Sensing towards the quantum limit: The convergence of molecular detection and artificial perceptrons

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The explosion in the number of newly available functional nanomaterials capable to sensitively change their conductance in the proximity of charged analytes in parallel with the advances in nanofabrication and nanoimaging techniques have made available and cost-efficient a realm of novel strategies to exponentially increase the selectivity and sensitivity boundaries of the electrical detection of nanoobjects. Highly personalized diseases diagnostics and ubiquitous environmental monitoring are only two possible applications which could address a number of societal challenges ahead related to human life in a strongly globalized world. Nanoparticles, nanowires, 2D materials are dominated by quantum effects and employing them as active elements in transducers for novel devices opens up enormous perspectives for innovative sensor systems. Such devices bear the potential not only to outperform conventional sensor technology with respect to speed, sensitivity, long time stability and signal reliability but even to define completely new application fields in platforms that are cost efficient, flexible and portable. After an introduction of the fundamental sensing mechanisms of nanomaterials-based devices, I will present the innovative design and fabrication strategies for our sensor elements. The close interaction of simulation and experiment allows us to elaborate tailored, but also transferable, technological functionalization strategies for different analytes to cover a wide range of application scenarios. In a strongly interdisciplinary approach, we face the need for sophisticated integration and packaging solutions of the sensors into versatile lab-on-a-chip systems. Integrating the latter in microfluidic setups to provide large numbers of different assays just-in-time directs our technology in direction of highly automatized analytic procedures. The results of our research prove the vast potential of our sensing approach but also show the enormous space for further fundamental developments to boost the concept of nanomaterials-based sensor technology to a powerful and smart analytic tool capable of multiplexed studies, providing and evaluating rich and robust statistical output data. Recent results on artificial neuron behavior in our sensor devices will help shedding new light on the role of nanoarchitectures for a true neuromorphic computing.

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