Surface-enhanced Raman scattering: principles and applications in catalysis, biomedicine, astrobiology and environmental research

ABSTRACT

Raman spectroscopy allows the identification of different molecules on the basis of their vibrational bands, providing an unambiguous molecular fingerprint. However, the low sensitivity of the Raman scattering, along with possible spectral interference due to fluorescence emission, impairs the use of this technique for the recognition of samples with a limited number of molecules. Nevertheless, the increase of the electromagnetic field associated with the localized plasmons allows obtaining an enhancement of several orders of magnitude (usually up to 10^7 factors) of the Raman response in the so called SERS (surface-enhanced Raman scattering) effect, when molecules are adsorbed on nanostructured surfaces of metals with high optical reflectivity, such as Ag, Au, Cu. In addition to this mechanism, also a chemical enhancement contribution to the Raman signal of the adsorbed molecules can be effective, due to the perturbation of the molecular polarizability because of the formation of surface complexes of the molecules themselves with the active sites of the metal surface. This latter contribution usually provides enhancement factors only up to 10^2, but gives rise to sizeable changes in both positions and relative intensities of the SERS bands with respect to those observed in the normal Raman spectra of non adsorbed molecules. Thanks to its peculiar properties, SERS spectroscopy, since its discovery at the beginning of the Seventies, has achieved a leading role in many research fields, finding wide applications in heterogeneous catalysis processes, diagnosis and therapy of several diseases, detection of trace pollutants in waters as well in soil, and search for possible life traces in extraterrestrial environments.