

Comparison of μ -PCD and SPV

Both the μ -PCD and the SPV measurement techniques are frequently used to determine the quality of silicon and to detect heavy metal contamination. SPV measures a bulk property of silicon called diffusion length, whereas μ -PCD measures a bulk property called carrier lifetime. Lifetime and diffusion length are mathematically related as follows. $L_D = \sqrt{D * \tau}$, where τ is the carrier lifetime, D is the diffusion constant of holes or electrons, and L_D is the diffusion length. The two measurement techniques are based on completely different theory and have very different strengths and weaknesses, making μ -PCD the better choice in some applications and SPV the better choice in other applications. Semilab is the only company that offers both the μ -PCD and the SPV techniques, and therefore Semilab can offer a completely unbiased explanation of the appropriate applications and limitations of each technique. What follows is, first, a summary of the conclusions, and then a bit of theory to explain some of the limitations.

μ -PCD is generally more repeatable, faster, and offers a smaller measurement area, which results in fast, high resolution maps. The disadvantage of μ -PCD is that measurements can be strongly influenced by the passivation of the wafer surfaces and the wafer thickness. With low lifetimes and thick wafers, the effect is negligible, but when the lifetime is high, the combination of a poor surface and a thin wafer can dominate the measurement. Thus, in most cases μ -PCD is the preferred choice when measuring wafers with well-passivated surfaces, such wafers that have been oxidized in a furnace. With very well-passivated surfaces, even the effect of the wafer thickness becomes negligible, and thin wafers can be measured using μ -PCD.

SPV is usually the preferred choice for measuring bare wafers, without passivated surfaces. The caution is that a good SPV measurement requires that the wafer thickness be greater than 2-3 times the diffusion length. Thus, neither technique works well when measuring a bare wafer with a long diffusion length / high lifetime. μ -PCD would require passivating the surface, and SPV would require increasing the wafer thickness. The latter is clearly not possible, so the only option to measure long diffusion length / high lifetime of a bare wafer is to passivate the surface. The quality of the required passivation depends on how long the diffusion length is.

Both techniques can be used to detect, identify, and quantify iron. SPV is much more sensitive to oxygen precipitates than μ -PCD, which is an advantage when trying to detect oxygen precipitates or BMDs (Bulk Micro Defects) but is a disadvantage when trying to detect iron in wafers with dissolved and precipitated oxygen. Thus, iron measurements via SPV should be done using wafers with no or very low oxygen content, *e.g.* Float Zone.

Both techniques are sensitive to contaminants such as Cu, Ni, Co, Cr, etc. – elements from the center of the periodic table. Empirical results of experiments done by multiple companies have shown that μ -PCD generally does a better job at detecting these elements than SPV.

Carrier lifetime is measured by creating additional carriers, via light, and measuring how long it takes for the excess carriers to recombine. Diffusion length is measured by creating additional carriers, via light, and measuring how successful they are in diffusing to the wafer surface. (For a basic explanation of each of these techniques, see Technical Notes 200 and 201.) SPV is a “low injection level” technique, which means that the number of photon used to create additional carriers is comparable to the minority carrier concentration. μ -PCD is a “high injection level”

technique, which means that the number of photons used to create excess carriers is comparable to the concentration of majority carriers. It turns out that different injection levels result in different diffusion constants, different diffusion lengths, and therefore different lifetimes. Further, the effect of injection level is different for different factors causing a reduction in lifetime or diffusion length. Thus, the simple mathematical relationship, written at the beginning of this note, between diffusion length and lifetime ($L_D = \sqrt{D * \tau}$) usually cannot easily be used to compare lifetime, measured via μ -PCD, with diffusion length, measured via SPV.

The chart below illustrates the effect of injection level on detecting oxygen precipitates, iron-boron pairs, and interstitial Fe.

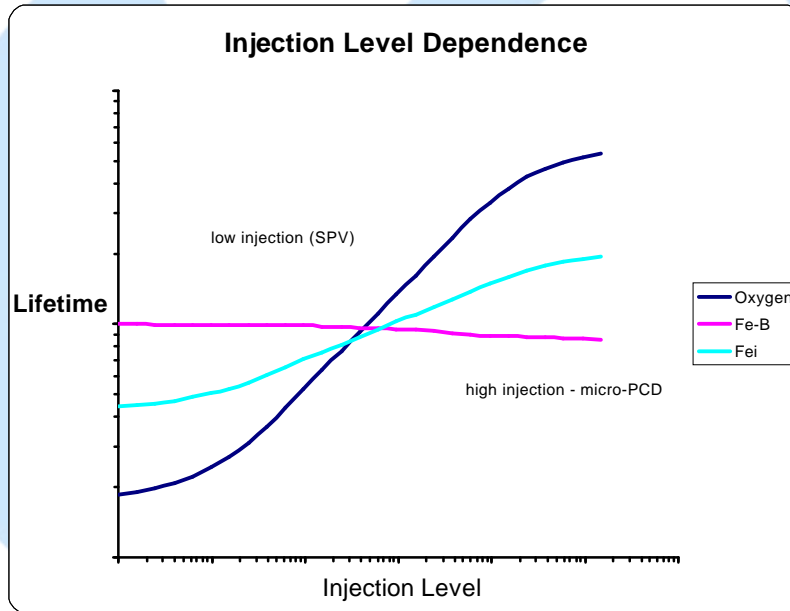


Figure 1 – Injection level dependence of oxygen, Fe-B, and Fei

The factor that is the most efficient lifetime killer dominates the measurement and represents the easiest factor to detect. Thus, SPV is very sensitive to oxygen, whereas μ -PCD is not. Note that both techniques can detect the difference between iron-boron pairs (Fe-B) and interstitial iron (Fei), but the effect on the measurement is completely opposite. With SPV, interstitial iron has a lower lifetime (and shorter diffusion length) than Fe-B, whereas with μ -PCD converting Fe-B to Fei actually results in longer lifetime.

Summarizing, SPV is preferred when the wafer surface is not passivated or when it is important to detect oxygen precipitates. It should not be used when the wafer thickness is less than three times the diffusion length. In other applications, μ -PCD is preferred.