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Estimation of iron concentration in silicon solar cell by kinetics of light-induced change in short-circuit current

O. Olikh[1], **V. Kostylyov**[2], **V. Vlasiuk**[2], **R. Korkishko**[2]

[1]*Taras Shevchenko National University of Kyiv, 64/13, Volodymyrska Str., Kyiv, 03028, Ukraine*
[2]*V. Lashkaryov Institute of Semiconductor Physic Institute of NAS of Ukraine, 41 Nauky Ave., Kyiv, 03028, Ukraine*
olegolikh@knu.ua

The iron is a major contaminant as well as one of the most detrimental metal impurities in silicon photovoltaic devices. Therefore non-destructive methods of iron concentration (N_{Fe}) estimation in solar cells (SCs) are important from an applied point of view. To date, a not little collection of both direct and indirect methods has been developed to solve this problem. But almost all of them require special sample preparing or/and specialized equipment. At the same time, the current-voltage curve (IVC) measurement is a common method of SC characterization. Short-circuit current (I_{SC}) is among the fundamental SC parameters, which easy determined from IVC as well as depend on N_{Fe}. The proposed method is based on ability of pair FeB to dissociate under carriers injection and to associate in the dark [1] and involves for the measurement of I_{SC} kinetics after intense illumination.

During the kinetic fit it was assumed, that I_{SC} under monochromatic light described by

$$I_{SC} = \frac{W_{ph}(1-R)q\beta\lambda}{hc}\frac{\alpha\sqrt{D\tau}}{1+\alpha\sqrt{D\tau}}, \tag{1}$$

where W_{ph} is the irradiance, D is the diffusion coefficient, τ is minority carrier lifetime in SC base:

$$\tau^{-1} = \tau_i^{-1} + \tau_{Fei}^{-1} + \tau_{FeB}^{-1} + \tau_{rest}^{-1}, \tag{2}$$

where τ_i describes intrinsic recombination, τ_{Fei} and τ_{FeB} concern to Shockley-Read-Hall recombination on interstitial iron $\mathrm{Fe_i}$ and FeB pair; τ_{rest} deals with other processes. The time dependence of the $\mathrm{Fe_i}$ concentration was used from [2] and it was believed that associate characteristic time can be written as

$$t_{ass} = 1.3\cdot 10^3 N_A^{-2/3}\exp(E_m/kT), \tag{3}$$

where E_m is the $\mathrm{Fe_i}$ migration energy, N_A is the doping level.

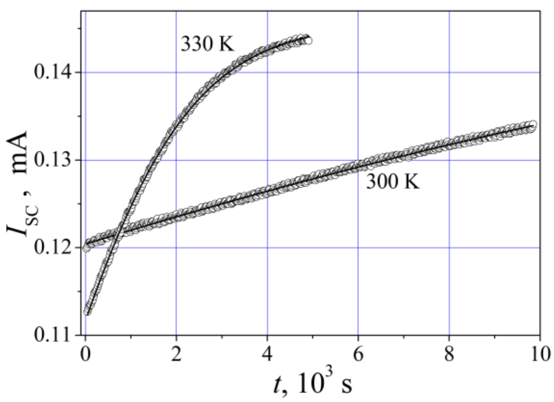

Fig. I_{SC} vs time after halogen lamp illumination (0.25 W/cm^2, 15 s). The marks are the experimental results, and the solid lines are the fitted curves. I_{SC} corresponds to the LED illumination (940 nm, 0.3 mW).

The n+-p-p+-Si diffusion-field type SCs were used in experiments. SCs were fabricated by using single-crystal *p*-silicon wafer with a resistivity of 10 Ω· cm. Some examples of I_{SC} kinetic curve are presented on Fig. We use Eqs. (1)-(3) by taking W_{ph}, E_m and N_{Fe} as fitting parameters to fit the experimental data. The obtained values were following: $W_{\mathrm{ph}} \approx 0.3$ mW; this value is in according with data, obtained by Power Meter Rk-5720 for used light source; $E_m \approx 0.679$ meV; this value is in according to known [2] $\mathrm{Fe_i}$ migration energy; $N_{\mathrm{Fe}} \approx 2\cdot 10^{13}$ cm^{-3}; this value is close to one, obtained by long-wavelength spectrum of internal quantum efficiency.

Thus, the proposed method allows to estimate the iron concentration in silicon solar cell. The work was supported by NRFU (project 2020.02/0036)

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