Unit-cell design of a force sensing device based on vertical piezoelectric nanowires

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Abstract

The efficiency of interconnected NW arrays for high sensitivity sensors and energy harvesters has already been investigated and validated[1]. Here, we present the results of multi-physics-static finite-element (FEM) simulations of the piezoelectric response of a force sensing device unit-cell (pixel) based on an individually contacted vertical nanowire (NW). The aim of this study is to establish reliable guidelines for micro-nanofabrication processing in order to increase the device sensitivity and reduce its variability in terms of piezoelectric pixel-to-pixel response, taking into account the different constitutive elements required by a real process.

The device pixel considered in this work includes a silicon substrate, a ZnO seed layer, a vertical ZnO NW and two metallic electrodes placed at the base of the NW. The pixel working principle is based on the collection of the charge generated in the bottom region of the NW upon bending [2]-[3]. This region, which is also called piezopotential inversion region[4], hosts the highest piezopotential values in our configuration.
Microfabrication was anticipated by studying the influence of several parameters such as the seed layer thickness (e_{ZnO}) or the distance δ between the electrodes and the base of the NW. Some experimental parameters are well controlled while others may suffer stronger variability inherent to device fabrication (such as δ).

We report the parametric study of the piezopotential evolution generated in the NW in the inversion region (V_{NW}) and in the electrodes (ΔV_c) as a function of e_{ZnO} and δ. We show that the collection efficiency ($\Delta V_c/V_{NW}$) is higher for thinner seed layers (up to 69% for e_{ZnO}=5nm). On the other hand, the efficiency drops from 64% to 33% when δ increases up to 3 nm and then slowly stabilizes for larger values of δ. The inversion region is somehow modified by the presence of electrodes and is observed to be confined between them. The impact of electrode dimensions is also studied, both in the $\delta=0$ and the $\delta>0$ cases.

Our model predictions can be used to improve the design of the elementary pixel, with the aim of keeping similar piezopotential generation with better micro/nanofabrication-processes compatibility and better tolerance to process variability.

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