Electron escape from porous silicon nanostructure probed by liquid-phase luminescence quenching dynamics

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The recovery of the photoluminescence (PL) of p-type porous silicon (PSi), after its quenching by electron injected from the substrate, was investigated. Electrons, minority carriers, were injected into PSi by photo-generating (by front-side illumination) electron-hole pairs in the substrate (space-charge-region), which were then separated by applying an electric field, with electrons being forced into PSi. The PL was quenched as a result of an electron excess and fast Auger recombination. After electron injection was stopped (applied electric field and illumination removed), the PL recovered (example shown in Fig. 1) as electrons escaped from PSi back into the substrate by tunnelling through an energy barrier at the PSi/substrate interface. The energy barrier was tuned by growing an oxide in PSi using electrochemical oxidation. The higher the electron concentration injected in PSi, or the less transparent the energy barrier, the slower the PL recovery. The PL recovery was energy selective, the higher energy part of the spectrum recovering earlier then the lower energy part, in agreement with a band emptying itself from the top down. The effect of the quantity of electron injected into PSi was also studied and discussed. A simple model was proposed, and tested in various situations, to confirm the origin of the PL quenching by electron injection and the electron escape process by tunnelling to the substrate. In some cases, it took about 10 min or more for the PL to fully recover, showing that electrons can be stored in PSi for long periods of time without recombining or escaping to the electrolyte. The results suggest that the defect density in wet PSi must be very low, especially compared dry state, which could have practical implications, for example for photovoltaics.

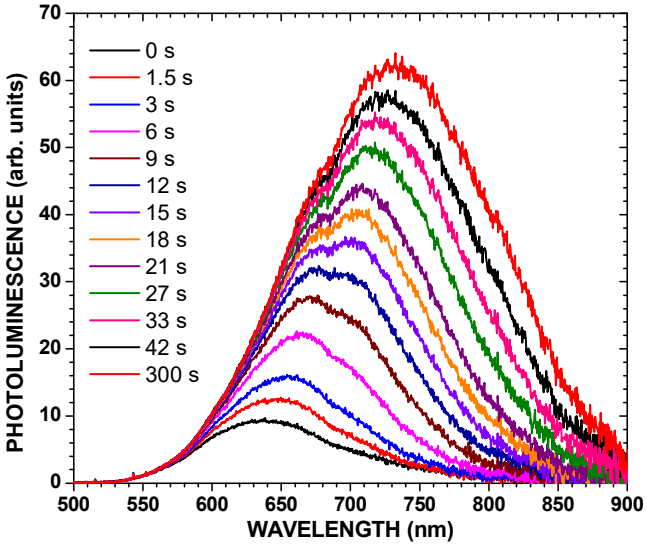

Figure 1: PL spectra during recovery (time indicated) after the injection of electrons in PSi was stopped, for a typical experiment where the energy barrier at the PSi/substrate interface was made less transparent by electrochemical oxidation.