Nanowire mechanical properties as revealed by in situ transmission electron microscopy

D.Tang, L. Fei, N. Fukata, N. Kawamoto, M. Mitome, Y. Bando, D. Golberg

International Center for Materials Nanoarchitectonics (MANA), National Institute for Materials Science (NIMS), Namiki 1-1, Tsukuba, Ibaraki 3050044, Japan

Email: golberg.dmitri@nims.go.jp

We applied in-situ HRTEM technique to directly study the mechanical properties of individual silicon and boron nanowires (NWs), Figs. 1 and 2, using various deformation modes, *e.g.* tension, bending and compression. The mean fracture strength of individual Si and B NWs was respectively measured to be 11.3 and 10.4 GPa in tensile tests. Si NWs were found to be brittle in tension but relatively ductile under bending. The tensile strength showed clear size dependence; the thinnest nanowires (~ 8 nm in diameter) were the toughest ones. Under a bending strain of <14 % Si NWs could repeatedly be bent without cracking along with a crystalline-to-amorphous phase transition. Under a larger strain of >20 % the cracks nucleated on the tensed side and propagated from the wire surface, whereas on the compressed side a plastic deformation took place due to dislocation activities and an amorphous transition. The averaged elastic modulus of B nanowires was calculated to be ~308 GPa. The maximum bending strain of B NWs reached 9.9 % and their ultimate bending stress arrived at ~36 GPa, which is higher than for Si and ZnO NWs. B NWs exhibited very high specific fracture strength of 3.9 GPa·cm^3/g and a specific elastic modulus of 130.6 GPa·cm^3/g.

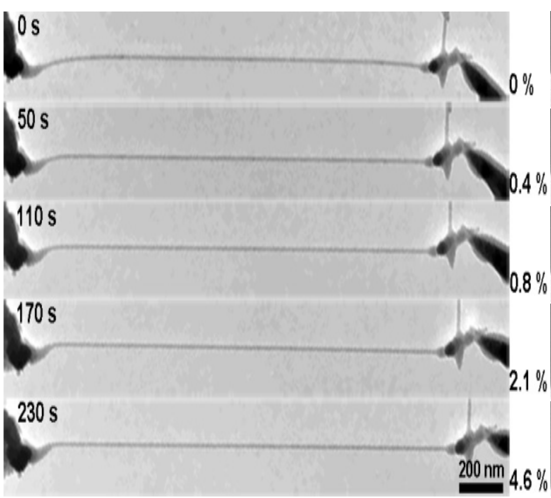

Figure 1: A tensile test on individual silicon nanowire in TEM.

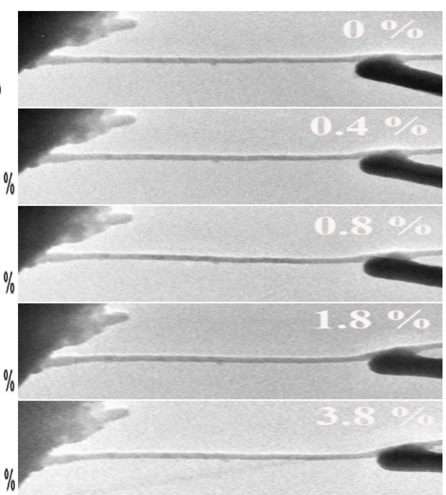

Figure 2: A tensile test on individual boron nanowire in TEM.

[1] D. Tang, C. Ren, M. Wang, X. Wei, N. Kawamoto, C. Liu, Y. Bando, M. Mitome, N. Fukata, and D. Golberg, *Nano Lett.* 12(4), 1898-1904 (2012).

[2] F. Liu, D. Tang, H. Gan, X.S. Mo, J. Chen, S. Deng, N. Xu, Y. Bando, and D. Golberg, *ACS Nano* (2013), *in press*.