Advanced field effect control of semiconductor nanowire-based devices: electrolyte-gating for energy scavenging and harvesting

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The electrostatic control of semiconductor nanodevices by exploiting the field effect is ubiquitous in nanoscience and technology and traditionally follows the metal-oxide-semiconductor approach [1,2]. In parallel to the MOSFET approach, we explored different routes for achieving higher degree of field-effect manipulation in nanoscale semiconductor devices. One routes envisions the use of metallic finger gates to exploit the quantum confined Stark effect. This allowed us to achieve full control of individual charge and spin degrees of freedom in nanowire quantum dot systems [3] and to investigate the tunneling rates [4].

A second route, with a true paradigm change, envisions the use of soft-matter as the gate medium for applying impressively high static electric fields to semiconductors. This route exploits the way of iontronics to electrostatic gating, using the movement and arrangement of ions to build up an electric double layer that is the ultimate responsible for the electrostatic gating. Applied first to 2D materials, this approach is currently rising great promise for application also with other types of semiconductor nanostructures such as nanowires. Recently we proposed the use of ionic liquids as gate media for III-V semiconductor nanowire-based devices, demonstrating unprecedented gating efficiency and gate-induced change of the temperature behavior in the device [5]. We investigate the ionic liquid dynamics with atomistic simulations, correlating the hysteretic features to the microscopic parameters of the ionic liquid. Based on these results, we develop innovative device architectures exploiting the electric double layer gating for thermal management and energy harvesting at the nanoscale, towards the full benchmark of the thermoelectric figure of merit resorting to substrate-unbound nanowire-based device architectures [6,7].

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