Shedding light on nanoparticles/cell membranes interactions with nonlinear optical spectroscopy

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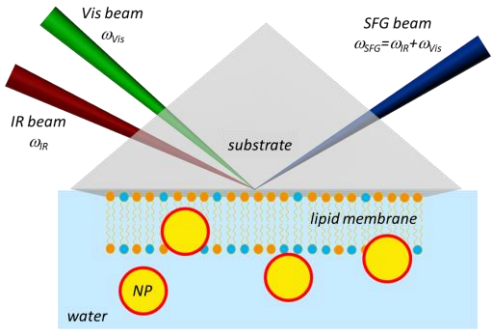
New technologies based on nanoscale materials have drastically increased the exposure of humans to nanoparticles (NPs). Numerous studies converge to prove that the first contacts of NPs with cell membranes may be the initiators of toxicity pathways. Due to the complexity of cell membranes, which are composed of a plethora of biological species (lipids, carbohydrates, peripheral and transmembrane proteins), and regulated by multiple dynamical processes, the mechanisms and the physicochemical properties that drive NPs to attach, penetrate and possibly disrupt cell membranes are still not well understood. New insights on those primary interactions provide key understandings to reconstruct the complex puzzle describing the mechanisms of NPs cytotoxicity.
The nanoscale dimension of membrane systems and their interfacial position, between the inner cell medium and the outer environment, make their probing challenging, because one shall discriminate signals of the few nanometers thick membrane from bulk responses of the macroscopic surrounding regions.

Here, we take advantage of the intrinsic sensitivity of second order nonlinear optical (NLO) phenomena to interfacial systems, to investigate the first contacts between NPs and models of lipid membranes (see picture). In particular, we use vibrational sum frequency generation (SFG) spectroscopy, a three-photon NLO technique, which probes the vibrational signature of the lone nano-bio-interface, without contributions from the inner and outer bulk regions.



We will discuss how SFG spectroscopy may provide new qualitative understandings of NPs/membrane interactions, with a molecular sensitivity [1,2], but also how it can be turned in a quantitative detection tool and become an innovative, highly sensitive and label-free sensing solution [3].

References

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[2] X. Toledo-Fuentes, C. Molinaro and F. Cecchet, “Interfacial charges drive the organization of supported lipid membranes and their interaction with nanoparticles” Colloids and Surfaces B: Biointerfaces, vol. 172, pp. 254-261, 2018.

[3] C. Molinaro and F. Cecchet, “Label-free, quantitative and sensitive detection of nanoparticle/membrane interaction through the optical response of water”, Sensors and Actuators B: Chemical, vol. 289, pp. 169-174, 2019.