Unraveling protein dynamics and interactions with single plasmonic gold nanoparticles

Katja Krüger[1], Sirin Celiksoy[1], Weixiang Ye[1,2] and Carsten Sönnichsen[1]
1 Institute of Physical Chemistry, University of Mainz, Duesbergweg 10-14, 55128 Mainz, Germany
2 Graduate School of Materials Science in Mainz, Staudingerweg 9, 55128 Mainz, Germany

Spectroscopy of plasmonic single nanoparticles (NanoSPR) has become a standard technique for label-free detection of macromolecules, and e.g. allows to obtain information on protein dynamics and protein-protein interactions [1,2]. The utilization of gold nanoparticles as sensors is advantageous because they are relatively easy to functionalize, are inert in most media, and have a potentially unlimited lifetime, restricting the observation time only to the (biological) system. We investigated protein dynamics and interactions in a microfluidic flow cell with our improved spectral imaging setup, that enables high statistics (over 2000 particles within two seconds) and long measurement times (24 hours) – both properties, which helped us to obtain a deeper understanding of two different biological systems.

For observation of dynamical protein-protein interactions, we covered gold nanorods with a biological membrane and detected the (de-)attachment of proteins (see figure 1). Since the particles' sizes determine their sensing range, details of the axial location (perpendicular to the substrate) of dynamical protein-protein interactions are obtainable considering each particles' individual dimensions. If the sensing range of the particle matches the location of the attachment, the signal reaches a maximum. The high statistics of our setup supports finding this coinciding distance by measuring several particles of different sizes at once [3].

Conformation dynamics of proteins are measurable by linking two gold nanospheres with a single protein, creating a plasmon ruler. The distance change, upon the protein traversing different states, results in a measurable signal (see figure 2). The longer lifetime of the plasmonic signal, compared to e.g. fluorescence, allowed measurement times of 24 hours at video rate, which revealed new states with long dwell times (beside the well-known fast dynamics in the 0.1-10s range) [4].

This work was financially supported by the ERC grant 259640 ("SingleSens").

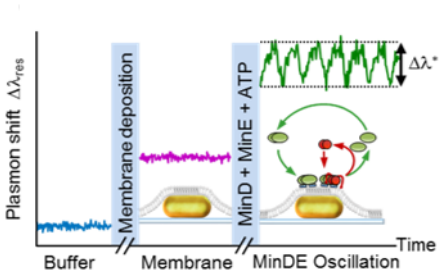

Fig. 1: Scheme of experimental procedure in detection of Min waves

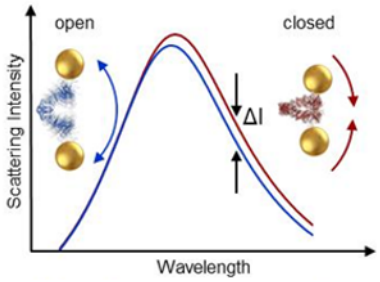

Fig. 2: Measurement principle of protein dynamics with the plasmon ruler.

[1] Lambertz, C., Martos, A., Henkel, A., Neiser, A., Kliesch, T.-T., Janshoff, A., Schwille, P. and Sönnichsen, C., Nano Lett. ***16****, 3540−3544 (2016).*
[2] Ahijado-Guzmán, R., Prasad, J., Rosman, C., Henkel, A., Tome, L., Schneider, D., Rivas, G. and Sönnichsen, C., Nano Lett. ***14****, 5528-5532 (2014).*
[3] Ye, W., Celiksoy, S., Jakab, A., Khmelinskaia, A., Heermann, T., Raso, A., Wegner, S., Rivas, G., Schwille, P., Ahijado-Guzmán, R. and Sönnichsen, C., J. Am. Chem. Soc. ***140****, 17901-17906 (2018).*
[4] W. Ye, M. Götz, S. Celiksoy, L. Tüting, C. Ratzke, J. Prasad, J. Ricken, S. V. Wegner, R. Ahijado-Guzmán, T. Hugel, C. Sönnichsen,, Nano Lett. ***18****, 6633 (2018)*