1.3.19 Surface-acoustic-wave biosensors and microfluidics

Surface acoustic waves (SAWs) are acoustic waves that travel on the surface of an elastic material, with an amplitude that typically decays exponentially with depth into the substrate. Given their very superficial nature, SAWs are highly sensitive to surface perturbations of the substrate along which they propagate. For example, they can interact with liquid droplets or streams inducing macroscopic fluid manipulations or, in a different configuration, be exploited for sensing applications. The interest of our research in this field is to explore and study novel SAW-driven microfluidic phenomena, and apply this new knowledge to the fields of biosensing and cell biology.

A Rayleigh surface acoustic wave (R-SAW) resonator biosensor based on positive and negative reflectors with sub-nanomolar limit of detection

A label-free sub-nanomolar Rayleigh surface acoustic wave (R-SAW)-based resonator biosensor has been demonstrated for biomolecular detection in liquid after drying [1]. The biosensor comprises two interdigital transducers for R-SAW generation and two positive and negative reflectors to confine the acoustic energy in the sensitive area. We benchmark this biosensor against biotin-streptavidin binding, which is a standard, well-known model for a variety of biosensing processes. The experiments demonstrate a limit of detection of 104 pM and a normalized sensitivity of $-296\ m^2\ kg^{-1}$. As a comparison with similar acoustic-wave based systems, both sensitivity and limit of detection are better than that of standard commercial gravimetric sensors (i.e., quartz-crystal-microbalances) and generally better than that of more common Love-SAW biosensors. Our biosensor has a dynamic range potentially comparable with several healthy and safety-related assays, among all cancer biomarker detection.

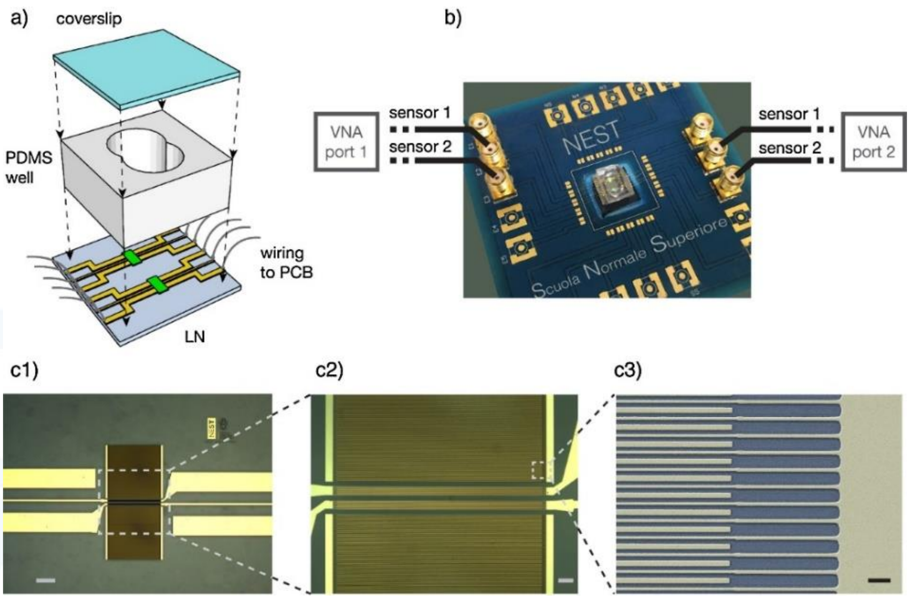

Figure 1. Chip and experimental setup. a) Exploded scheme of the biosensor chip. b) Photo of the mounted biosensor chip with external connections for electrical measurements. c1) and c2) Representative optical microscope images of a resonator. Scale bars are 200 µm (c1) and 40 µm (c2). c3) Representative scanning electron microscopy detail of a PNR (scale bar is 2 µm).

Full-SAW Microfluidics-Based Lab-on-a-Chip for Biosensing

Many approaches to diagnostic testing remain decades old. Well-established biosensing technologies (e.g., enzyme linked immunosorbent assays, radioimmunoassays) typically cannot fulfill the requirements of portability and ease of use necessary for point-of-care purposes. Several alternatives have been proposed (e.g., quartz-crystal-microbalances, electrochemical sensors, cantilevers, surface-plasmon-resonance sensors) but often lack high performance or still necessitate bulk ancillary instruments to operate. Here we present a highly sensitive, versatile and easily integrable microfluidic lab-on-a-chip (LoC) for biosensing, fully based on surface acoustic waves (SAWs) [2]. By using ultra-high-frequency resonator-biosensors, we show that it is possible to perform highly sensitive assays in complex media. This all-electrical readout platform is benchmarked with the biotin-streptavidin binding in presence of non-specific binding proteins (serum albumin) at physiological concentration. The benchmark experiments were performed with the idea of mimicking a biological fluid, in which other molecular species at high concentration are present together with the analytes.

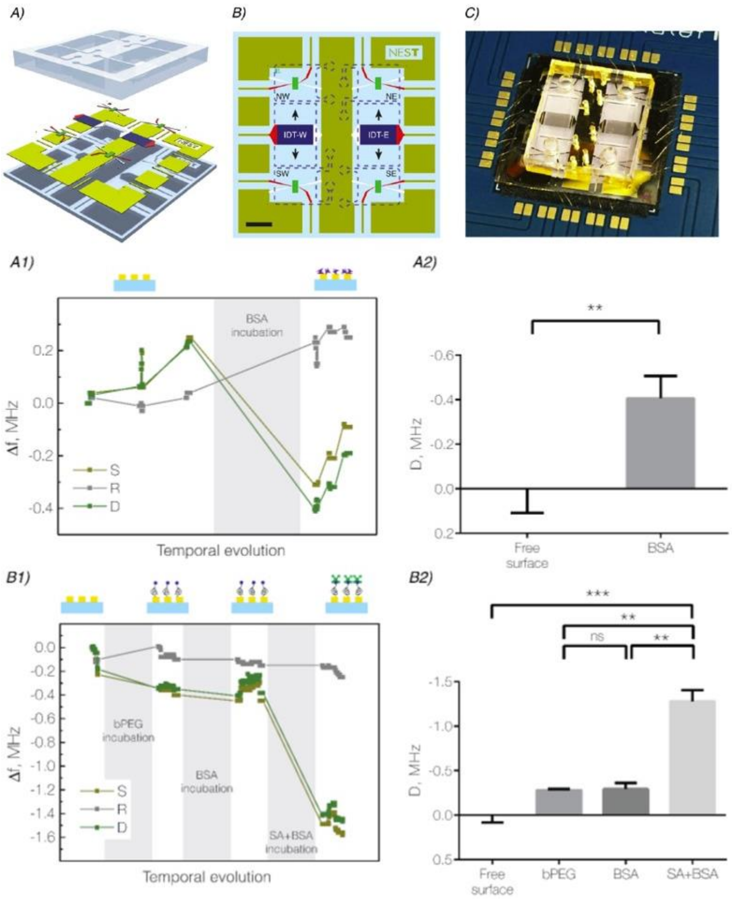

Figure 2. A-C) Chip and experimental setup. A1-2; B1-2) Biosensing measurements of biotin-streptavidin binding in presence of non-specific binding proteins (bovine serum albumin, BSA).

We demonstrate that this LoC can detect sub-nanomolar concentrations of analytes in complex media. As a comparison with similar acoustic-wave based systems, this full-SAW platform outperforms the standard commercial gravimetric sensors (i.e., quartz-crystal-microbalances) and the more common Love-SAW biosensors. This full-SAW LoC could be further developed for the detection of biomarkers in biological fluids.

References

[1] M. Agostini, G. Greco, M. Cecchini, *A Rayleigh surface acoustic wave (R-SAW) resonator biosensor based on positive and negative reflectors with sub-nanomolar limit of detection*, Sensors and Actuators B: Chemical **254**, 1 (2018).

[2] M. Agostini, G. Greco, M. Cecchini, *Full-SAW Microfluidics-Based Lab-on-a-Chip for Biosensing*, IEEE Access **7**, 70901 (2019).