Influence of Surface Treatment and Passivation on Photoluminescence of Wet Chemically Etched Silicon

F. Voigt,[1, 2] V. Gerliz [2] V. G. H. Bauer,[2] R. Har-Lavan,[4] D. Cahen,[4] V. Sivakov,[1] and S. Christiansen[3, 1]

1) Institute of Photonic Technology (IPHT), Jena, Germany
2) Institute of Physics, Carl-von-Ossietzky University, Oldenburg, Germany
3) Max Planck Institute for the Science of Light, Erlangen, Germany
4) Weizmann Institute of Science, Department of Materials and Interfaces, Rehovot, Israel

Abstract
Wet Chemical Etching (WCE) of Silicon is an adaptable method to create either films of freestanding nanowires on a silicon substrate or to produce spongy porous silicon structures. Especially the first kind is a potential candidate for the creation of novel thin film solar cells. Some time ago we already concluded that a two-media model appropriately describes the photoluminescence (PL) on the as-prepared samples and the HF-dipped samples. Recently, several methods of surface treatment and passivation were performed on the WCE samples, such as HF dips, passivation by methoxy groups and measurements in dilute HF. Furthermore, some samples were entirely oxidized either in water vapour. Effects of these surface and volume structural changes on steady state PL and on PL decay will be discussed.

Experiments and Results
Either porous structures or free standing Si nanowires (Si-NWs) were produced by WCE of crystalline Si wafers. For weakly doped wafers (B, N_d = 10^{16} cm^{-3}) we obtained typical Si-NW structures, whereas from heavily doped ones (As, N_d = 10^{20} cm^{-3}) porous morphologies were created (see Fig. 1).

(a) (b)

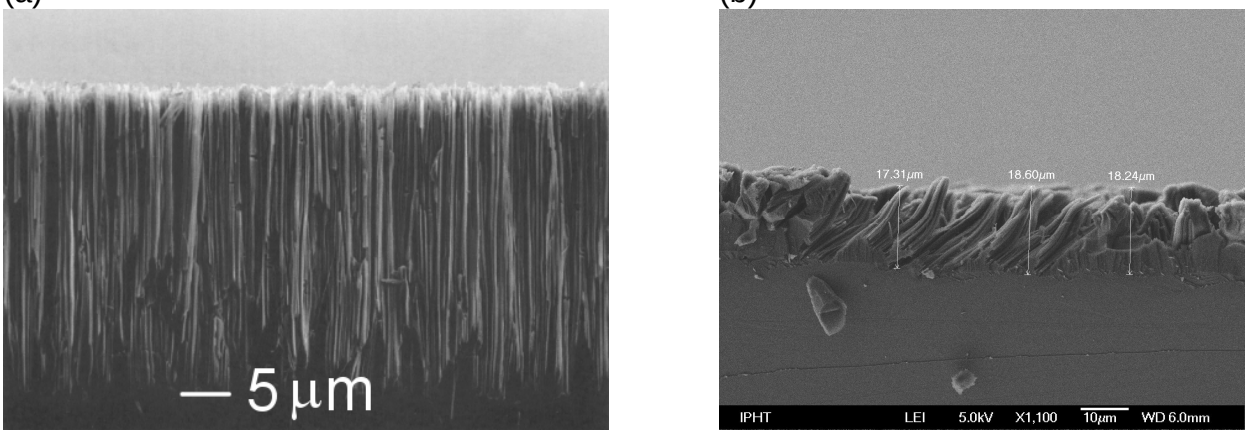

Figure 1: SEM micrographs of WCE samples. (a) Sample 1, created from weakly doped wafer, showing free standing Si-NWs. (b) Sample 2, produced from heavily doped wafer, porous structure.

Sample 1 showed very low PL, in contrast to sample 2, which emitted PL visible by the naked eye. PL decay transients could be recorded for sample 2, whereas intensity was too low for sample 1 in order to measure PL decay. By surface passivation PL intensity dropped more than one order of magnitude (see Fig. 2 a). In the decay traces a large difference in time constants is visible, depending on whether the samples were surface passivated by methoxy groups or not (see Fig. 2 a). A

different passivation method by forming gas anneal lead to similar transient PL behavior as for methoxy passivation (see Fig. 2 b).

Conclusions

We explain the PL contributions in different photon energy ranges in the framework of a two media model. In this concept we assume 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 arises from SiO_x related states located around the Si-NW surfaces and on top of the sample surface (Fig. 3). For the passivated samples PL via SiO_x related states is suppressed leading to a decrease in PL intensity. Furthermore the PL decay time constant decreases due to a change in the recombination mechanism.

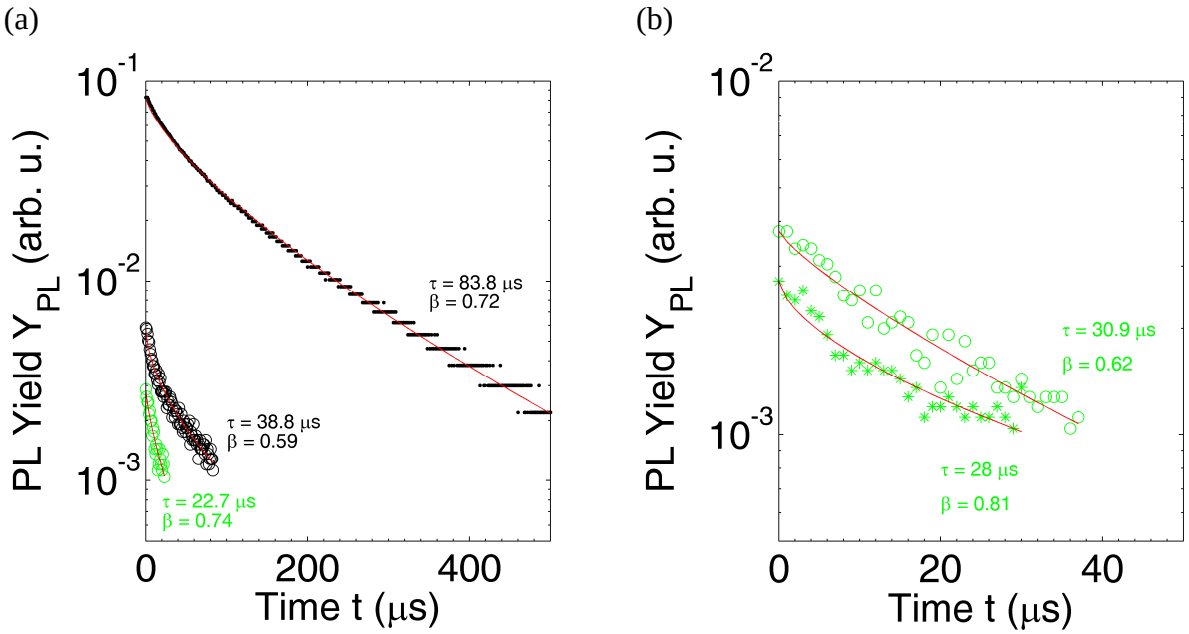

Figure 2: PL decay measured on passivated and non-passivated samples. Fits according to a stretched exponential are shown as red lines, and fit parameters indicated within the figures. (a) Decay traces of heavily doped samples (black: passivated (open circles) and non-pasivated (dots) state, green: passivated state).. (b) Effect of different passivations on same sample; open circles: methoxy passivated, stars: Forming gas passivated.

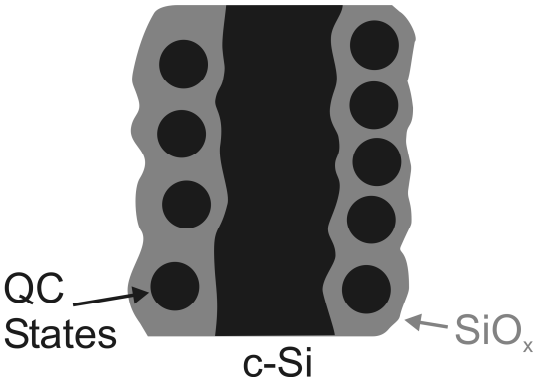

Figure 3: Two media model for PL of samples produced by WCE, schematic.