Detection of iron contamination in internally gettered p-type silicon wafer by lifetime measurements

A. Haarahiltunen, H. Väinölä, M. Yli-Koski, E. Saarnilehto, and J. Sinkkonen

Electron Physics Laboratory, Department of Electrical and Communications Engineering, Helsinki University of Technology, P.O. BOX 3500, 02015-HUT, Finland

Iron is one of the most common transition metal contaminant in silicon wafer. It is relatively fast diffusing and it is a strong recombination center, thus, it has deleterious effects on the device performance even when present in small concentrations. In internal gettering iron is captured by oxide precipitates and extended defects which are formed conventionally in the bulk of wafer by a three-step high - low - high anneal (1).

There are several well-known detection methods for iron, such as standard lifetime measurements techniques (SPV and μ-PCD)(2,3) and DLTS (4). The SPV and μ-PCD are indirect measurements: iron concentration is determined from the change in the diffusion length or the lifetime after breaking iron-boron pairs. The DLTS can be considered as a direct measurement as it determines the density of states in the band gap, which can be identified to be either iron or iron-boron pairs.

The DLTS is often used when characterizing the internal gettering efficiency of iron (5-7). The DLTS has high sensitivity for iron and oxide precipitates have no effects on the measurements. However, DLTS is hardly suitable for large area detection i.e. wafer mapping, as an additional contact preparation is needed.

The SPV and μ-PCD measurements do not need any additional sample preparation and wafers can be mapped routinely. This enables the possibility to detect non-homogeneities in the gettering efficiency. If it is assumed that a procedure for breaking the iron-boron pairs does not dissolve precipitated iron nor change the recombination properties of oxide precipitates, the iron concentration can be measured by SPV and μ-PCD (8-10) in an internally gettered wafer.

In this work we have studied the effect of the high-low-high process on iron detection by SPV and μ-PCD. After the high-low-high annealing wafers were iron contaminated to the level of 1-2E13 cm^{-3}. Different kinds of gettering treatments (10) were applied to obtain a wide range of dissolved iron concentration. The reference measurements were done by DLTS.

Ideally the SPV and the μ-PCD results are not affected by backround diffusion length (lifetime) as in subtraction it is cancelled out. In practice the detection is limited by the backround lifetime (diffusion length) caused by recombination at oxide precipitates and by the resolution of measurement system. Figure 1 shows the calculated detection limits for μ-PCD with different backround recombination level. The curve is calculated by using capture coefficient 3.4E-8 cm^{3}s^{-1} (2) for FeB-pairs and conversion factor of 3.4E13 (11) after breaking FeB-pairs to Fe$_i$. In the SPV the width of the precipitate free zone limits the backround diffusion length and hence the detection limit is higher. The effect of low backround lifetime in μ-PCD measurement is illustrated in table I.

1. Borghesi, A., Pivac, B., Sassella, A. and Stella, A., *J. Appl. Phys,*. **77**, 4169 (1995).
2. Yli-Koski, M., Palokangas, M., Sokolov, V., Storgårds, J., Väinölä, H., Holmberg, H. and Sinkkonen, J., *Physica Scripta* **T101**, 86 (2002).
3. Kempf, A., Blöchl, P., Huber, A., Fabry, L. and Meinecke, L., in *Recombination Lifetime Measurements in Silicon*, Gupta, D. C., Bacher, F. R. and Hughes, W. M., Editors, p. 259,ASTM,West Conshohocken (1998).
4. Lang, D. V., *J. Appl. Phys*. **45**, 3023 (1974).
5. Aoki, M., Hara, A. and Ohsawa, A., *Japn. J. Appl. Phys*., **30**, 3580 (1991).
6. Aoki, M. and Hara, A., *J. Appl. Phys.*, **74**, 1440 (1993).
7. Hieslmair, H.,Istratov, A., A., Mchugo, S. A., Flink, C., Heiser, T. and Weber, E. R., *Appl. Phys. Lett*., **72**, 1460 (1998).
8. Haarahiltunen, A., Yli-Koski, M., Väinölä, H., Palokangas, M., Saarnilehto, E., and Sinkkonen, J., *Physica Scripta T* (accepted for publication).
9. Shabani, M. B., Shiina, Y., Shimanuki, S. and Kirscht, F. G., *Sol. State Phen*.. **82-84**, 331 (2002).
10. Väinölä, H., Haarahiltunen, A., Saarnilehto, E., Yli-Koski, M., Sinkkonen, J. and Anttila, O., ECS 2004.
11. Zoth, G. and Bergholz, W., J. Apll. Phys **67**, 6764 (1990).

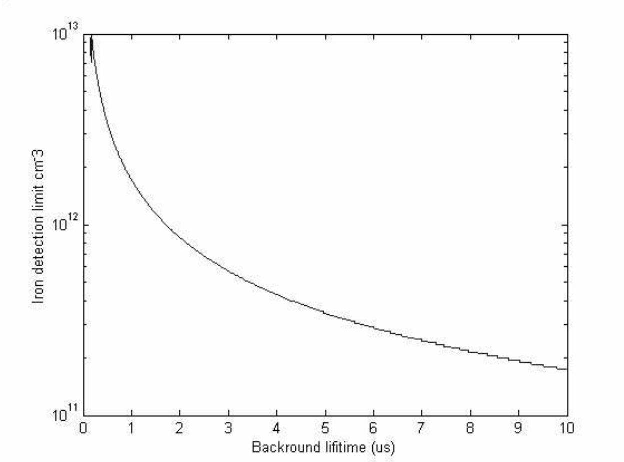

Figure 1. Iron detection limit with different backround lifetimes, when five percent measurement error is assumed.

Sample	DLTS [Fe] cm^{-3}	μ-PCD [Fe] cm^{-3}
B8	2.23E+11	Not detectable
B7	9.11E+11	1.19E+12

Table I. Detected iron concentration after gettering by DLTS and μ-PCD. In the sample the B7 detection is not possible because too low backround lifetime.