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Supporting Information

Fabrication of a novel hierarchical assembly of ZnO nanowires on WOx nanowhiskers for highly efficient field electron emission

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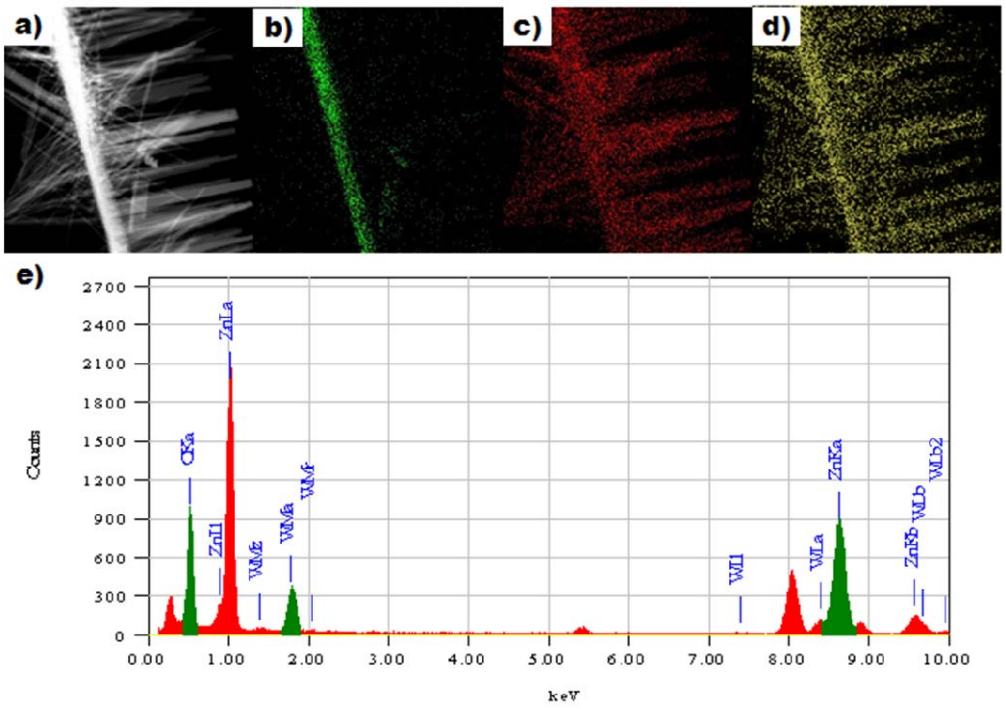

Fig.S1. TEM analysis of the hierarchical ZnO/WOx heteronanostructures (a) A high angular annual dark field (HAADF) scanning TEM image of single hierarchical ZnO/WO_x sample and scanning TEM-EDX elemental mapping images of (b) W, (c) Zn, and (d) O. (e) Energy dispersive spectra(EDS) recorded from the hierarchical ZnO/WOx heteronanostructures.

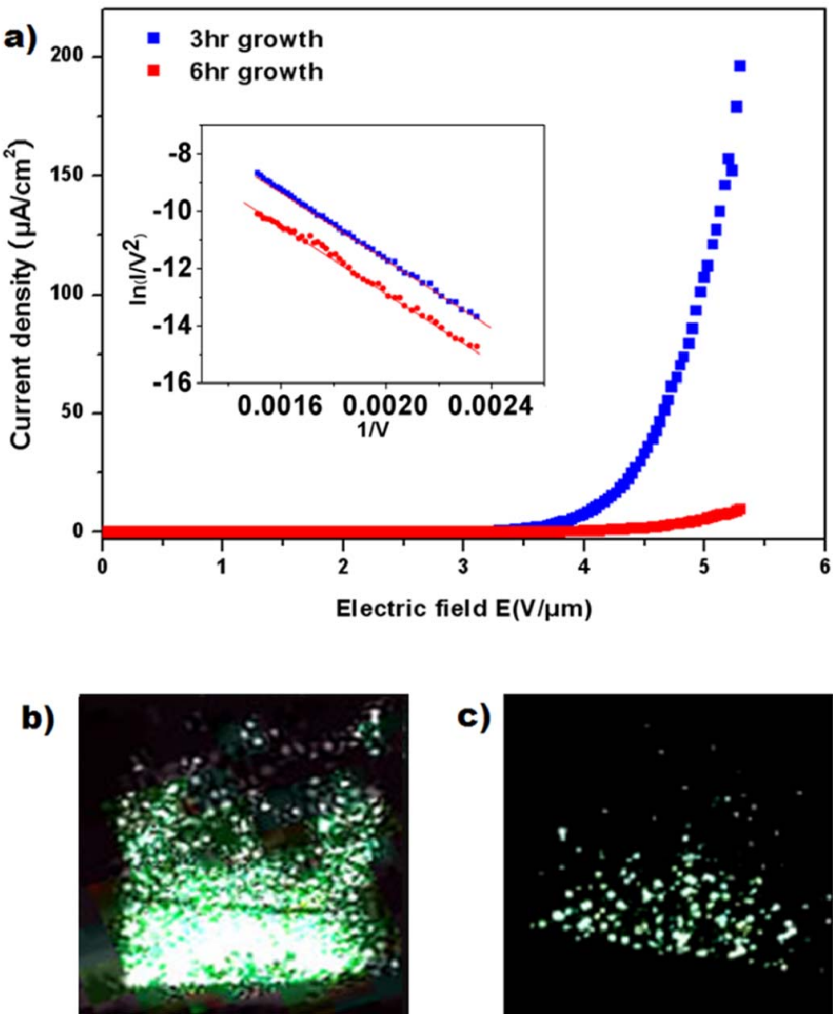

Fig.S2. Field-emission J-V curves: (a) ZnO nanowires/$W_{18}O_{49}$ nanowhisker arrays on tungsten substrates with different growth times for the ZnO NWs (3 hr and 6 hr).The inset includes the FN plots of both samples. (b) and (c) depict the field emission images of samples grown in 3 hr and 6 hr , respectively.

Figure S2 depicts the field emission characteristics of the ZnO/WO_x hierarchical nanostructures with different ZnO growth times of 3 hr and 4.5 hr at 95 ^oC using 10 mM $Zn(NO_3)_2$ with an ammonia solution. Although the ZnO nanowires were grown for longer time duration, the field emission current was decreased as observed from these results. The obtained turn-on field voltages at 10 mA/cm^2 were estimated to be 4.1 and 4.6 Vμm^{-1} for the samples that were grown at 3 hr and 4.5 hr, respectively. The reasons for the observed degradation in emission properties may be ascribed to screen effects due to an increased density of ZnO nanowires. A longer growth time produced ZnO nanowires having longer lengths with higher densities on the WO_x nanowhiskers, as confirmed by the SEM images. The field emission images of both samples were taken at 0.8 kV (5.3Vμm^{-1}). As seen in the field emission images of figure S2(b, c), the 3hr grown sample exhibited a brighter and more uniform emission in comparison to the 4.5 hr grown sample.