NanoEnergy: challenges and opportunities

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Nano-energy devices have an outstanding potential for several applications, including but not limited to energy harvesting, innovative electronics (e.g. re-writable 2D electronics), and wireless nanotransducers.

In fact, besides classic scaling laws, at nanoscale it may be possible to take advantage of mechanisms of transduction that would be much less effective or would not be feasible at macroscale. As an example at nanoscale there can be more degrees of freedom in terms of structures, positions of contacts, types of mechanical input, dimensionalities, and shapes. As another example, materials that are not piezoelectric in their bulk form because of the opposite (i.e. canceling each other) contributions of adjacent atomic layers, can be piezoelectric as single atomic layers. Moreover, 2D materials can enable methods of fabrication or transduction that would not exist at macroscale (e.g. tunneling triboelectrification for creating re-writable floating ghost gates).

Despite these opportunities, it is very difficult to reproducibly fabricate high-performance and reliable nanoenergy devices. In this talk, I will first discuss some of the most important open challenges, including compatibility among different processes, spread and complexities associated with the statistically significant characterization of materials, real-time monitoring, homogeneity, and inaccurate geometrical characterizations. Afterward, I will discuss some strategies which, at least in some circumstances, can greatly help to overcome these challenges, including synthesis procedures with feedback and/or with dynamic adjustment of parameters, ultra-efficient wet-chemical syntheses, 3D reconstruction of quasi-1D single crystal nanostructures from conventional SEM images, tunneling triboelectrification for creating time-variant (rewritable) 2D electronics on demand, and twin-wire networks for effectively obtaining statistically significant electrical characterizations of materials.