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Growth and Characterization of Zn/ZnO Coreshell Nanowires by Plasma-Assisted Molecular Beam Epitaxy

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In recent years, many research groups have shown interest in one dimensional zinc oxide (ZnO) nanostructure such as nanowires (NWs) and nanorods. One dimensional nanostructure has the advantage of electron confinement in a single direction therefore creating a quantization of the density of states. Another advantage of NWs is the increase in surface area which makes it suitable for possible applications in the field of sensors, field emission and solar cell. ZnO has a large energy band-gap of 3.3 eV and an exciton binding energy of 60 meV which is two times higher than the value of thermal energy at room temperature (RT). As a result, high quality crystalline structures with stable exciton states are achievable at RT which can lead to highly efficient optical devices such as LED [1-2]. ZnO has been chosen as a possible material to replace indium tin oxide (ITO) because ZnO is much cheaper and environmental friendly due to the abundance of Zn and O resources. Undoped ZnO has an n-type character which is caused by the O vacancy and Zn interstitial therefore making ZnO a suitable transparent conductive oxide electrode. In this presentation, we report the growth of Zn/ZnO NWs by MBE.

(100) oriented Si wafer was used as the substrate for NWs growth. Knudsen cell (K-cell) with a tantalum crucible was used for evaporating the Zn buffer layer on Si substrate at 100°C. Subsequently, the Zn buffer layer was treated with O radicals supplied by ionizing 99.999% O_2 gas with a 300W RF-plasma source to produce Zn/ZnO NWs. Scanning electron microscopy (SEM) and transmission electron microscopy (TEM) techniques were used to study the microstructural properties of the Zn/ZnO NWs.

Fig.1 shows the SEM images of the NWs. It was observed that the diameter of the NWs ranged from 60-100nm and the length is approximately 3-12 μm. It was found that the length of the NWs increases with longer Zn deposition time but is not affected by the increase in O_2 plasma treatment time. NWs with length of up to 12μm have been successfully obtained with 10 minutes of Zn evaporation creating a high aspect ratio structure of more than 100. However, the growth direction of the NWs was not aligned.

Fig.2 shows the TEM image and diffraction pattern. From the diffraction pattern, Zn/ZnO NWs with $(1\bar{1}00)$ orientation can be clearly observed. In general, crystal growth of HCP structure exhibit c-plane orientation with the exception of epitaxial growth which produces m-plane when grown on r-plane sapphire[3]. However, the growth orientations of the NWs were mainly m- and a-plane but not c-plane. Hence it has been shown that m- and a-plane oriented Zn/ZnO NWs has been successfully obtained even though it was not epitaxial growth. From the diffraction pattern, it was also observed that both Zn and ZnO are aligned in each individual m- and a- plane.

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References

[1] A. Tsukazaki et al., Jpn. J. Appl. Phys. 44, pp L643 (2005)
[2] Z. Z. Ye et al., Appl. Phys. Lett. 91, 113503 (2007)
[3] N. Fujimura et al., J. Crystal Growth, 130, 269 (1993)

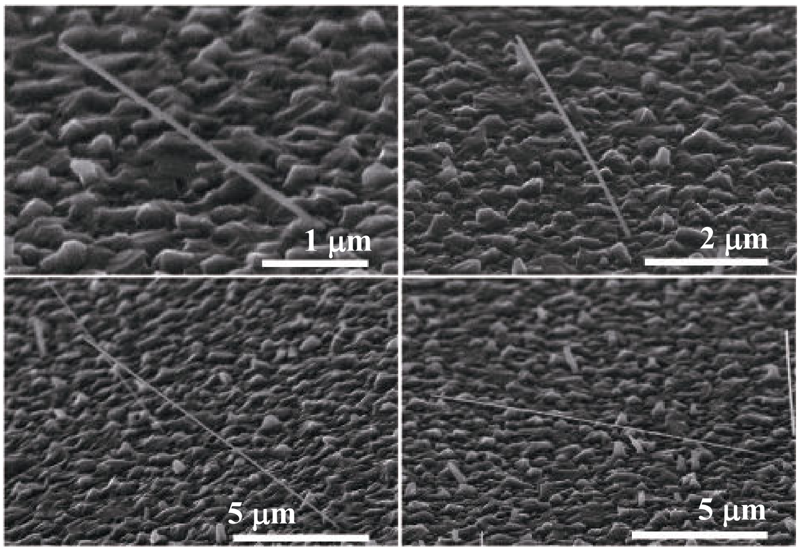

FIG. 1. SEM images of NWs. (a) Zn deposition of 5min and O_2 plasma irradiation of 10 min. (b) Zn deposition of 5min and O_2 plasma irradiation of 20 min. (c) Zn deposition of 10min and O_2 plasma irradiation of 10 min. (d) Zn deposition of 10min and O_2 plasma irradiation of 20 min.

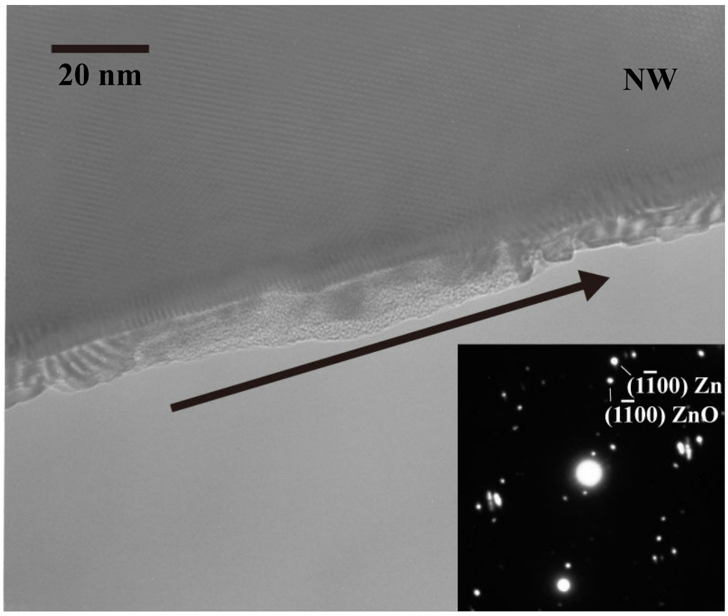

Fig 2. TEM image of the NW. Arrow indicates growth direction.