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A Study on the Structure-Piezoresponse Property of a ZnO Nanobelt by In Situ Transmission Electron Microscopy

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The coupled piezoelectric and semiconducting properties of the NWs and NBs accommodate charge creation, accumulation, and discharge processes. Here, we report the mechanically triggered generation of piezoresponse in the uniaxially compressed piezoelectric ZnO nanobelts. In order to correlate the structure-piezoresponse property of a nanobelt, we conducted structural imaging simultaneously with the piezoresponse measurements using a Nanoindentor (NI) /TEM system (capacitance < 3 pF) with a conducting probe. These nanobelts self-ignites electrically once subjected to an externally applied uniaxial compressive load without any external bias.

Fig.1a shows the contact of a nanobelt with the NI tip in an uncompressed state. The ZnO nanobelt was moved against NI tip by the incremental movement of the piezodriven gold tip. As the ZnO nanobelt was strained, a few regions on the nanobelt showed local bright field contrast. The local changes observed in contrast may be related to atomic distortion resulting from stress concentration. Fig. 1b shows the nanobelt under slightly compressive state (strain, ε_1~5%) and the state of the nanobelt with strain, ε_2~10 % is shown in Fig. 1c. The nanobelt in the highest compression state (ε_3~25 %) is shown in Fig. 1d. The corresponding current variation in the uncompressed, increased compression and highly compressed and finally at the relaxed state (after unloading) is shown in Fig. 2.

As observed in Fig. 2, the current increases to its maximum value (~64.7 nA) under the compression mode with the applied load of ~9.98 μN. It should be noted that our ZnO nanobelts are short (~1-2 *μm*) as compared to the previously studied ZnO nanowire/nanobelts (~10-20 *μm*) [1, 2], and therefore compression of such nanobelts did not form physical bending on the nanobelt but rather uniaxial compression. The effect of loading mode on the output piezoelectric signal can be explained by taking into account the effect of deformation modes on the separation of positive and negative ionic charges (Zn^{2+} and O^{2-}).

In contrast to the bending mode, the magnitude of the electrical current increased with the increase of uniaxial compression, which indicates load-mode dependency of the detected current. The flow of electrical current through the ZnO nanobelt under applied stress was explained based on the separation of ionic charges along the two ends of the nanobelt due to the applied compressive force. The charge separation is expected to induce an internal electric field inside the nanobelt and facilitates the free charge carriers to move through the nanobelt. Due to the separation and accumulation of charges, the metal-semiconductor system becomes forward biased when contact is established, leading to the flow of electrons through the Schottky barrier.

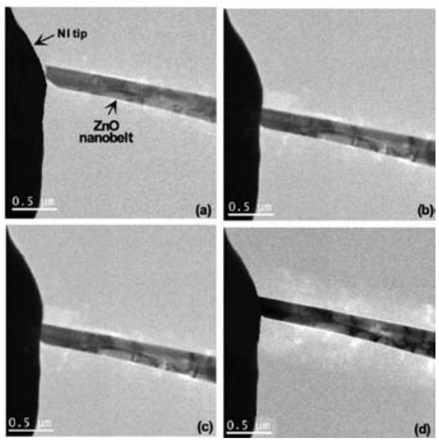

Fig. 1

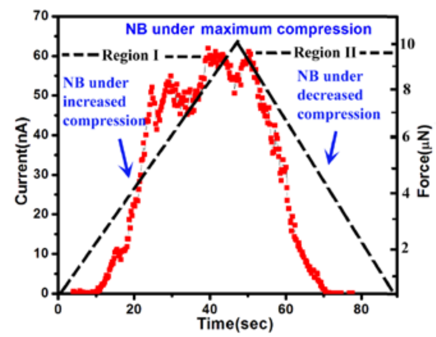

Fig.2

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