TEM Characterization of MBE-Grown Core/Shell (Zn,Mg)O Nanorods

Karin Pruessner[#,*], Young-Woo Heo[#], Michael J. Kaufman[#,**], Matt Chisholm[$], and David P. Norton[#]
[#]Department of Materials Science and Engineering, University of Florida, Gainesville, FL 32611; [$]Solid State Division, Oak Ridge National Lab, Oak Ridge, TN; *now at: Advanced Materials Research Institute (AMRI), University of New Orleans, New Orleans, LA 70148; **now at: University of North Texas, Denton, TX

ZnO has an interesting combination of properties that make it a promising candidate material for functional nanodevices. Possible applications include gas sensors, field emitters, and single-electron transistors. The band-gap of this n-type oxide semiconductor is 3.37 eV. The n-type behavior is due to Zn interstitials or hydrogen[1,2]. Modification of the bandgap can be achieved by doping. The fabrication of heterostructures exhibiting quantum confinement is of particular interest. Planar heterostructures have been reported, but heterostructures in nanowires are difficult to grow.[3,4,5]

We report here on the growth and characterization of core/shell (Zn,Mg)O nanorods. These were grown assisted by Ag catalyst particles on silicon wafers in an MBE system. Growth temperatures were typically in the range between 300 and 600 deg C. This process permits site-specific nucleation and growth of nanorods. Compositional modification of the rods was accomplished by simultaneous or sequential use of a Zn and a Mg source in the MBE chamber.

The microstructure of pure ZnO nanorods and of Mg-modified nanorods was characterized using scanning and transmission electron microscopy techniques. The (Zn,Mg)O nanorods were found to be typically 15-40 nm in diameter and more than 1 μm long. The growth direction of the nanorods is [0001] of the hexagonal wurtzite structure of ZnO. While pure ZnO nanowires are single crystalline with continuous lattice planes extending through the wire (Fig. 1), (Zn,Mg)O nanowires exhibit a core/shell structure: a single-crystalline core of hexagonal $(Zn_{1-x}Mg_x)O$ is surrounded by (Mg,Zn)O in the cubic rocksalt structure (Fig. 2). The shell has an epitactic orientation relationship to the core and misfit dislocation are found along the core/shell interface (Fig. 3). The growth mechanism and structural development of the nanorods and their effect on their properties will be discussed.

Acknowledgements:
The work was supported by the Army Research Office through Grant No. DAAD19-01-1-0603 and the National Science Foundation through Grant No. DMR-0305228.

References:

[1] D.C. Look, J.W. Hemsky, and J.R. Sizelove, Phys. *Rev. Lett.* **82** (1999) 2552.
[2] C.G. Van de Walle, *Phys. Rev. Lett.* **85** (2000) 1012.
[3] M.T. Björk, B.J. Ohlsson, T. Sass, A.I. Persson, C. Thelander, M.H. Magnusson, K. Deppert, L.R. Wallenberg, L. Samuelson, *Appl. Phys. Lett.* **80** (2002) 1058.
[4] Y. Wu, R. Fan, and P. Yang, *Nano Lett.* **2** (2002) 83.
[5] W.I. Park, G.-C. Yi, M.Y. Kim, and S.J. Pennycook, *Adv. Mater.* **15** (2003) 526.

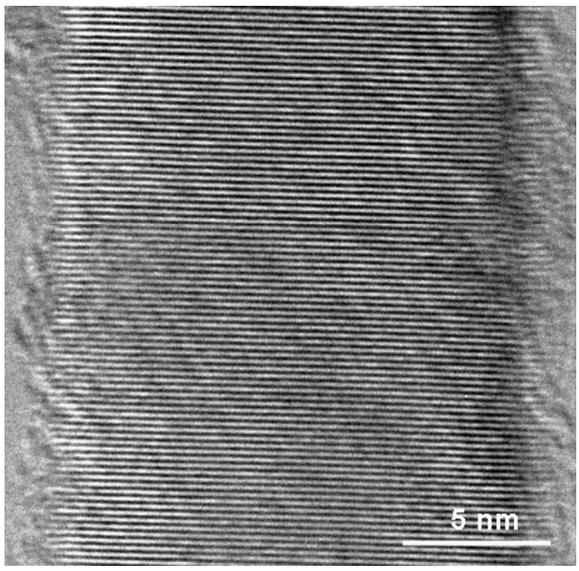

Fig. 1: HRTEM-image of a ZnO nanorod

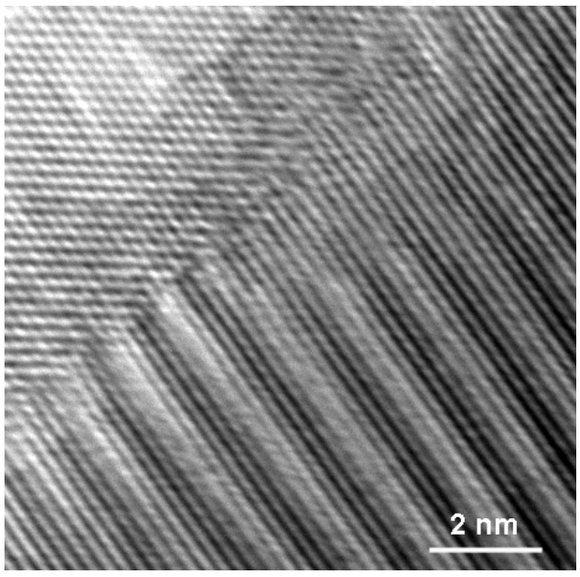

Fig. 2: HRTEM-image of a (Zn,Mg)O nanorod showing the core/shell structure

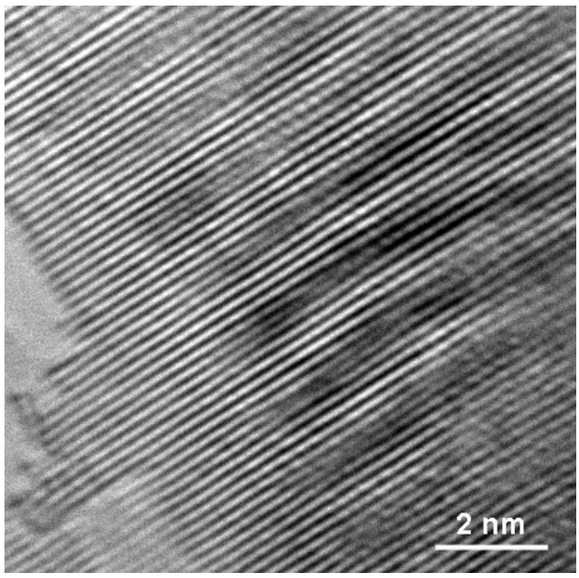

Fig. 3: HRTEM-image of a (Zn,Mg)O nanorod showing misfit dislocations along the core/shell interface