Will composite nano-materials replace piezoelectric thin films for energy transduction?

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Piezoelectric thin films are widely used in applications ranging from MEMS and NEMS actuators to resonators [1]. Other applications include mechanical sensors and energy harvesters used typically for wireless sensor networks (WSNs), with the objective of monitoring human health, environment or structures such as airplanes or buildings [2]. The most-used piezoelectric materials in these applications are PZT and AlN thin films [1]. At the nanoscale, ZnO and GaN in the shape of nanowires (NWs) are the most studied materials because they are relatively easy to fabricate [3] and because of their electromechanical properties: higher flexibility and higher piezoelectric coefficients compared to their thin film counterparts [4]. Composite materials can be fabricated by integrating vertically grown piezoelectric NWs into an insulating matrix, a structure known as a VING (vertically integrated nano-generator), see Fig. 1(a). Proof-of-concept VING devices have been fabricated for sensing, with a sensitivity of 7 mV/mm [5], and for mechanical energy harvesting with an estimated generated power density of 0.2 W/cm^3 [6]. We will discuss several options to improve the performance of these composite materials. For instance, in compressive mode, the generated voltage and electrical energy can be increased up to 3 and 6 times, respectively, compared to their thin film counterparts, see Fig. 1(b) and (c) [7]. A different configuration is required if this structure is evaluated in flexion mode [8]. This can be translated into increased electrical energy (or power) when used for energy harvesting or increased sensitivity when used for mechanical sensing.

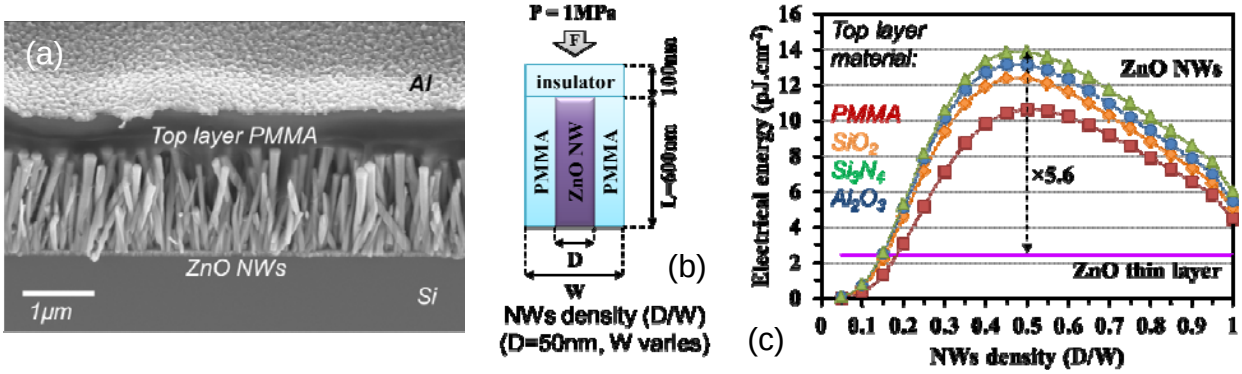

Fig. 1: VING structure and performances under compression. (a) SEM Image of a VING built on silicon, with ZnO NWs embedded in PMMA; (b) side view of a VING elementary cell, where D is the NW diameter and W is the cell width; (c) simulated energy generated by a VING cell in mechanical compression [7].

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