Online supporting information

Phosphorus doped $Zn_{1-x}Mg_xO$ nanowire arrays

S. S. Lin[1], J. I. Hong[1], J. H. Song[1], Y. Zhu[2], H. P. He[2], Z. Xu[2],
Y. G. Wei[1],Y. Ding[1], R. L. Snyder[1], and Z. L. Wang[1,*]

[1] School of Materials Science and Engineering, Georgia Institute of Technology, Atlanta, Georgia 30332-0245 USA

[2] State Key Laboratory of Silicon Materials, Zhejiang University, Hangzhou, 310027，China

* Corresponding authors: zhong.wang@mse.gatech.edu (ZLW)

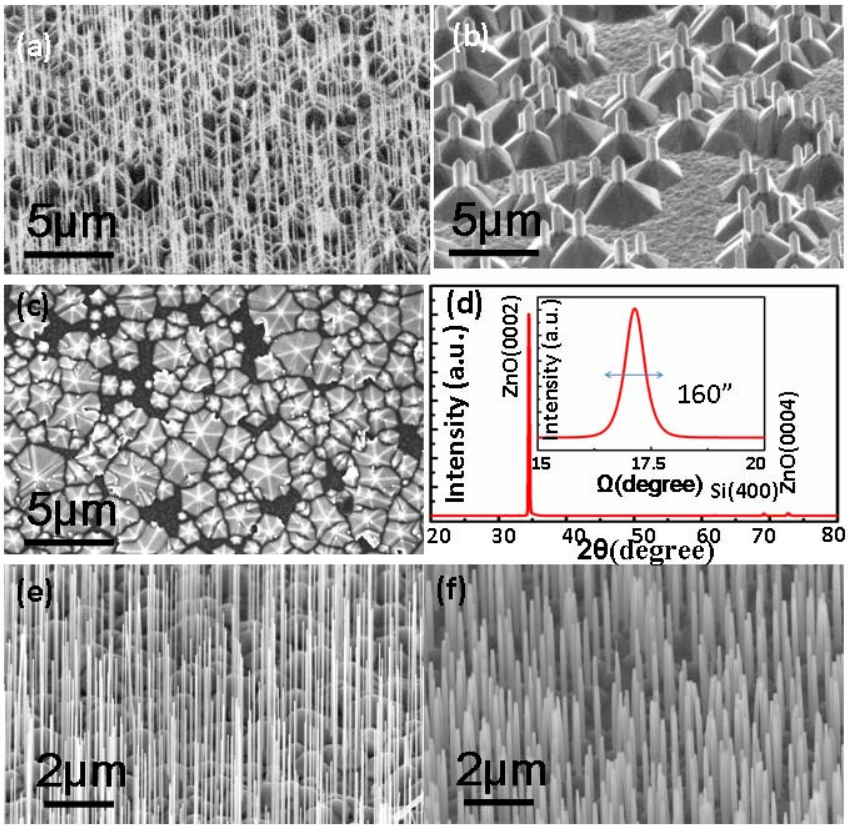

Figure S1. SEM and XRD data of NWs prepared from pure ZnO targets under 5 Torr of (a) pure argon; (b) argon mixed with oxygen with flow ratio of 1:1. (c) Top view of NWs in (a). (d) XRD spectra of NWs in (a), showing only ZnO and Si can be found; the inset show the rocking curve with FWHM of only 160". NWs prepared from 0.1 at.% lithium doped $Zn_{1-x}Mg_xO$ (x=0.05) ceramic target under 5 Torr of (e) pure argon, (f) argon mixed with oxygen with flow ratio of 6:1. We should point out that more than 15 targets with different kind of doping and Mg alloying have been adopted to fabricate NWs and the reproducibility is excellent for preparing NWs array.

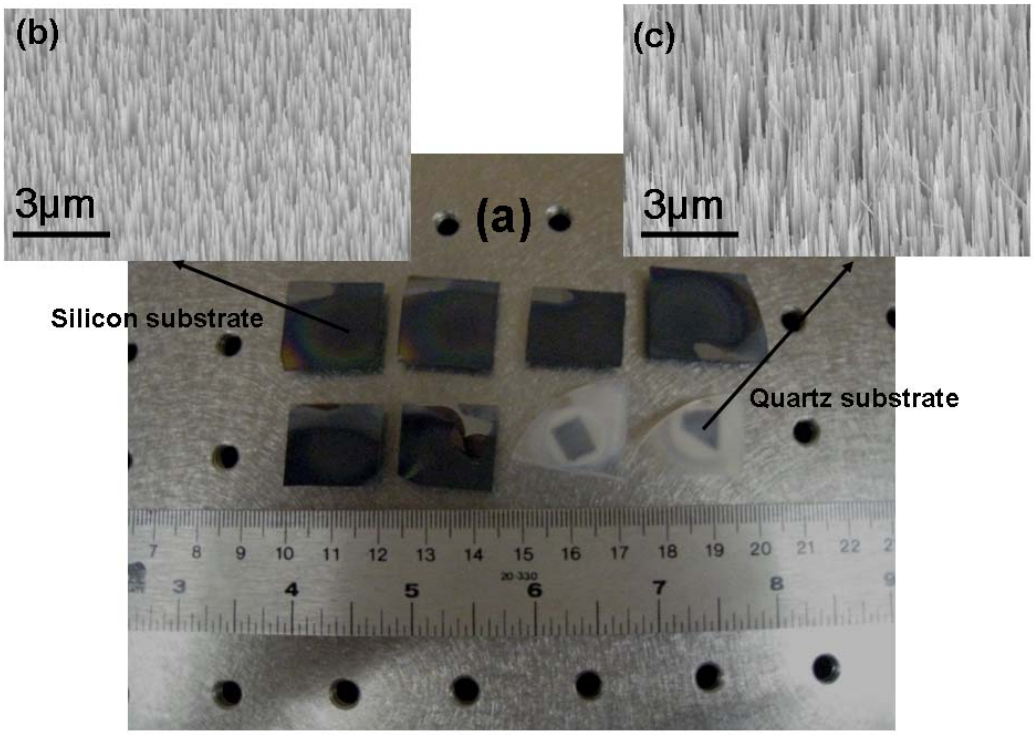

Figure S2. (a) Optical image of the NWs array samples prepared under repeated times for different substrates. The technique demonstrated here is a good method for reproducibly growth of NW arrays with a control over aspect ratio, density, band gap and/or conductivity type on cheap substrates, such as silicon and transparent quartz. Typical SEM images of phosphorus-doped $Zn_{1-x}Mg_xO$ NWs on (b) silicon substrate and (c) quartz substrate.

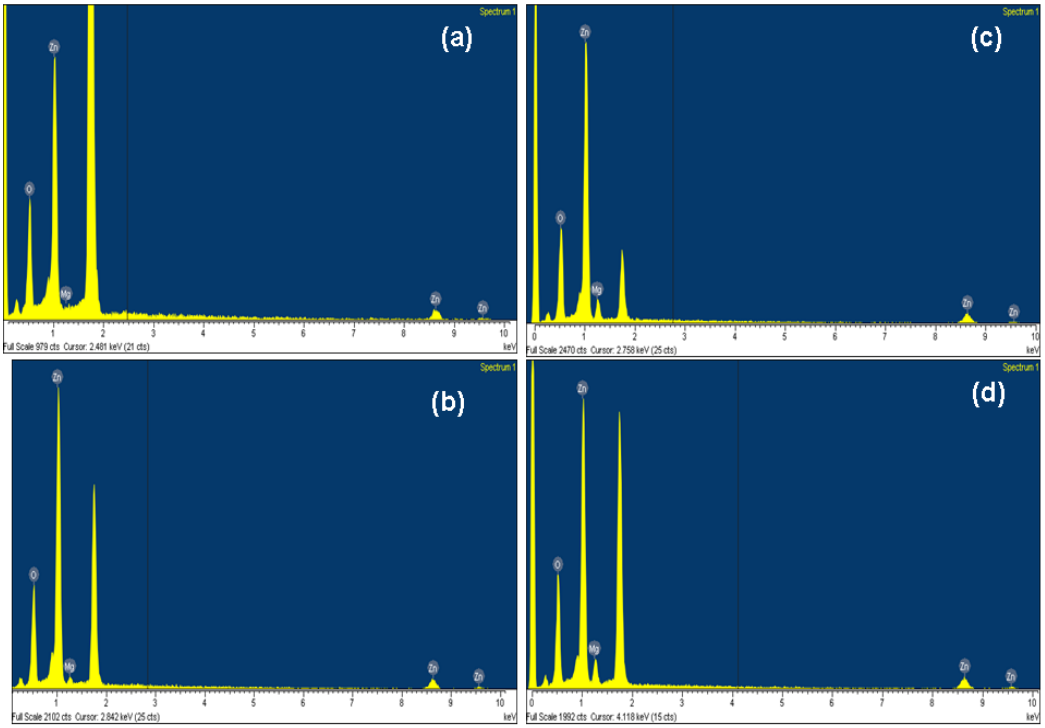

Figure S3. EDS spectra of $Zn_{1-x}Mg_xO$ NWs grow by ablating $Zn_{0.9}Mg_{0.1}O$ targets under different pressure (Ar:O=6:1). (a) 4.5 Torr (b) 4.0 Torr (c) 3.5 Torr, (d) 3.0 Torr. These spectra show that Mg signal enhances as growth pressure decreases. Quantitative analysis show that Mg contents are ~0, 2 at.%, 8 at.%, 19 at.% and 23 at.% for the $Zn_{1-x}Mg_xO$ NWs grown at 5.0, 4.5, 4.0, 3.5, 3.0 Torr, respectively.

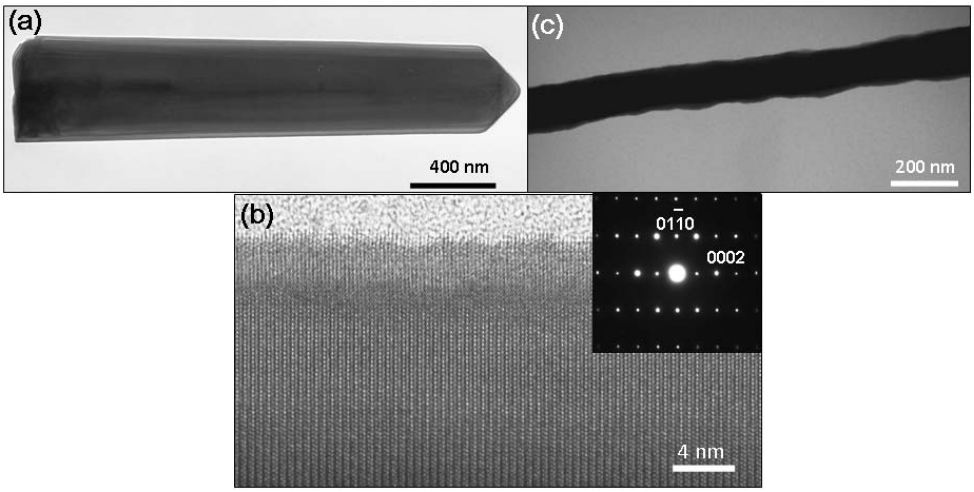

Figure S4. (a) Low-magnification transmission electron microscope (TEM) image a NW prepared under the pressure of 5.0 Torr; XPS and PL spectra shows it is pure ZnO NW (not shown here) (b) the corresponding High-resolution TEM image show that the NW has a smooth surface and good crystallinity. The lattice constant and electron diffraction shown as inset reveal that the NWs grow along [0001] direction. (c) Phosphorus-doped NWs show that the surface is rather rough, which reflects the morphology change caused by doping. This could be a character of the phosphorus-doped NWs in comparison to the undoped NWs.

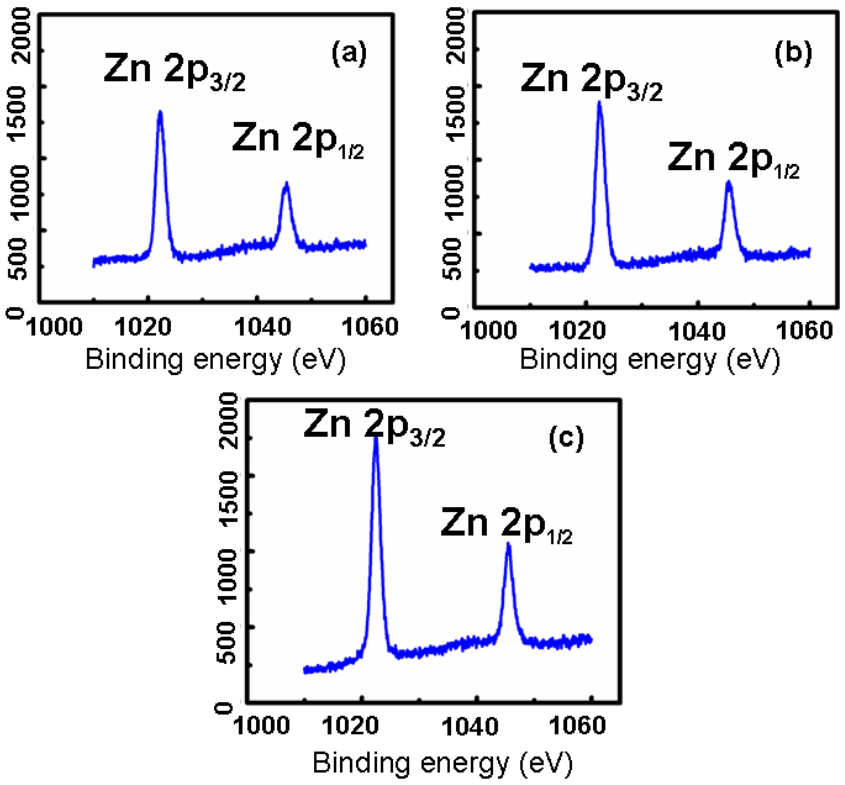

Figure S5. High-resolution XPS spectra of the Zn $2P_{3/2}$ and Zn $2P_{1/2}$ binding energies for phosphorus-doped NWs grown at different pressure ($Ar:O_2$=6:1) (a) 3.3 Torr (b) 4.0 Torr (c) 4.5 Torr. The signal counts increase slightly as the growth pressure increases. Combining the high-resolution XPS spectra of P_{2P} shown in Fig. 4b in the manuscript, we can conclude that the phosphorus doping concentration decreases as the growth pressure increases, similar to the case of Mg alloying (Fig. S3).