Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 124 (2017) 2–9

Energy Procedia

www.elsevier.com/locate/procedia

7th International Conference on Silicon Photovoltaics, SiliconPV 2017

# Predicting bulk lifetime values by applying wet chemistry H-termination for inline quality control of silicon wafers

Saed Al-Hajjawi*, Jonas Haunschild, Martin Zimmer, Tobias Dannenberg, Ralf Preu

*Fraunhofer Institute for Solar Energy Systems ISE, Heidenhofstraße 2, 79110 Freiburg, Germany*

**Abstract**

The measurement of bulk lifetime values of as-cut wafers is a problematic issue. In this work, a MDPLinescan tool was directly integrated in the last stage of an inline wet chemistry tool. It is shown that running as-cut wafers through a bath of 5% HF solution with an inline transportation speed of 1m/min without rinsing will increase the effective lifetime value from 2µs to more than 100µs.Consequently, it is possible to forecast the bulk lifetime at later stages leading to an approach for early inline quality control. Multicrystalline wafers revealed the best correlation with an average prediction error of 15%. Monocrystalline wafers showed an average prediction error of 32%. Finally, a prediction of the bulk lifetime values for n-type wafers showed preliminary correlations with an error of 3%.


Peer review by the scientific conference committee of SiliconPV 2017 under responsibility of PSE AG.

*Keywords:* H-termination;bulk lifetime; surface recombination velocity; solar cells

## 1. Introduction

A basic problem that we inspected in this work is the difficulty of classifying as-cut wafers for manufacturers using kerfless technologies, where ingot bulk lifetime measurements that are needed for the classification are not possible. To overcome this limitation, wet chemical processes are used. It is proved that dipping wafers into special wet chemical solutions provides a temporal passivation. This is because of the saturation of dangling silicon bonds

* Corresponding author. Tel.: +49-176-4588-5640
*E-mail address:* saed.al-hajjawi@ise.fraunhofer.de

1876-6102 © 2017 The Authors. Published by Elsevier Ltd.
Peer review by the scientific conference committee of SiliconPV 2017 under responsibility of PSE AG.
10.1016/j.egypro.2017.09.332

at the surface which in turn reduces the number of defect states at the interface [1, 2]. Consequently, the high surface recombination velocity (S) of unpassivated wafers which strongly limits the detectable range of charge carrier lifetime is dramatically reduced. Therefore, incoming quality control based on reasonable lifetime measurements becomes feasible.

Sugimoto et al.[3] showed the possibility of characterizing multicrystalline wafers by dipping them in a HF Solution and obtaining Photoluminescence (PL) images during the immersion. It had been proved that this immersion in a HF-dip increases the PL intensity temporarily which eventually increases the measured effective lifetime values.

Yoshida et al.[4] compared the values of S after chemical surface passivation by an iodine-ethanol solution and thermal oxidization. The latter process ended up with higher values of S= 70cm/s for p-type wafers and S= 15cm/s for n-type wafers. On the other hand, wet chemical immersion of wafers in iodine-ethanol solution resulted in lower values of S= 20 cm/s for p-type wafers and S= 3cm/s for n-type wafers. This reveals that wet chemical processes have a good potential regarding the reduction of surface recombination.

Moreover, Solcansky et al. [5] studied the chemical passivation in iodine/ethanol solution and quinhydrone/ methanol solution in terms of the passivation stability and reproducibility of measurements.

In this work, we integrated a prediction model of bulk lifetime values. This model predicts the bulk lifetime values from the measured effective lifetime values by the Microwave detected Photoconductivity (MDP) tool from Freiberg instruments [6–8] after H-termination. In order to evaluate the model and study the correlation between the predicted and measured bulk lifetime values, standard passivation techniques were used and the bulk lifetime values were measured using the Quasi Steady State Photoconductivity (QSSPC) tool in our laboratory [9–11].

## 2. Effective lifetime decay after H-termination

The fundamental equation that we used in this approach, which represents the relationship between the effective, surface, diffusion and finally bulk lifetime values is [12]:

$$\frac{1}{\tau_{eff}} = \frac{1}{\tau_{bulk}} + \frac{1}{\frac{w}{2S} + \frac{w^2}{\pi^2 D}} \qquad (1)$$

Where $S$ stands for the surface recombination velocity, $w$ for the wafer thickness and $D$ for the diffusion constant.

Taking into account a reproducibility error of 5% for the measurement of the effective lifetime value, a wafer of a presumed bulk lifetime value of 200µs at a surface recombination velocity of 200cm/s has a measured effective lifetime value of (41±2) µs, the relative predicted bulk lifetime value will be (210±51) µs However, a higher measured effective lifetime of (77±4) µs will lead to a predicted bulk lifetime of (202±26) µs This emphasizes the fact that increasing the measurable effective lifetime value of as-cut wafers will make it conceivable to evaluate bulk lifetime values without confusing them with the error span.

In order to inspect the durability of the increment of the effective lifetime values after H-termination, we measured the effective lifetime of an H-terminated Cz-Si wafer using the QSSPC tool. 70 consecutive measurements were taken in a time span of 3 hours. The following decay behavior was spotted: