DOI: 10.1017/S1431927605504471
Microsc Microanal 11(Suppl 2), 2005
Copyright 2005 Microscopy Society of America

Mean Inner Potentials in Oxidized Germanium Nanowires by Electron Holography

Jayhoon Chung, Ji-Ping Zhou, and Lew Rabenberg

Texas Materials Institute, University of Texas at Austin, Austin, TX 78712

One-dimensional semiconductor nanowires are promising bottom-up elements for nanoelectronics. Radially modulated core/shell nanowires, composed of a core surrounded by a shell of a different material or doping, should have greater functionality for device applications [1]. Charge transport in such a core/shell nanowire depends on the local dopant distribution and potential near the interface and the free surface. Imaging of the electrostatic potential distribution within such a nanowire, which can be used to characterize the local electronic structure and electronic properties, can be very useful for device engineering of one-dimensional nanowires. In this communication, we present initial electron holography results on the determination of the mean inner potential distributions within oxidized Ge nanowires.

Electron holography is a TEM technique to record both amplitude and phase of the electron wave function exiting the specimen [2]. Since electron holography produces a quantitative measure of the phase shifts imposed on the electron wave, it enables the inner potential distribution within a nanostructure to be visualized two-dimensionally. For this work, holography parameters such as fringe width and fringe spacing were optimized using the approach of Wang et al. [3] in which the TEM objective lens is used to create a virtual image of the specimen.

Fig. 1 shows the reconstructed phase image of an intrinsic germanium nanowire (Ge diameter = 98.3 nm) [4] with a thick (27.9 nm) oxide layer, which was unwrapped from the phase image shown in the inset. Fig. 2 is a plot of phase shift as a function of the projected thickness for the same wire. In this plot, "thickness" is the length of a chord parallel to the electron trajectory. The A region represents the phase change due to the oxide shell only; in regions B and C, the electron propagates through oxide, germanium, and oxide before emerging; the fraction of this trajectory that is in the oxide shell is noted on the right coordinate. Using the slope, a, of the A regions for several oxidized nanowires, and the expression for the phase shift $\varphi(x,y) = C_E V_0 t(x,y)$, where C_E is a cluster of known constants, V_o is the mean inner potential, and t is the thickness, the mean inner potential of germanium oxide was determined to be 7.94 ±0.41V. As seen in Fig. 2 approaching the center of nanowire, the phase shift is toward tangent line b, representing the phase shift of the Ge core. We calculated the phase shift of region C for several nanowires using the slope, b, and then corrected the values for the core germanium using the average fraction of the shell layer and the mean inner potential of oxide. The mean inner potential of the germanium core was determined to be 15.22 ±0.51V. The black squares of Fig. 3 represent the simulated phase changes using $\varphi(x,y) = C_E V_0 t(x,y)$, and the white circles correspond to the measured phase data by electron holography. Fig. 3 shows that the simulated phase data coincide very well with the experimental data.

These results show that holography can be used to determine the potential distribution within a nanowire to an accuracy of better than 0.1V, and that the surface oxide layers must be taken into account when analyzing holograms from nanowires. This level of accuracy should be sufficient to

https://doi.org/10.1017/S1431927605504471 Published online by Cambridge University Press

characterize the potential distributions within heterostructure nanowires consisting of cores and shells composed of two different semiconductors.

References

[1] L. J. Lauhon, M. S. Gudiksen, D. Wang, and C. M. Lieber, Nature 420, 57 (2002)
[2] E. Volkl, L. F. Allard, and D. C. Joy, eds., Introduction to Electron Holography, Kluwer Academic (1999)
[3] Y. Y. Wang, M. Kawasaki, J. Bruley, A. Domenicucci, and J. Gaudiello, Ultramicroscopy 101, 63 (2004)
[4] The authors thank Tobias Hanrath and Brian Korgel for the Ge nanowires.

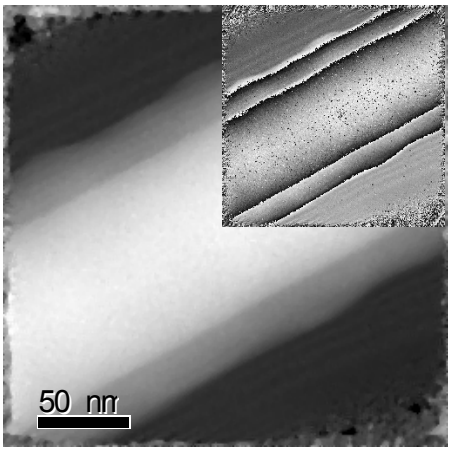

FIG. 1. Phase image of germanium nanowire with oxide layer

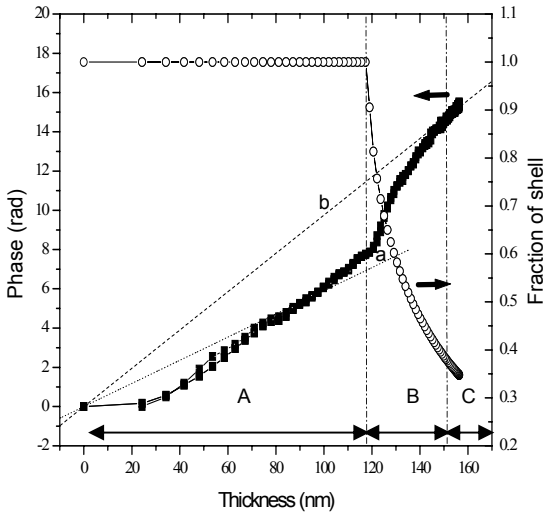

FIG. 2. Phase shift depending on the lateral position of germanium nanowire with oxide layer

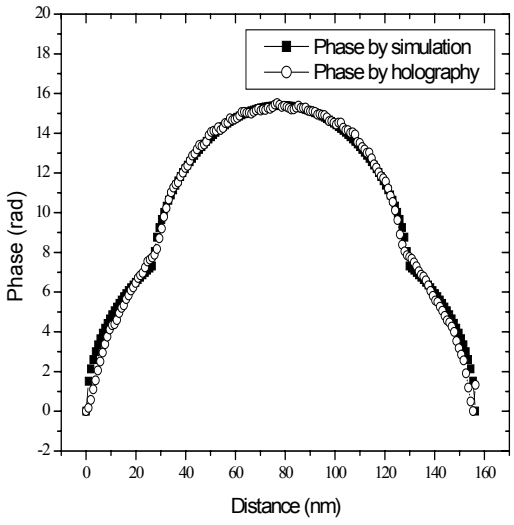

FIG. 3. Phase comparison of simulated and measured data

https://doi.org/10.1017/S1431927605504471 Published online by Cambridge University Press