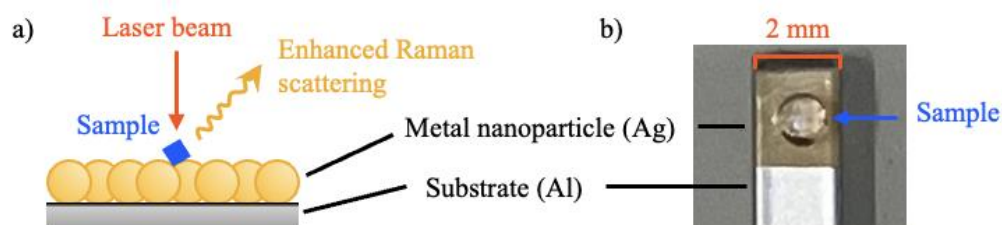


# Sensitive analysis of energy drinks using surface-enhanced Raman scattering (SERS)

## Introduction

Surface-enhanced Raman scattering (SERS) is a phenomenon in which Raman scattering intensity is significantly enhanced when molecules are adsorbed on the surfaces of metal nanostructures, such as gold or silver nanoparticles (Fig. 1a).<sup>1</sup> Raman spectroscopy is widely used for qualitative analysis of samples in the gas, liquid, and solid states; however, because the Raman signal is inherently weak, sensitivity can be a limiting factor, particularly for low-concentration solutions. In contrast to conventional Raman spectroscopy, SERS enables highly sensitive detection of trace constituents and can provide vibrational information for specific molecular species.<sup>2</sup>

In this study, three energy drinks (A, B, and C) containing trace levels of vitamins (reported as several  $\text{mol m}^{-3}$ ) were analyzed, analytes that are difficult to detect under non-SERS (conventional) measurement conditions. Measurements were performed under both non-SERS and SERS conditions, and the resulting spectra were compared. For the SERS measurements, a SERS substrate coated with metal nanoparticles was used (Fig. 1b).



*Fig.1 a) Schematic illustration of SERS measurement and b) Photograph of SERS sample on a substrate*

## Keywords

SERS, surface enhanced raman scattering, resonance raman spectroscopy, food, raman spectrometer

## Experimental

### Sample

One drop (a few  $\mu\text{L}$ ) of three commercial energy drinks (A, B and C) on each substrate

## System

Instrument: NRS-5500 Raman Spectrometer

## Parameters

### • Non-SERS conditions

Substrate: Liquid/powder holder (8 holes)

Laser wavelength: 532 nm

Laser power: 10.9 mW

### • SERS conditions

Substrate: Nano = Kraft AluSERS (ANVOS Analytics)<sup>3)</sup>

Laser wavelength: 785 nm

Laser power: 0.1 mW (sample A), 1.1 mW (sample B, C)



Fig.2 NRS-5500 Raman Spectrometer

The optimum values for each sample were set for other parameters.

Non-SERS measurements were performed using the standard excitation wavelength of 532 nm. For the SERS measurements, the excitation wavelength and laser intensity were selected according to the SERS substrate used.

## Results

### • Non-SERS conditions

Figure 3 shows Raman spectra measured under non-SERS conditions. For all three samples, a band attributed to C–H vibrations was observed in the 2800 to 3000  $\text{cm}^{-1}$  region, confirming the presence of organic compounds. In sample B only, additional bands were observed at 1518  $\text{cm}^{-1}$  and 1155  $\text{cm}^{-1}$ . These bands may be associated with C=C and C–C stretching vibrations<sup>4</sup> of  $\beta$ -carotene, which is present only in sample B, and may be enhanced via resonance Raman scattering.<sup>a</sup> However, based on these spectra alone, it was difficult to clearly distinguish among the three samples.

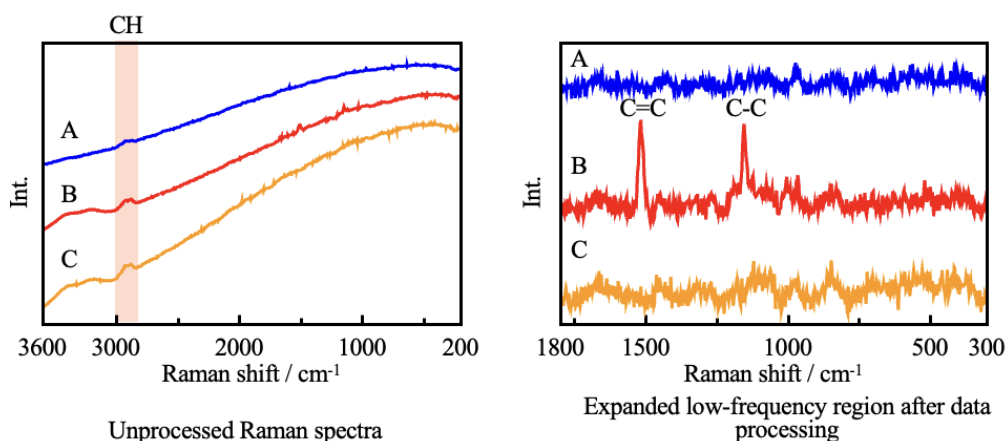
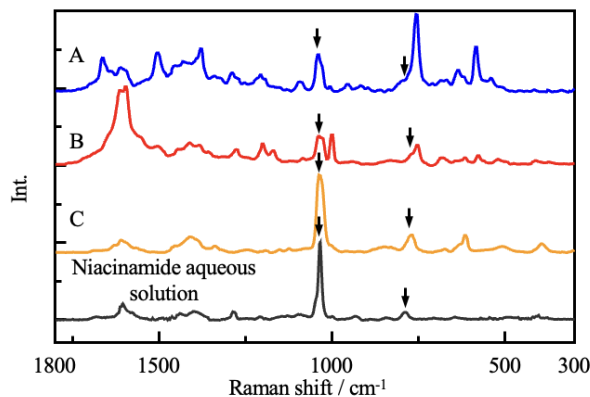


Fig. 3 Raman spectra under non-SERS conditions

- SERS conditions

Figure 4 shows the SERS spectra acquired for samples A, B, and C using the SERS substrate, together with the spectrum of an aqueous niacinamide solution (black trace). Niacinamide is a constituent common to all three samples and the reference solution. Similar bands are observed in all spectra at approximately 1040 and 780  $\text{cm}^{-1}$  (arrows). In addition, clear differences are evident near 1600 and 1000  $\text{cm}^{-1}$  bands attributable to aromatic and pyridine-ring vibrations, as well as in the low-wavenumber region below 600  $\text{cm}^{-1}$ , enabling discrimination among the samples.

The niacinamide concentration in the energy drinks was low ( $<1.6 \text{ mol m}^{-3}$ ), even in the most concentrated sample. These results indicate that SERS enables high-sensitivity detection of low-concentration components that are difficult to observe under non-SERS (conventional) conditions.



*Fig. 4 Raman spectra under SERS conditions (after data processing)*

## Conclusion

The use of SERS enabled highly sensitive detection of niacinamide and other trace constituents in energy drinks at concentrations below a few  $\text{mol m}^{-3}$ . Measurements were performed using a simple procedure that required only a single drop of sample applied to the substrate.

SERS is expected to enable straightforward, sensitive analysis of chemical structures using sample volumes of only a few microliters ( $\mu\text{L}$ ) in fields such as pharmaceuticals, food safety, and environmental monitoring.

## References

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