Carrier Lifetimes in SOI Material

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Carrier lifetimes are an important indicator of the quality of semiconductor material. Low minority carrier lifetimes are indicative of defects such as metal contamination and excess recombination centers at stacking faults, decorated dislocations, or grain boundaries. Low generation lifetimes are also indicators of defect problems.

In SOI material, the recombination lifetime is a convolution of the "bulk" recombination in the film and the surface recombination at the two interfaces: the film / surface and the film / BOX. The Si film / BOX interface is similar to a gate oxide / Si interface and appears to have low recombination velocities in both bonded material and SIMOX. The upper interface therefore dominates the net recombination in SOI. Using photoconductivity decay excited by UV laser pulses, , the effective lifetime in unpassivated SOI material is less than 1 nanosecond and is essentially unmeasurable. Passivation by the formation of a gate oxide on the upper surface reduces the surface recombination velocity by orders of magnitude. Minority carrier lifetimes in SIMOX range from 100 to 600 nanoseconds, while lifetimes in bonded SOI have been as high as 1.1 microsecond.. These are still far less than typical lifetimes in bulk Si and indicate that even in passivated SOI layers, surface recombination still dominates. The measured decay profiles of 3 different SOI wafers are shown in Figure 1.

The recombination lifetime in the bulk substrate below the BOX can be measured using longer wavelength pulses where the light is weakly absorbed in the Si film. The BOX/substrate interface is highly passivated by the buried oxide and the lifetime is a true indication of the bulk. Figure 2 shows the PC decay for SOI wafers measured at long wavelength with different levels of Cu contamination as measured by SIMS [1]. The lifetime of 65 microseconds in the low Cu case is typical of "clean" bulk material after either SIMOX or bonding processing. The lifetime in the high Cu case of 17 microseconds is typical of metal contaminated SOI substrates. Similar effects have been observed in Ni contaminated material.

The generation lifetime is a far better parameter to determine the quality of the Si film than the recombination lifetime. The recombination lifetime is dominated by the surfaces, as mentioned above, but the generation lifetime is nearly independent of the surface processes and the net generation lifetime is a good measure of events taking place in the "bulk" of the Si film , as long as the electrical contacts are not a significant source of minority carriers. The pseudo-FET [2,3] is an excellent device for measuring the drain current decay after the gate voltage is removed. This device places ohmic contacts on the Si surface to act as source and drain and uses the BOX as the gate oxide. Figure 3 shows the drain current decay for pseudo-FETs made to a SIMOX wafer. The decay represents the generation lifetime magnified by (Na/Ni) which is over 10^5 at room temperature. Both the hole and electron generation lifetimes can be obtained by appropriate choice of the ohmic contact metallurgy. The decay rates are highly temperature sensitive, decreasing by several orders of magnitude for a 50° C rise in temperature, making wafer mapping possible.

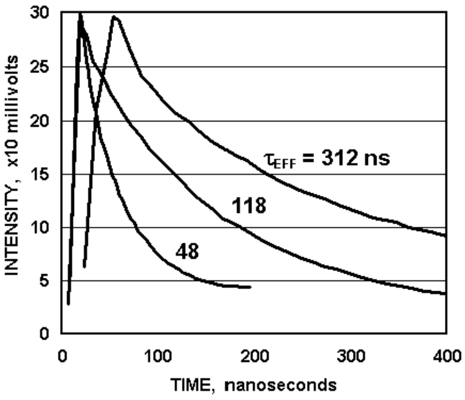

Figure 1. PC decay profiles of the Si film in 3 SOI wafers excited by UV laser pulses.

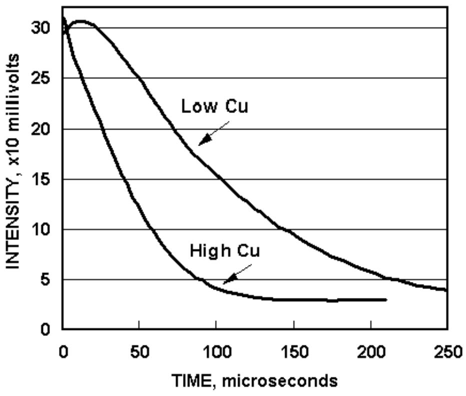

Figure 2. PC decay profiles for long wavelength excitation in metal-contaminated SOI substrates.

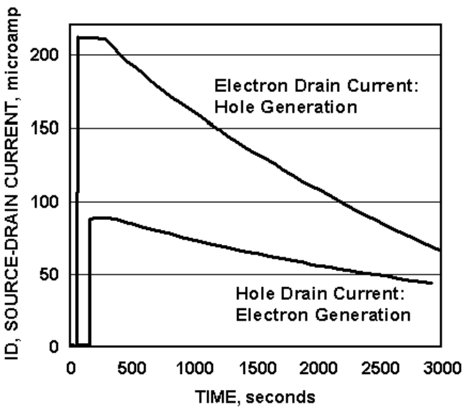

Figure 3. Drain current decay after gate voltage removal using a pseudo-FET device, showing both hole and electron generation.

References.

1. Paul Ronsheim, private communication.

2. S. Cristoloveanu, D. Munteanu, and M. Liu, IEEE Trans. Elect. Dev. 47, 1018 (2000).

3. H.J. Hovel, Proc. IEEE 1997 Intern. SOI Conf., pg. 180, (Oct. 1997); Sol. State Elects., Submitted.