Estimation of Iron Concentration in Silicon Solar Cell by Kinetics of Light-Induced Change in Short-Circuit Current

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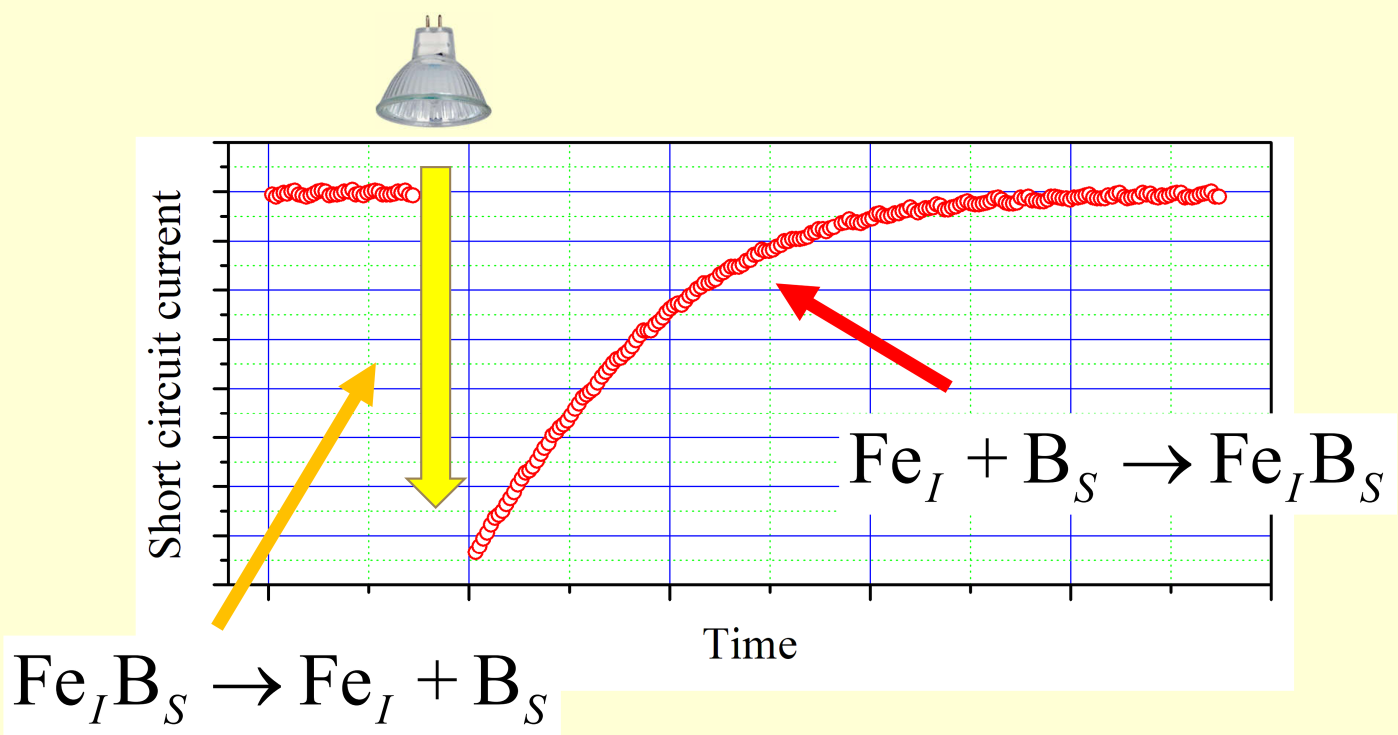
Introduction. Metal contamination control remains an important challenge for silicon processing both for microelectronics, logic technologies and solar cells (SCs). Typically, metal related defect characterization is performed by Fourier-transform infrared spectroscopy, electron-paramagnetic resonance, minority carrier lifetime measurements, deep level transient spectroscopy (DLTS), Laplace DLTS etc. However, these techniques are time-consuming, require special equipment or/and sample preparing. At the same time, the current-voltage (IV) measurement is a standard rapid industrial SC characterization technique. The proposed approach bases on short circuit current measurements, envisages the utilization of a simple and widely applicable setup and does not require a much time.

IDEA and CALCULATIONS



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

$$\frac{1}{\tau} = \frac{1}{\tau_{BtB}} + \frac{1}{\tau_{Auger}} + \frac{1}{\tau_{Fei}} + \frac{1}{\tau_{FeB}} + \frac{1}{\tau_{rest}},$$

$$\tau_{SRH}^{Fei,FeB} = \frac{\tau_{p0}(n+n_1)+\tau_{n0}(N_A+p_1)}{N_A+n}$$

$$\tau_{n,p0} = \frac{1}{N_d\sigma_{n,p}\upsilon_{th,n,p}}$$

$$N_{Fe}(t) = (N_{Fe,0}-N_{Fe,eq})\exp\left(-\frac{t}{\tau_{ass}}\right)+N_{Fe,eq}$$

$$N_{Fe,eq} = \frac{N_{Fe,0}}{\left[1+N_A 10^{-23}\exp\left(\frac{0.582}{kT}\right)\right]\left[1+\exp\left(\frac{E_F-0.394}{kT}\right)\right]}$$

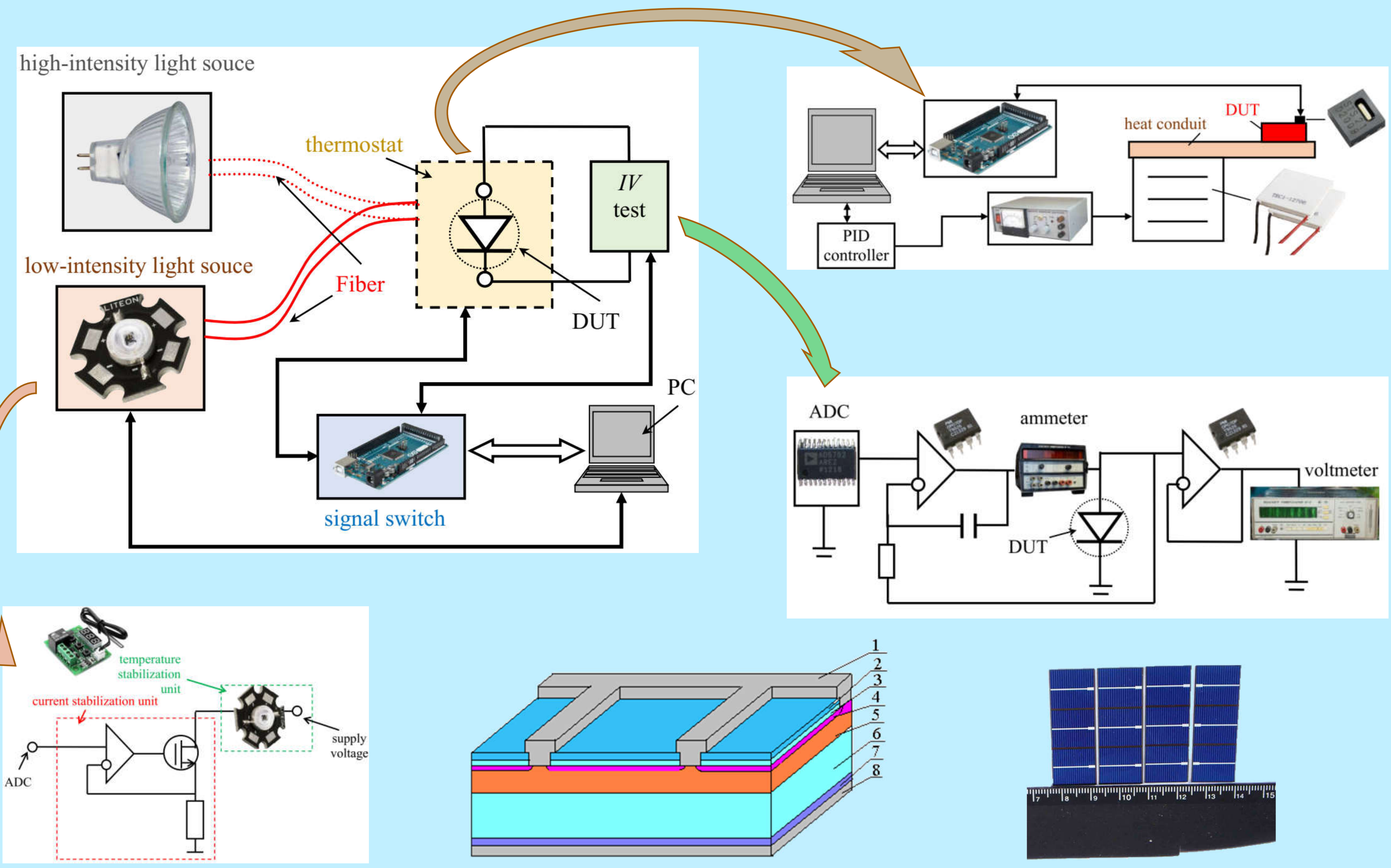
$$\tau_{ass} = \frac{5.7\cdot10^5}{N_A}T\exp\left(\frac{E_m}{kT}\right)$$

$$N_{FeB}(t) = N_{Fe,0} - N_{Fe}(t)$$

W_{ph} is the LED irradiance, $N_{Fe,0}$ – iron concentration after illumination, E_m is the Fe_i migration energy, N_A is the doping level.

calculated values   experiment parameters

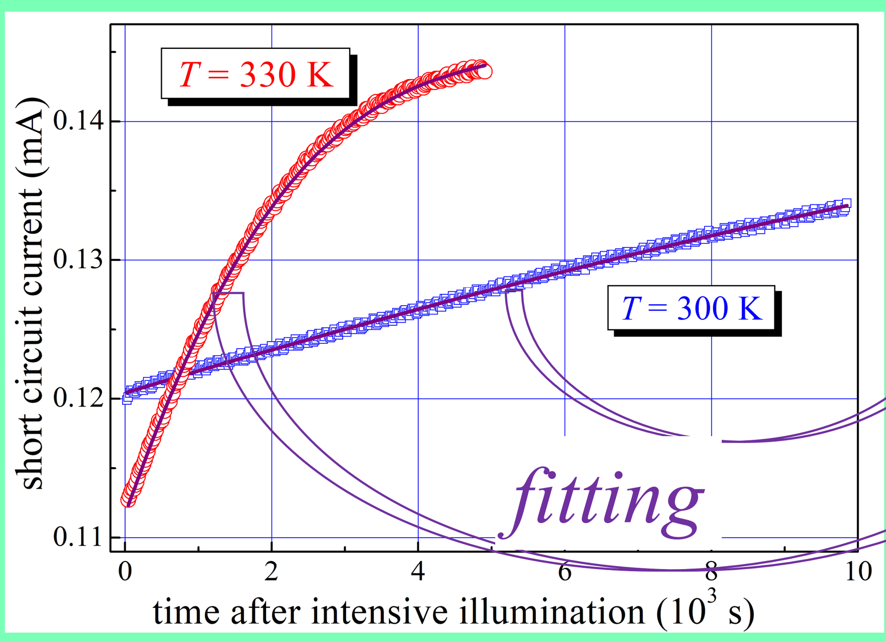
EXPERIMENTAL SETUP and SAMPLES



1 - front metal electrode (Al); 2 - Si_3N_4 (40 nm); 3 - SiO_2 (30 nm); 4 - induced n ++ - layer; 5 - diffusion n + - layer (0.7 μm); 6 - base region (p-Si, KDB10, 380 μm); 7 - diffusion p + -layer (0.6 μm); 8 - rear metallization (Al)

RESULTS

Proposed procedure: (i) to dissociate FeB pair (illumination, heating, carrier injection); (ii) to measure kinetic of short circuit current (at monochromatic illumination); (iii) to approximate the measured dependence and extract iron concentration



The marks are the experimental results, and the solid lines are the fitted curves.

$N_{Fe} = 2\cdot10^{13}$ cm^{-3}
$W_{ph} = 3.2\cdot10^{-4}$ W $3.1\cdot10^{-4}$ W
$E_m = 0.655$ eV   0.66 eV

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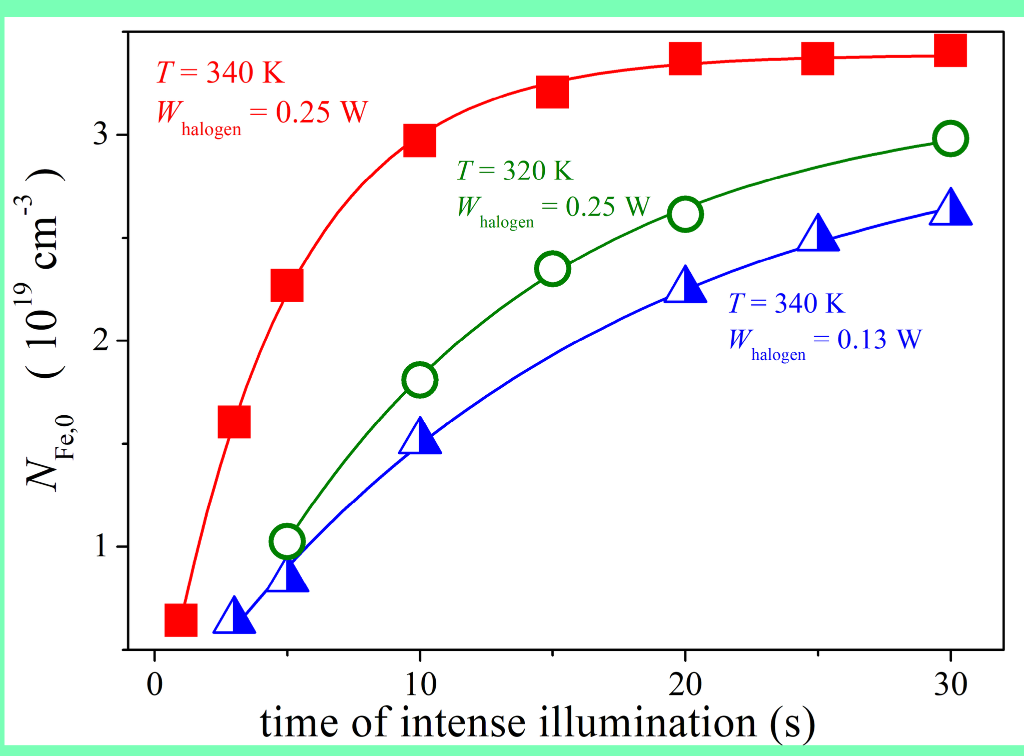
Cross-validation: the dissociation time (τ_{dis})

(i) proportionate to $(W_{halogen})^2$ [*J.Appl.Phys.* **116** 024503]

(ii) decrease approximately twice per 20°C increase [*Appl.Phys.Lett* **63** 3044]



T, K	$W_{halogen}$, W	τ_{diss}, s
340	0.13	16±2
340	0.25	4.6±0.2
320	0.25	11±1

Conclusion. The method to predict iron contamination in silicon solar cell by using kinetic of short circuit current is proposed. These approach envisages the utilization of a simple and widely applicable setup and does not require a much time. The method was validated by studying the temperature and illumination dependences of FeB pair dissociation time.