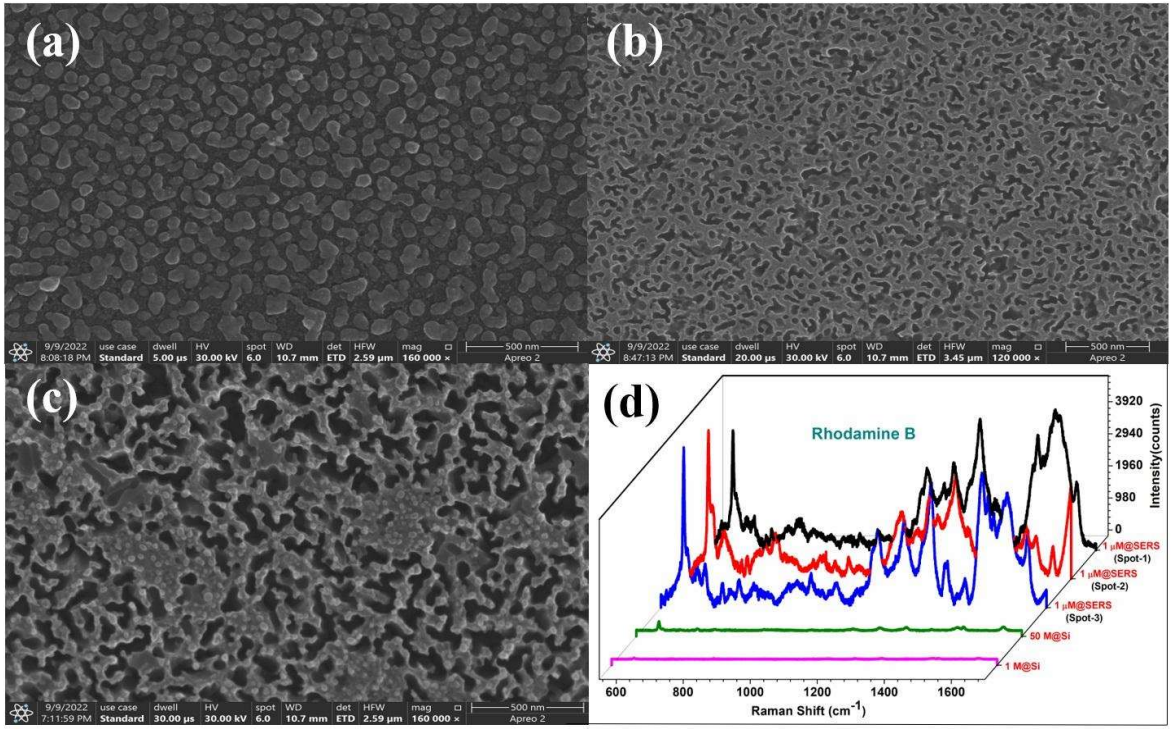


Specifications of nanosensor

- **Plasmonic feature size: 20nm – 200nm**
- **Enhancement factor: 10^6 –10^9**
- **Limit of detection: ppm/ ppb**
- **Target AI algorithms for integration: CNN, SVM or EA**

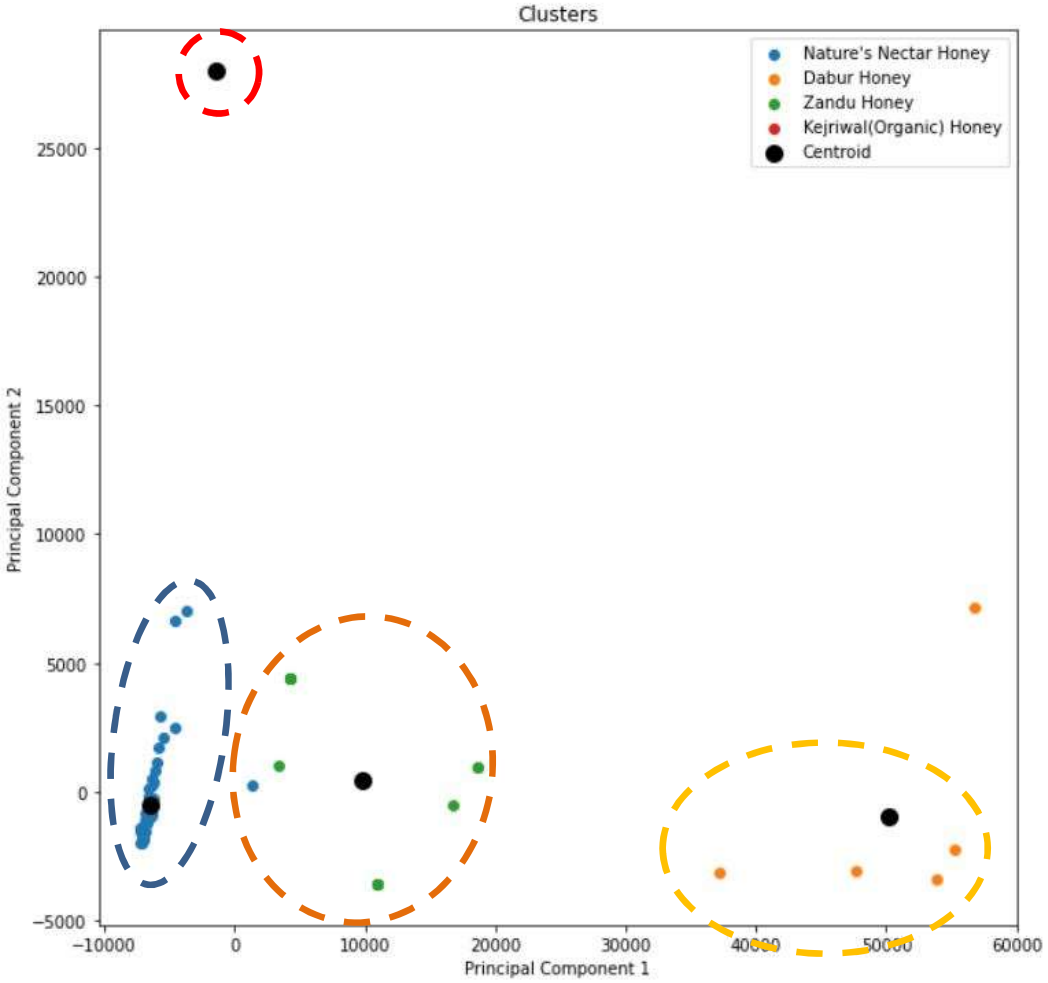
S. Singh, A. Agarwal, et al., "Rapid Detection of Paraquat Pesticide in Honey using SERS-Based Portable Nanosensing Platform," in IEEE Sensors Letters, vol. 7, no. 10, pp. 1-4, Oct. **2023**, Art no. 6006804

Initial results:



FESEM images of Si SERS substrate after
(a)Ag NP deposition on planar Si surface
(b)porous Si fabrication by chemical etching
(c)Ag NP deposition on porous Si
(d)SERS behavior of nano-sensor with Rhodamine B (RhB) at 03 spots compared with bulk RhB on planar Si

K-means Algorithm for Honey Classification



- Asymmetric Partial Least Squares method was used for Spectra smoothing
- K-means clustering model was used for auto-classification of the four honey types using Raman Spectroscopy
- The accuracy can be improved by using other deep learning models such as convolutional neural networks etc.

Questions?