Miniaturized, labelfree Surface Nanosensing, based on Low-Q-Whispering Gallery Modes

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Abstract

The increasing integration and miniaturisation of analytical processes requires new sensory methods. Especially interactions on surfaces, such as adsorption or desorption of (bio-)molecules or nanoparticles, which occur in native form, i.e. do not have an extra label, are increasingly in demand.

For this purpose, some label-free methods have been developed in the last decades that detect surface processes either electromechanically (Quartz Crystal Microbalance) or optically, such as Surface Plasmon Resonance (SPR), Bio-Layer Interferometry (BLI) or Ellipsometry. In these systems, the optical waves are influenced once per adsorbed molecule, so that many molecules are necessary to achieve sufficient sensitivity. All methods require direct coupling with the transducer and have planar sensor surfaces of relatively large areas in common, which, are difficult to miniaturise. Hence they are not suitable for measurements in microfluidics or three-dimensional systems such as cell arrays.

Whispering Gallery Modes (WGM)

WGM are light waves that circulate up to 10^5 times (Q-factor) by total reflection at the inner surface of a sphere and are therefore influenced many times by an adsorbed molecule. Depending on the difference in refractive index between the sphere and the outer medium as well as the diameter of the sphere, only discrete wavelengths can circulate, all others are cancelled out.

In order to introduce light waves into an optically denser medium, usually light guides are brought tangentially to circular resonators with 30-300 nm diameter, for which Q-factors of 10^5 are achieved. For miniaturisation, we used a simpler setup (Fig.1) in which fluorescent dyes are excited inside microparticles. Their emission forms WGMs in the particles. The ad- or desorption of molecules changes both refractive index and particle diameter, resulting in shifts of the WGM resonance frequencies (Fig. 2). With 7-10 µm sized sensor particles and Q-factors of 10^4 (low-Q-WGM), we could achieve sensitivities as with SPR or BLI.

We present the developed measuring device as well as advantages of the new technology in terms of miniaturisation and microfluidics, which is illustrated by application examples by coating and release kinetics of drugs from nanometre-thin layer-by-layer films (Fig. 3) as well as from protein binding kinetics[1]

References

[1] Jimena A. Freile, Ghizlane Choukrani, Kerstin Zimmermann, Edwin Bremer, Lars Dähne *Sensors and Actuators B: Chemical* 364, (**2021**), 130512

[2] M. Olszyna, A. Debrassi, C. Üzüm, L. Dähne. *Advanced Functional Materials* **(2018)** 29: 1805998

Figures

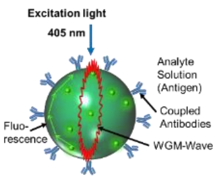

Fig. 1: WGM Sensor Principle

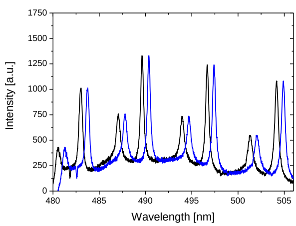

Fig. 2: Emission before (black) and after adsorption of molecules (blue)

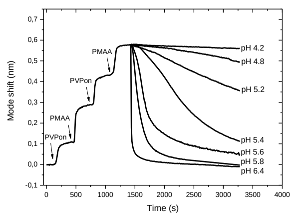

Fig. 3: stepwise adsorption of nano-metre multilayers and dissolution