Photoluminescence of Wet Chemically Etched Silicon Nanowires

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Anodeless Wet Chemical Etching (WCE) is a novel method to produce silicon nanowire (Si-NW) material from crystalline silicon wafers. Si-NWs built by WCE were investigated by photoluminescence (PL) measurements with excitation at 488 nm and power density of about 3.2 mW per mm^2. The as-prepared samples show strong visible PL at room temperature peaking at 1.5 eV to 1.6 eV. After treatment by hydrofluoric acid (HF) PL partly vanishes, but substantial PL remains, peaking now at 1.4 eV. In this paper the possible origins of PL of the Si-NW samples are investigated.

Experimental and Results

A series of samples was deposited with similar qualities (Fig. 1) but different etching times ranging from 1 min to 240 min. All samples were investigated by PL measurements prior and posterior to HF treatment. The PL peak energies increase with etching time for the as-prepared samples (Fig. 2), while the PL peaks stay pinned to 1.4 eV for the HF-treated ones.

Conclusions

We interpret the results in the framework of a two media model, assuming that one part of the PL contribution stems from quantum confined nanocrystalline states located at the Si-NW sidewalls and another part of the PL arising from SiO_x related states located around the Si-NW surfaces and on top of the sample surface. Considering the known possibilities of PL origin for various Si based material compositions (Fig. 3) we deduce a coherent picture describing the PL origin of the Si-NW based samples under investigation.

[Brandt1992] M. S. Brandt, H. D. Fuchs, M. Stutzmann, J. Weber, and M. Cardona, Solid State Communications 81, 307 (1992), Paper.
[Carius2000] R. Carius, Philosophical Magazine B-Physics Of Condensed Matter Statistical Mechanics Electronic Optical And Magnetic Properties 80, 741 (2000).
[Colder2004] A. Colder, F. Huisken, E. Trave, G. Ledoux, O. Guillois, C. Reynaud, H. Hofmeister, and E. Pippel, Nanotechnology 15, L1 (2004).
[Hibino1985] Y. Hibino, H. Hanafusa, and S. Sakaguchi, Applied Physics Letters 47, 1157 (1985).
[Huisken2002] F. Huisken, G. Ledoux, O. Guillois, and C. Reynaud, Advanced Materials 14, 1861 (2002).
[Nishikawa1991] H. Nishikawa, R. Nakamura, K. Nagasawa, Y. Ohki, and Y. Hama, Proceedings Of The 3rd International Conference On Properties And Applications Of Dielectric Materials, Vols 1 And 2 , 1032 (1991).
[Noe2007] P. Noe, J. Guignard, P. Gentile, E. Delamadeleine, V. Calvo, P. Ferret, F. Dhalluin, and T. Baron, Journal Of Applied Physics 102, 016103 (2007).
[Sivakov] V. A. Sivakov, F. Voigt, G. Bauer, and S. H. Christiansen, submitted to Nano Lett. (2010).
[Skuja1979] L. N. Skuja and A. R. Silin, Physica Status Solidi A-Applied Research 56, K11 (1979).
[Stutzmann1993] M. Stutzmann, M. S. Brandt, M. Rosenbauer, J. Weber, and H. D. Fuchs, Phys. Rev. B (Rapid Communications) 47, 4806 (1993).
[Voigt] F. Voigt, V. A. Sivakov, G. Bauer, and S. H. Christiansen, submitted to Appl. Phys. Lett. (2010).
[Wolkin1999] M. V. Wolkin, J. Jorne, P. M. Fauchet, G. Allan, and C. Delerue, Phys. Rev. Lett. 82, 197 (1999).

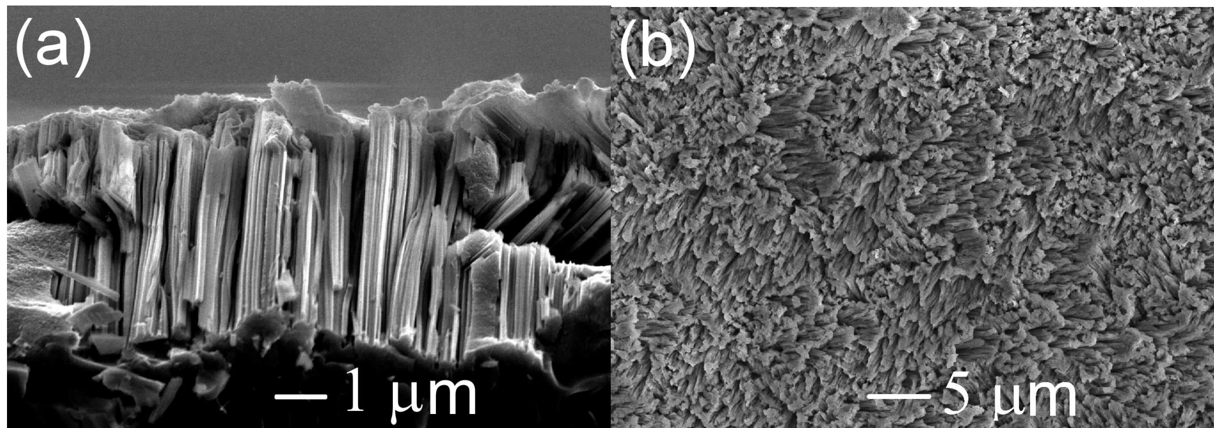

Figure 1: Scanning Electron Micrograph (SEM) of a Si-NW based sample. (a) Side view. (b) Top view.

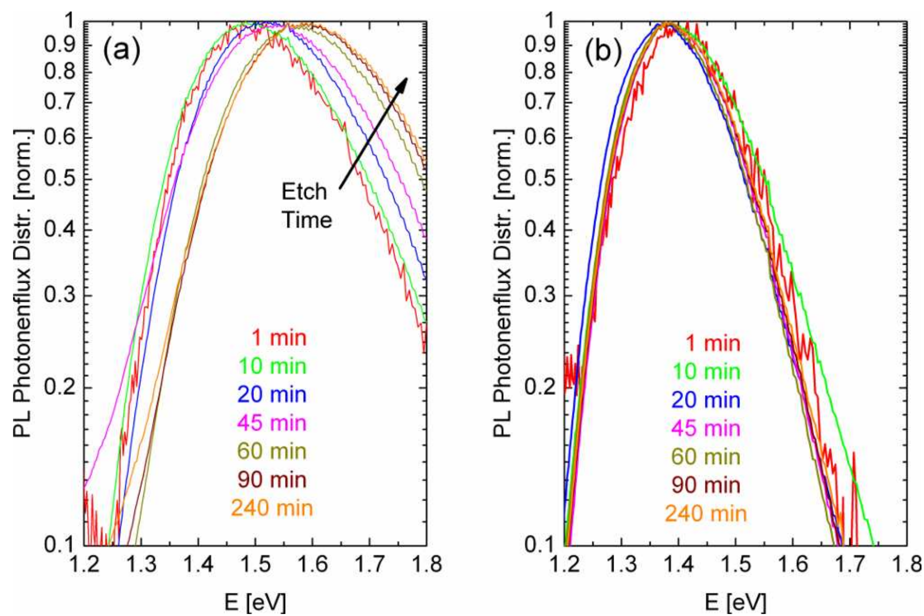

Figure 2: PL of the sample series with varying etching times. (a) As-prepared samples. (b) Samples treated by HF.

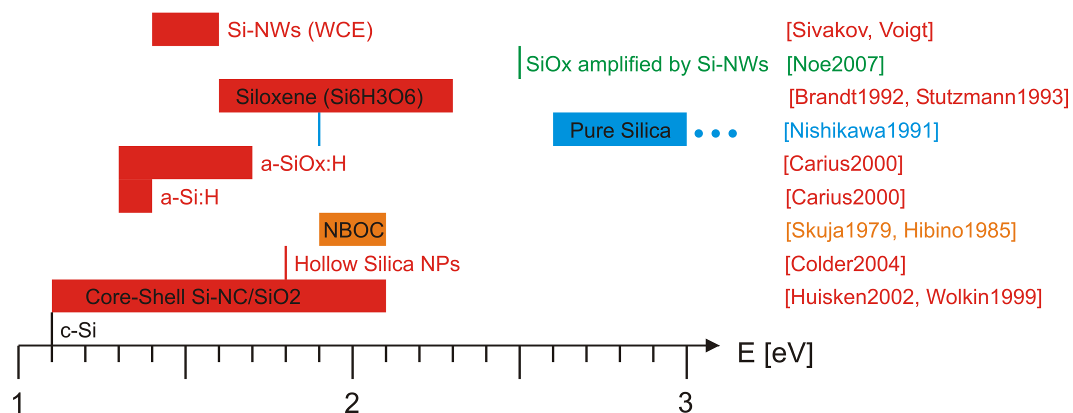

Figure 3: Various possible regions of PL peak emission of Si based material. References see above.