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Nonlinear optical transducers as innovative, label-free and highly sensitive bio-recognition solutions

Francesca Cecchet
Namur Institute of Structured Matter-University of Namur, Belgium
Namur Institute for Life Sciences-University of Namur, Belgium

Label-free and high sensitive measure of bio-recognition processes is a scientific quest and a technological objective, which inspires scientists to explore new solutions for innovative detection systems. In this presentation, we will show the promising perspectives in bio-detection of an advanced vibrational technique, called sum frequency generation (SFG) spectroscopy, which belongs to the family of nonlinear optical (NLO) techniques. Due to the selection rules of second order NLO processes, SFG spectroscopy is intrinsically sensitive to interfacial systems, as biological films acting as bio-sensing platforms and probes molecular vibrations owing specific symmetry and orientations. We will present how SFG spectroscopy can detect biological interactions, either by measuring specific chemical fingerprints of a host-guest pair, or by recording the signal of water close to the bio-sensing platform. Firstly, we applied SFG spectroscopy to the detection of antigen-antibody recognition between a dinitrophenyl (DNP) lipid layers anchored on a glass surface, and a solution of complementary monoclonal mouse anti-DNP antibody. We demonstrated that, whilst an anti-fouling layer was not used, specific bio-recognition was univocally detected thanks to the intrinsic sensitivity of the vibrational second order NLO phenomenon. Secondly, we exploited the specific NLO signal of interfacial water to unravel qualitative and quantitative data of the interaction of gold nanoparticles (NPs) with a lipid membrane platform. The ability to probe interfacial water is indeed one of the major assets of SFG spectroscopy. We demonstrated that the signal of interfacial water changed proportionally to the NPs concentration, and enabled to achieve very low detection thresholds. Both results highlight the high sensitivity of SFG spectroscopy to bio-recognition events, and open to the possibility to detect a wide range of bio-interactions, thanks to the intrinsic fingerprints of biomolecules or to the signal of their surrounding water environment. This unique sensitivity makes SFG spectroscopy a powerful optical transducer of biological processes at bio-sensing platforms.

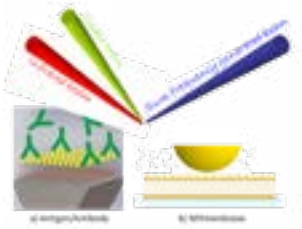

Figure: 1. Schematic representation a) of an antigen-antibody platform, and b) of a nanoparticle/membrane platform, probed with the three beams (infrared, visible and sum-frequency generated, respectively) that make an SFG response.

Recent Publications

1. Lis D and Cecchet F (2016) Unique vibrational features as a direct probe of specific antigen–antibody recognition at the surface of a solid-supported hybrid lipid bilayer. ChemPhysChem 17(17):2645-2649.
2. Toledo-Fuentes X, Lis D and Cecchet F (2016) Structural changes to lipid bilayers and their surrounding water upon interaction with functionalized gold nanoparticles. J. Phys. Chem. C. 120(38):21399-21409.
3. Lis D and Cecchet F (2014) Localized surface plasmon resonances in nanostructures to enhance nonlinear vibrational spectroscopies: towards an astonishing molecular sensitivity. Beilstein J. of Nanotechnology 5:2275-2292.

4. Lis D, Caudano Y, Henry M, Demoustier-Champagne S, Ferain E and Cecchet F (2013) Selective plasmonic platforms based on nanopillars to enhance vibrational sum-frequency generation spectroscopy. Advanced Optical Materials 1(3):244-255.
5. Lis D, Caudano Y, Henry M, Demoustier-Champagne S, Ferain E and Cecchet F (2013) Metallic nanopillars: selective plasmonic platforms based on nanopillars to enhance vibrational sum-frequency generation spectroscopy. Advanced Optical Materials 1(3):274-274.

Biography

Francesca Cecchet is an Associate Researcher at the Belgian National Fund for the Scientific Research since 2010 and appointed to the Laboratory of Lasers and Spectroscopies (LLS) of the Namur Institute of Structured Matter (NISM) and the Namur Institute for Life Sciences (NARILIS) at the University of Namur, Belgium. She has completed her Graduation in Chemistry at the University of Bologna, Italy in 1999 and PhD in Sciences at the University of Namur in 2003. From 2004 to 2006, she worked as Postdoctoral Researcher at the University of Louvain-la-Neuve, Belgium, and from 2006 to 2010 as F.R.S.-FNRS Postdoctoral Researcher at the University of Namur. Her research interests include investigation of the physicochemical properties of (bio-) molecular films, by using nonlinear optical spectroscopies. Her current research interests concern the investigation of bio-inspired systems, which play a role in bio-detection, or mimic the behavior of nano-objects interacting with living cells. She has published over 50 papers in international journals.

francesca.cecchet@unamur.be

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