Enhanced Raman spectroscopy – a novel technique for versatile environmental gas analysis

TORSTEN FROSCH[1,2,3], ANNE BACHMANN[1], ROBERT KEINER[1], TOBIAS JOCHUM[1], JÜRGEN POPP[1,2,3]

[1] Leibniz Institute of Photonic Technology, Albert-Einstein-Str. 9, 07745 Jena
[2] Institute for Physical Chemistry, Friedrich Schiller University, Helmholtzweg 4, 07743 Jena
[3] Abbe Center of Photonics, Friedrich Schiller University, Max-Wien-Platz 1, 07743 Jena

Continuous online monitoring of gas compositions and exchanges helps to reveal complex processes in ecosystems without disturbance. In this contribution enhanced Raman gas spectroscopy is exploited for the investigation of the biodegradation of contaminants in soil [1], monitoring of the total nitrogen budget during denitrification [2], monitoring isotopic labeling in eco-physiological studies [3,4], the characterization of eco-system parameters [5], the characterization of the life cycle of biomineralizing cave bacteria [6], and the investigation of drought stress on the substrate use and vitatilty of trees.
In the first application, the fate of a benzene surface contamination was analyzed [1]. Continuous online quantification of reduction of ^{15}N-labelled nitrate by *Pseudomonas stutzeri* was demonstrated and the total nitrogen element budget was monitored online [2]. Sterile online acquisition of the pH changes in the *P. stutzeri* culture was demonstrated [2]. An isotopic labeling of plant metabolites was observed via photosynthetic uptake of $^{13}CO_2$ in order to investigate the flow of resources in plants [3,4]. The concentrations and fluxes of O_2, CO_2, and CH_4 were quantified in the head space of a water-saturated peat bog soil column, in order to determine important ecosystem parameters such as the maximum photosynthesis rate of the sphagnum as well as the extent of soil and plant respiration [5]. The headspace gas composition of a culture of carbonate precipitating Arthrobacter sulfonivorans was monitored in order to characterize the respiratory activity during the bacterial lifecycle [6].
In summary, it was proven that enhanced Raman gas spectroscopy is an extremely versatile new analytical technique for fast and continuous environmental gas analysis.

Acknowledgement: Funding by the Collaborative Research Centre 1076 “AquaDiva” from the German Research Foundation (DFG) is gratefully acknowledged. We thank our collaboration partners.

Literature

1. Jochum T, Michalzik B, Bachmann A, Popp J, Frosch T. Microbial respiration and natural attenuation of benzene contaminated soils investigated by cavity enhanced Raman multi-gas spectroscopy. *Analyst*, 140(9), 3143-3149 (2015).
2. Keiner R, Herrmann M, Kuesel K, Popp J, Frosch T. Rapid monitoring of intermediate states and mass balance of nitrogen during denitrification by means of innovative cavity enhanced Raman multi-gas sensing *Analytica Chimica Acta*, 864, 39-47 (2015).
3. Keiner R, Gruselle MC, Michalzik B, Popp J, Frosch T. Raman Spectroscopic Investigation of 13CO2 Labeling and Leaf Dark Respiration of Fagus sylvatica L. (European Beech). *Analytical and Bioanalytical Chemistry* 407, 1813–1817 (2015).
4. Keiner R, Frosch T, Massad T, Trumbore S, Popp J. Enhanced Raman multigas sensing - a novel tool for control and analysis of (13)CO2 labeling experiments in environmental research. *Analyst*, 139(16), 3879-3884 (2014).
5. Frosch T, Keiner R, Michalzik B, Fischer B, Popp J. Investigation of gas exchange processes in peat bog ecosystems by means of innovative Raman gas spectroscopy. *Analytical Chemistry* 85(3), 1295-1299 (2013).
6. Keiner R, Frosch T, Hanf S *et al.* Raman Spectroscopy-An Innovative and Versatile Tool To Follow the Respirational Activity and Carbonate Biomineralization of Important Cave Bacteria. *Analytical Chemistry*, 85, 8708−8714 (2013).