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LD-13

Element Specific Diagnosis Using μ-PCD

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The photoconductive decay technique, using the change of reflectivity of microwaves after pulsed optical excitation of excess minority carriers, is a very convenient, i.e. nondestructive, contactless and fast way for the indirect in-line monitoring of metallic contamination in silicon [1, 2].

Although the phenomenon of μ-PCD was known for decades [3], recently, it has reattracted high interest due to the availability of automated and computerized equipment with both high lifetime resolution (0.1 μs) in a range of 0.1 μs-10 μs and lateral resolution (1 mm) [4].

For certain metals, the recombination lifetime, *per se*, is not specifically sensitive. The contamination level due to lifetime data, however, can be understood by a simple correlation equation that has been established for the concentration of Fe (C) as a monitor element in B-doped CZ-Si [5]:

$$\tau(\mu s) = 10^{13}/C_{Fe(atoms*cm^{-3})} \qquad \text{Eq. 1}$$

Thus, a concentration of 10^{12} Fe at.cm^{-3} already limits the lifetime to 10 μs. The detection limit for metals is estimated to be about 10^{10} at.cm^{-3}. Similar results were found for Ti in specially grown B-doped CZ-crystals of Si (Fig. 1).

Three aspects must be taken into account when tracking down metallic contamination:

1. The diffusion coefficient of the element of interest in monocrystalline silicon

2. Its solubility and saturation concentration in monocrystalline silicon at the drive-in / diffusion temperature

3. Distribution of the lifetime killer between electrically active and inactive sites including solid state chemical reactions

Lifetime and DLTS data on B-doped FZ wafers confirmed the anticipation after different thermal processes in a contaminated annealing furnace (Fig. 2).

In order to estimate the influence of one Fe particle of the size of 0.3 μm we can calculate from Eq. 1 that it can locally reduce the lifetime to less than 100 μs after drive-in at high temperature. Alkaline cleaning solutions containing 50 pptw Fe are in equilibrium with the same amount of Fe (1×10^{10} at.cm^{-2}). Due to known adsorption isotherms [6], 10 pptw Fe corresponds only to 1/5 of the above surface contamination. However, the lifetime would increase to 1000 μs after drive-in.

If absolute lifetime values are required, the measured effective lifetime can be traced back to the thickness of a wafer if both high surface recombination rate and low bulk recombination rate are provided (Fig. 3).

Unfortunately, the integrative parameter "lifetime" is influenced by many other elements or defects such as Pt or Au, by crystal defects, oxygen precipitates and even contaminants can interfere with each other. The injection level also affects the effective carrier lifetime [7]. As yet, much work has to be done in order to recognize, identify, understand and separate these influences.

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ABSTRACT / SSDM '94

T (°C)			600	800	1.000	1.100	1.200
Fe	L (µm)		30.4	70.7	126	158	192
	S (cm⁻³)		$2*10^9$ *	$2.6*10^{12}$	$3.4*10^{14}$	$2.3*10^{15}$	$1.2*10^{16}$
Cu	L		1.230	2.000	2.780	3.160	3.540
	S		$1.4*10^{15}$	$5.5*10^{16}$	$7.0*10^{17}$	$1.9*10^{18}$	$4.4*10^{18}$
Ni	L		480	860	1.290	1.500	1.720
	S		$2.5*10^{14}$	$1.6*10^{16}$	$2.7*10^{17}$	$8.4*10^{17}$	$2.2*10^{18}$

Table 1.
Diffusion length after 10 min. of diffusion and the solubility of Fe, Cu and Ni in monocrystalline silicon
*According to M. Aoki, Ultra Clean Technol., 5/3, 190 (1993): $3*10^{10}$ Fe.cm⁻³.

Temperature (°C)	av. lifetime (µsec)	tot. trap concentration (cm⁻³)	trap
400	400	$7*10^{10}$	?
500	100	$2.2*10^{12}$	NiB
600	50	$1.5*10^{13}$	NiB Cu(D, A)
1.100	2.5	$4.4*10^{12}$	FeB

Table 2.
µ-PCD lifetimes and DLTS trap concentrations of p-type FZ Si after various thermal treatments in a contaminated annealing furnace.
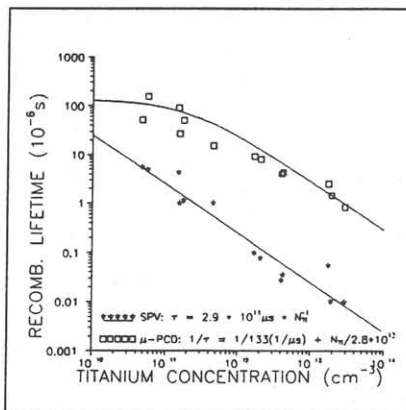

Figure 1

SPV- and µ-PCD-lifetimes
of Ti-doped p-type CZ-Si.
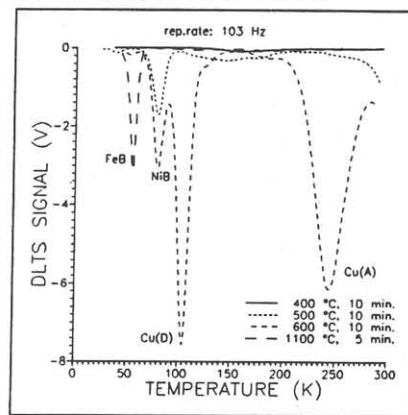Ti concentration determined by DLTS.

Figure 2

DLTS-spectra of p-type FZ
after various thermal treatments
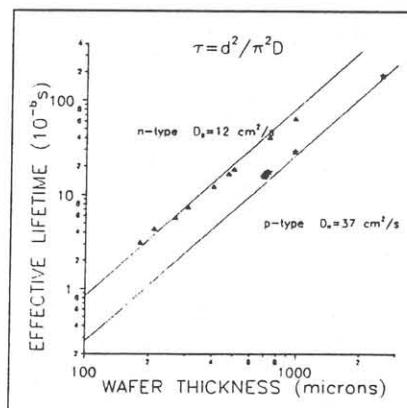in a contaminated annealing furnace.

Figure 3

Measured effective lifetimes
on lapped wafers of various thicknesses