Nanomechanics and Nanomechanical Systems for Biology and Medicine

J. Tamayo,
O Malvar, J.J. Ruz, S. García-López, M.L. Yubero, A. Cano, V. Puerto, A. Sanz, E. Gil-Santos, D. Ramos, A. San Paulo, P.M. Kosaka & M. Calleja

Instituto de Micro y Nanotecnología(IMN-CNM), CSIC, Tres Cantos, Madrid, Spain.

jtamayo@imm.cnm.csic.es

Millions of people dies of cancer or infection every year in the first world and developing countries, respectively. Most of these lives could be saved if patients had timely access to early detection. Mass spectrometry and multiplexed immunoassays have rapidly developed during last years with improved limits of detection. Still these technologies can hardly probe the deepest region of the plasma, at concentrations below the pg/mL level in the case of cancer protein biomarkers or below 1000 virions per mL in the case of viral infections. Overcoming these detection limits is required for early detection [1]. This clearly indicates the need of implementing novel ultrasensitive techniques can cover the inaccessible regions of the plasma. We here propose biological detectors based on nanomechanical systems for discovery and detection of cancer protein biomarkers and pathogens in plasma. We review the modes of operation of these devices [2], putting our focus on recent developments on nanomechanical sandwich immunoassays [3] and nanomechanical spectrometry [4]. The first technique enables reproducible immunodetection of proteins at concentrations well below the pg/mL level, with a limit of detection on the verge of 10 ag/mL as well as the detection of one pathogen in 10 mL of plasma. The second technique enables the identification of individual pathogens by two physical coordinates, the mass and stiffness, instead of the mass-to-charge ratio of the protein constituents. This technology can enormously simplify the identification of pathogens such as virus and bacteria that are not accessible to current mass spectrometry detectors (http://viruscanproject.eu/). Finally, I will show some of our most recent developments for deciphering the role of the cell stiffness in cancer.

References

[1] Kosaka, P. M., Calleja, M. & Tamayo, J. Optomechanical devices for deep plasma cancer proteomics. Seminars in cancer biology 52, 26-38 (2018).

[2] Kosaka, P. M. et al. Detection of cancer biomarkers in serum using a hybrid mechanical and optoplasmonic nanosensor. Nature nanotechnology 9, 1047-1053 (2014).

[3]Kosaka, P. M., Pini, V., Calleja, M. & Tamayo, J. Ultrasensitive detection of HIV-1 p24 antigen by a hybrid nanomechanical-optoplasmonic platform with potential for detecting HIV-1 at first week after infection. PloS one 12, e0171899 (2017).

[4]Malvar, O. et al. Mass and stiffness spectrometry of nanoparticles and whole intact bacteria by multimode nanomechanical resonators. Nature communications 7, 13452 (2016).