English

Research Express@NCKU Volume 5 Issue 4 - August 1, 2008
[http://research.ncku.edu.tw/re/articles/e/20080801/2.html]

A ZnO nanowire vacuum pressure sensor

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Nanotechnology 19 (2008) 095505 (4pp)

Vacuum pressure sensors are indispensable devices for applications such as thin film deposition, biomedical experiment and industrial process control. For example, thermopile [1], thermocouple [2] and super Pirani sensor [3] have all been extensively used in various industries. To minimize the size, it has also been shown that field emission (FE) devices, micro-opto-electro-mechanical system (MOEMS) devices [4] and micro-electro-mechanical system (MEMS) devices [5] are also capable of sensing vacuum pressure. However, the manufacturing processes of MOEMS and MEMS devices are complex in general. On the other hand, FE devices are operated at high electric fields. These drawbacks make it difficult to commercialize MOEMS, MEMS and FE devices as practical vacuum pressure sensors.

In recent years, one-dimensional (1D) ZnO nanowires (NWs) have attracted much attention due to their potential applications in nano-electronics and nano-optoelectronics. In this paper, we report a more detailed study on the properties of these lateral ZnO NWs and the fabrication of vacuum pressure sensors. Properties of the fabricated vacuum pressure sensors will also be discussed.

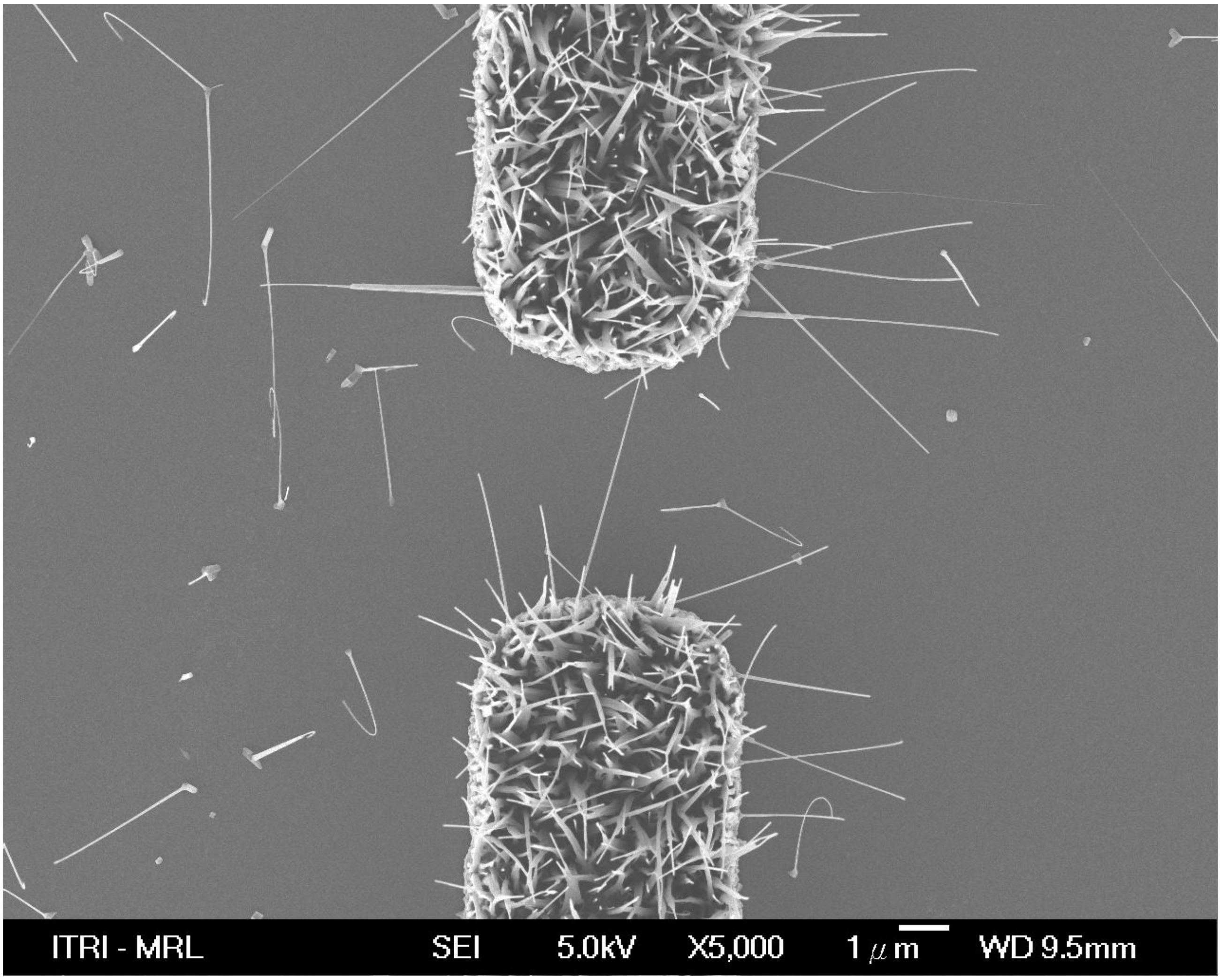

Figure 1 Top-view SEM micrograph of the NWs.

Figure 1 shows top-view SEM micrograph of the NWs. It was found that ZnO NWs were grown only on top of the patterned ZnO:Ga film while no NWs were grown directly on the glass substrate. Similar selective growth has been reported by Hsu et al. [6, 7]. It was also found that the ZnO NWs were randomly oriented and some NWs were even grown laterally. Furthermore, it was found that average length and average diameter of the laterally grown ZnO NWs were 5 μm and 30 nm, respectively. Notably, in some cases, a single NW bridged the two fingers, as shown in figure 1. As a result, the two electrodes were no longer electrically open. We can thus apply a constant voltage across the two electrodes and measure the corresponding current.

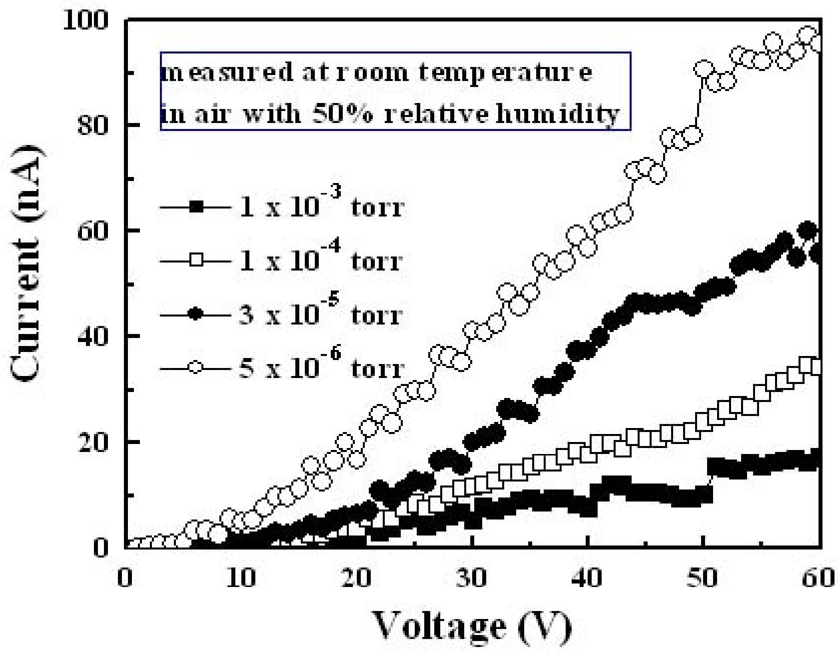

Figure 2 I-V characteristics of the sample measured at low pressures.

Figure 2 shows I-V characteristics of the sample measured at low pressures. It can be seen that measured current increased linearly with the applied bias for all four cases. Such an observation indicates that the NW bridged the two electrode remains pure resistive at low pressures. With the same applied bias, it was found that measured current increased as the chamber pressure was decreased. It is known that reactive oxygen species such as O_2^-, O^{2-} and O^- originated from oxygen gas and/or water vapor are adsorbed easily on ZnO surface. These adsorbed reactive oxygen species will become negatively charged by capturing a free electron from the n-type ZnO NW. Thus, a highly resistive depletion layer will be formed at the NW surface while the overall conductance of the NW will become smaller [8]. As we decreased the chamber pressure through pumping, we significantly reduced the amount of oxygen gas and water vapor. As a result, the ZnO NW bridged the two electrodes will become more electrically conductive. Thus, we observed an increased current at low chamber pressures. From the I-V relationships shown in figure 2, we can determine the resistance of the lateral ZnO NW as a function of chamber pressure, as shown in figure 3. For comparison, resistance of the NW measured at 760 Torr was also plotted. It was found that measured NW resistance increased logarithmically as the chamber pressure was increased.

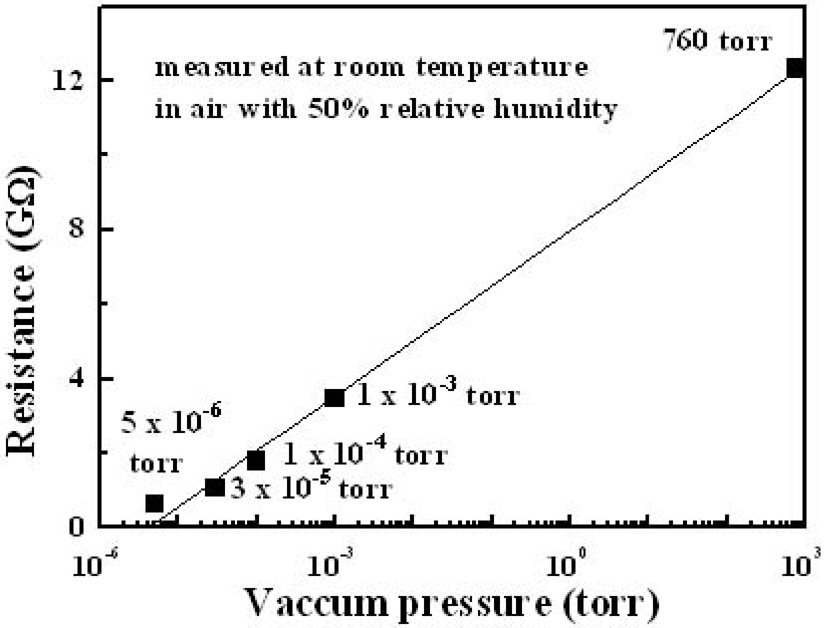

Figure 3 Measured resistance of the lateral ZnO NW as a function of chamber pressure.

In summary, we report the growth and characterization of lateral ZnO NWs on ZnO:Ga/glass templates. Vacuum pressure sensor was then fabricated using one single NW bridged across two electrodes. It was found that measured NW resistance increased logarithmically as the chamber pressure was increased.

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