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Increase of planar homogeneity of multi-silicon structures by gettering treatments

V.G. Litovchenko, A.A. Efremov, A.A. Evtukh, Yu.V. Rassamakin, M.I. Klyui, V.P. Kostylov
Institute of Semiconductor Physics, NASU, Kiev, Ukraine, E- mail: ALEF@isp.kiev.ua.
Tel./FAX: 044-265-62-90

Abstract. Two types of gettering treatments are considered and compared from the viewpoint of their usefulness to decrease L_D scatter over the wafer in multi-silicon photovoltaic structures. It was found that in both cases high degree of homogeneity in L_D distribution over the sample surface and cleaning of the samples from recombination active impurities are achieved. Possible mechanisms of the homogenization are briefly discussed.

Keywords: gettering, planar inhomogeneity, diffusion length, surface photovoltage.

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1. Introduction.

The present work is devoted to study of influence of gettering and passivation procedures on planar homogeneity (uniformity) planar distribution of recombination parameter L_D.

Typically the multi-crystalline silicon (m-Si) is rather non-homogeneous material as to structural, electrical and photo-electrical properties. This feature is very undesirable for reproducibility, characterization, and for calculations of the basic parameters of photovoltaic solar-cell devices.

Therefore, it is very important to find out such types of technological procedures, which will be able to decrease sufficiently the scatter of recombination parameters along the surface of the m-Si wafers used for solar cell fabrication. Besides, suitable approaches for description and characterization of recombination homogeneity have to be developed.

2. Samples

The m-Si material, which we deal with, was from two different manufacturers. The two batches of samples were distinguished in bulk oxygen contain:
(*i*) ~ $5{\cdot}10^{17}$cm^{-3} for series I;
(*ii*) ~ $5{\cdot}10^{16}$cm^{-3} for series II;

Below we shall pay more attention to behavior of samples from the second series.

We have checked usefulness of two different types of gettering and passivation treatments in decrease of the scattering of recombination parameters.

We used (*i*) Al backside getter deposited on m-Si surface and (*ii*) combined getter when Al layer was deposited on preliminary developed (roughened) Si surface. Gettering treatments were done at 650–1000°C for 1h.

3. Method for inhomogeneity characterization

We have measured: (*i*) distribution function for crystallite size along the both surfaces of a wafer determined by optical method and (*ii*) diffusion length L_D distribution function for photo-excited minor carriers $L_D = (D\tau)^{1/2}$.

L_D were measured by means of capacitance photovoltage spectra (Fig. 1) [1]:

$$V_{ph}/V^{max}_{ph} = L_D k/(1+L_D k) \tag{1}$$

Here $k = k(l)$ is an absorption coefficient as a function of exciting light wavelength. According to ASTM standards approximation [1]:

$$k(\lambda) = (84.732/\lambda - 76.417)^2 \tag{2}$$

where k is in cm^{-1} and λ is in mm.

Therefore, on decaying part of $V_{ph}(\lambda)$ spectrum (approximately from 600 to 1100 nm) it is easy to calculate L_D and τ, which characterize photosensitivity of semiconductor material .

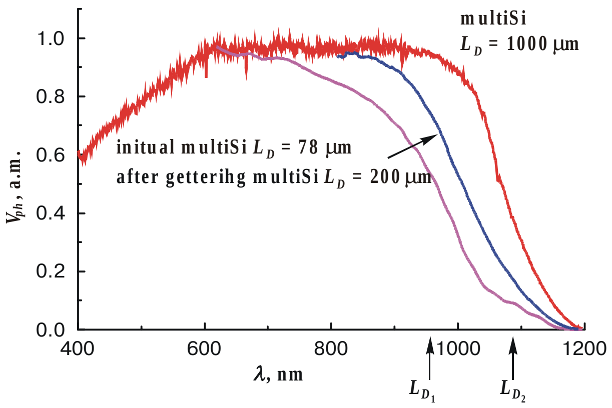

Fig. 1. Spectral dependence for normalized photovoltage for single crystalline silicon (L_D = 1000 µm), multi-silicon before (L_D = 78 µm), and after (L_D = 200 µm) gettering.

Typical view of photovoltage spectra is shown in Fig. 1. The most interesting feature of the m-Si spectrum is the longwave tail caused by heterogeneous distribution of L_D over the sample. After gettering treatment this tail decrease remarkably due to homogenization.

4. Results

Optical measurements have shown that samples of series I with higher content of oxygen are characterized by about 3 times smaller diameter of crystallites (d_m ~ 0.3 cm) than samples from batch II (d_m ~ 1.0 cm).

After L_D measurements in several points on the wafer surface both average $\langle L_D \rangle$ and scatter value ΔL_D have been obtained for each wafer.

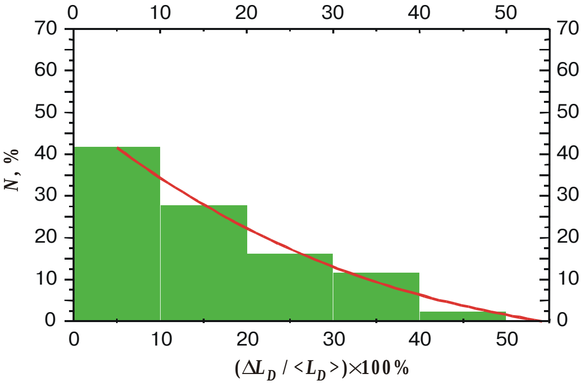

Fig. 2. The general statistical distribution of $\Delta L_D / \langle L_D \rangle$ for all samples from Batch II. $\langle L_D \rangle$ = 50.7 µm, $\langle \Delta L_D \rangle$ = 15.5 µm, $\Delta L_{D\max}$ < 5 µm

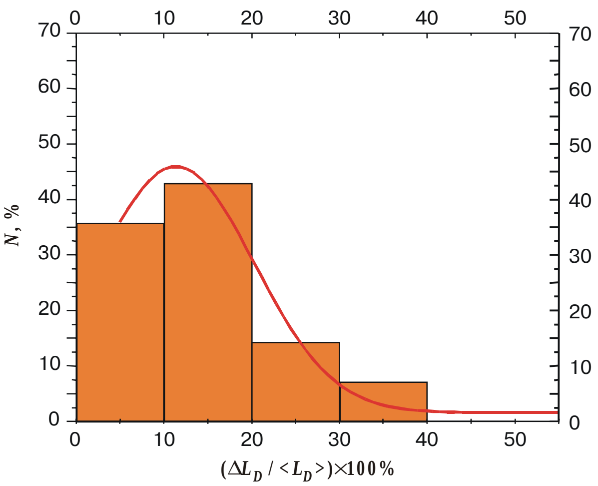

Fig. 3. Special selection #1 (with combined getter dev-Si + Al) prepared for gettering procedure from samples of general selection (Fig. 2). $\langle L_D \rangle$ = 52.4 µm, $\langle \Delta L_D \rangle$ = 14.3µm, $\Delta L_{D\max}$ = 14.3 µm

$$\Delta L_D = \langle | \langle L_D \rangle - L | \rangle \tag{3}$$

The general statistical distribution of $\Delta L_D / \langle L_D \rangle$ for all samples from Batch II is presented in Fig. 2. Than special selections was performed (Figs 3 and 4) from the samples with higher dispersion and subjected to gettering treatments mentioned. One can see that after the both treatments $\Delta L_D / \langle L_D \rangle$ ratio decreased sufficiently (Figs 5,6).

5. Discussion

In order to understand mechanisms of L_D planar inhomogeneity decrease due to gettering treatments, let us outline the main reasons that result in heterogeneity. They are: (*i*) existence of numerous grain boundaries

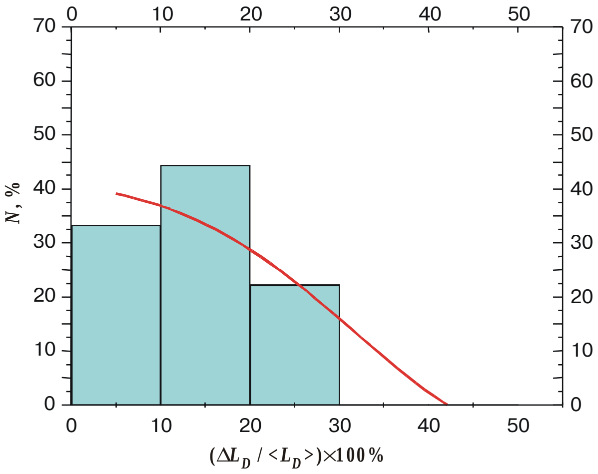

Fig. 4. Special selection #2 (with Al) prepared for gettering procedure from samples of general selection (Fig. 2). $\langle L_D \rangle$ = = 45.1 µm, $\langle \Delta L_D \rangle$ = 13.9 µm $\Delta L_{D\max}$ = 15 µm.

Table 1. Change of statistical characteristics of L_D distribution function

	Initial			After gettering		
Series II	$<L_D>$	ΔL_D	$\Delta L_D/<L_D>$	$<L_D>$	ΔL_D	$\Delta L_D/<L_D>$
	μm	μm	%	μm	μm	%
General	50.7	15.5	10			
Al	45.1	13.9	15	58.2	9.4	10
Dev-Si+Al	52.4	14.3	12	91.0	10.7	12

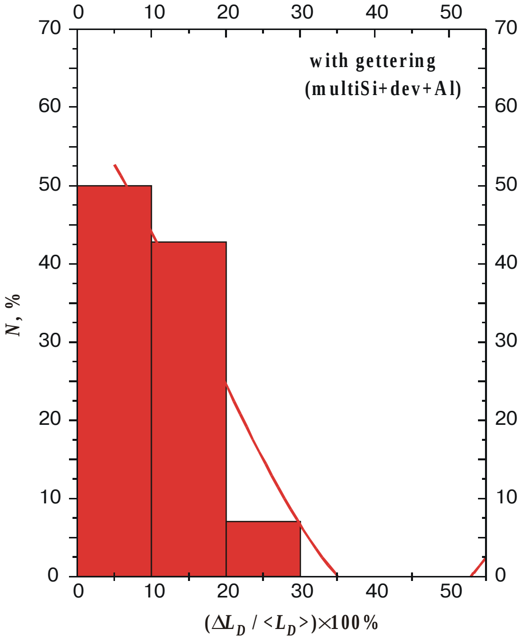

Fig. 5. Special selection #1 after gettering procedure. $<L_D>$ = = 91.0 μm, $<\Delta L_D>$ = 10.7 μm $\Delta L_{D\max}$ < 5 μm.

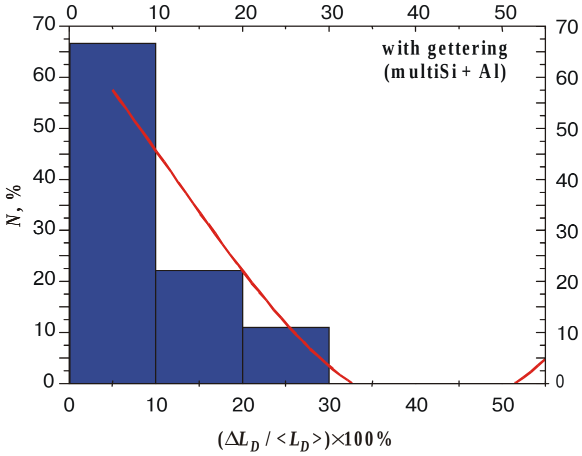

Fig. 6. Special selection #2 after gettering procedure. $<L_D>$ = = 58.2 μm, $<\Delta L_D>$ = 9.4 μm $\Delta L_{D\max}$ < 5 μm.

decorated by recombine active impurity atoms with large radius (Fe, Cu, Au). These atoms are rather mobile; (*ii*) existence of SiO_x precipitates which also have a tendency to be formed in the vicinity of boundary grains. Therefore, in a case of m-Si we have more pronounced fluctuations in spatial distribution of all factors which are responsible for L_D suppression.

Thermal treatments result in 3 the most important consequences: (*i*) diffusion induced smoothing in spatial distribution of active impurity (*ii*) decomposition/growth of initially formed SiO_x precipitates under silicon interstitials flow (in the case of combined getter) with following re-nucleation of them at nucleation centers in the bulk of grains; (*iii*) cleaning wafer due to impurity removal and suppression of inhomogeneities in 3D- spatial distribution of impurity atoms.

6. Conclusion

It is well known that gettering procedures result in increase of L_D. We have demonstrated that the mentioned treatments lead to another important gain namely, to sufficient homogenization of L_D spatial distribution. If combined getter (dev-Si + Al) give more increase in average L_D value, the ordinary Al getter proves to be more effective just for suppression of L_D spatial fluctuations.

References

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