A Study of the Degradation Mechanisms of Ultra-Thin CIGS Solar Cells Submitted to a Damp Heat Environment.

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INTRODUCTION

Alkali atoms, such as Na and K have been used in CIGS solar cells for years in order to improve their performance. Recent results by Theelen et al. suggest, however, that including alkali atoms into the absorber might be detrimental to the stability of the produced cells, as their efficiency drops dramatically when submitted to accelerated ageing conditions [1]. In order to verify and expand upon the conclusions drawn by Theelen et al., accelerated lifetime testing is performed on un-encapsulated ultra-thin CIGS solar cells doped with Na and/or K. Atom probe tomography is then used to get a unique insight into the atomic constitution of the devices before, during, and after degradation.

EXPERIMENTAL PROCEDURE

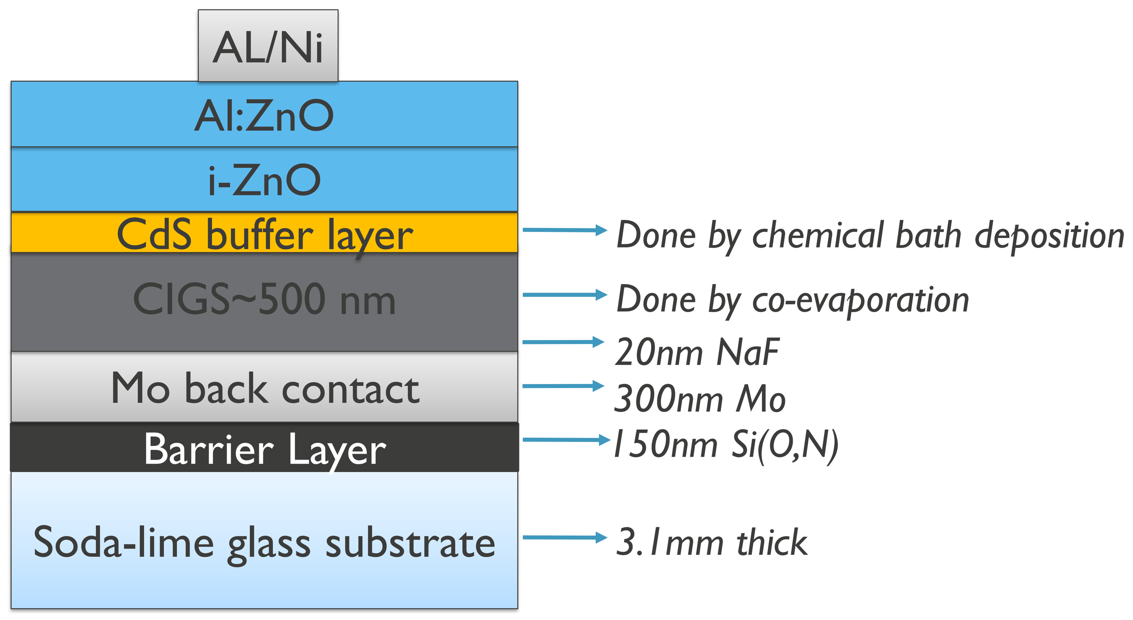

Figure 1: *Schematic representation of the finished solar cell stack*

- KF is deposited by spin coating on the samples selected for potassium treatment.
- The samples are submitted to **85°C/85%RH** conditions for up to **1000h** to induce ageing.
- IV is measured on the samples.
- Further characterization is performed.

EXPERIMENTAL RESULTS

1. IV Results of accelerated lifetime test

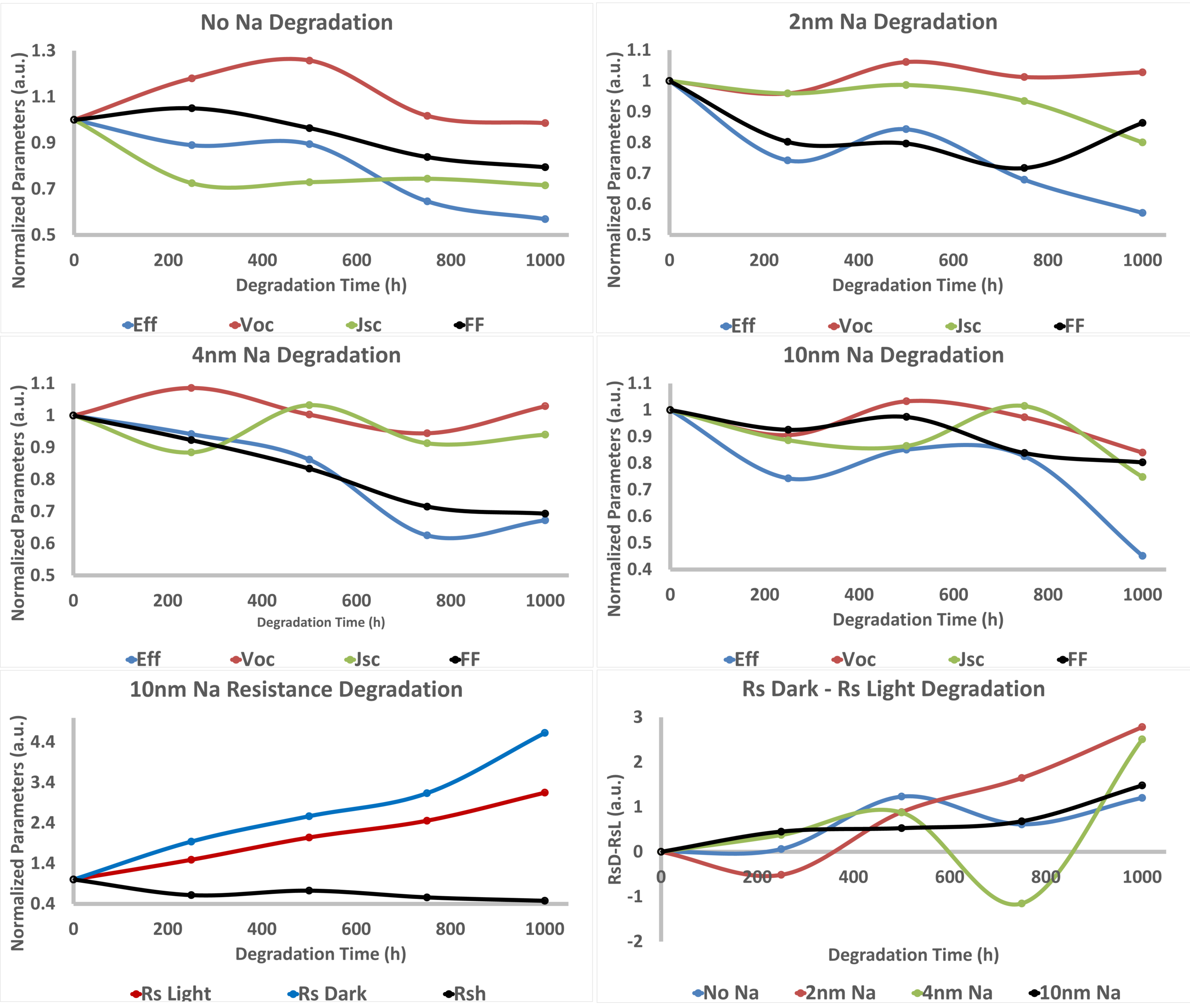

Figure 2: *Solar cell parameters as measured all along the 1000h long degradation experiment*

EXPERIMENTAL RESULTS

2. APT Results: Before and after ageing comparison

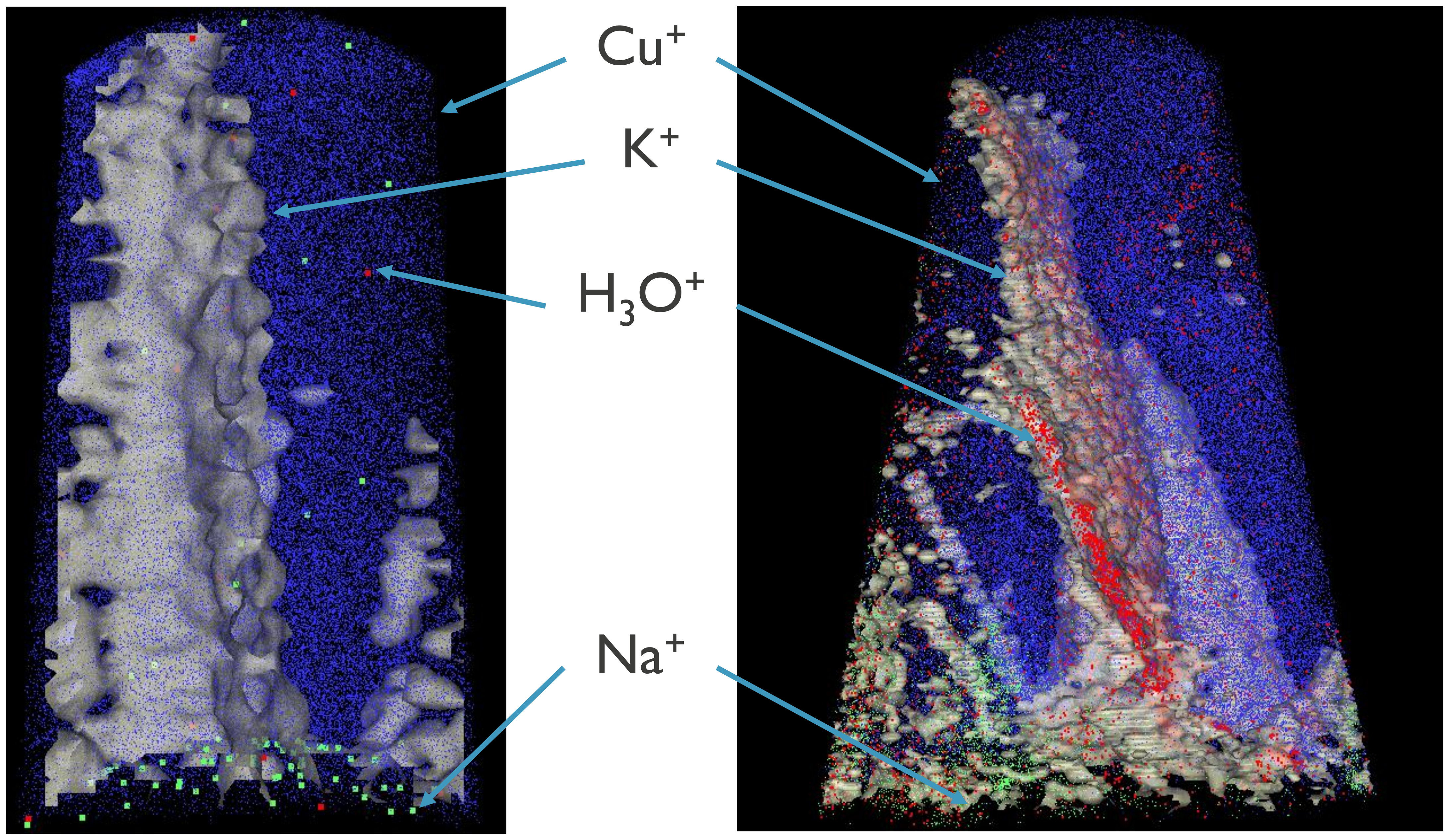

Figure 3: *Reconstructed APT, before (left) and after (right) accelerated ageing for 1000h. Cu atoms are represented in blue, K atoms are represented by an iso-surface, which makes the grain boundaries visible, and Na atoms are represented in green. Additionally, ions that were identified as H_3O^+ are represented in red.*

3. IV Results of the recovery experiment

- The samples are annealed at 100°C in N_2 to dry them out and initiate recovery. This should allow to determine if the water can be evaporated and the efficiency restored.

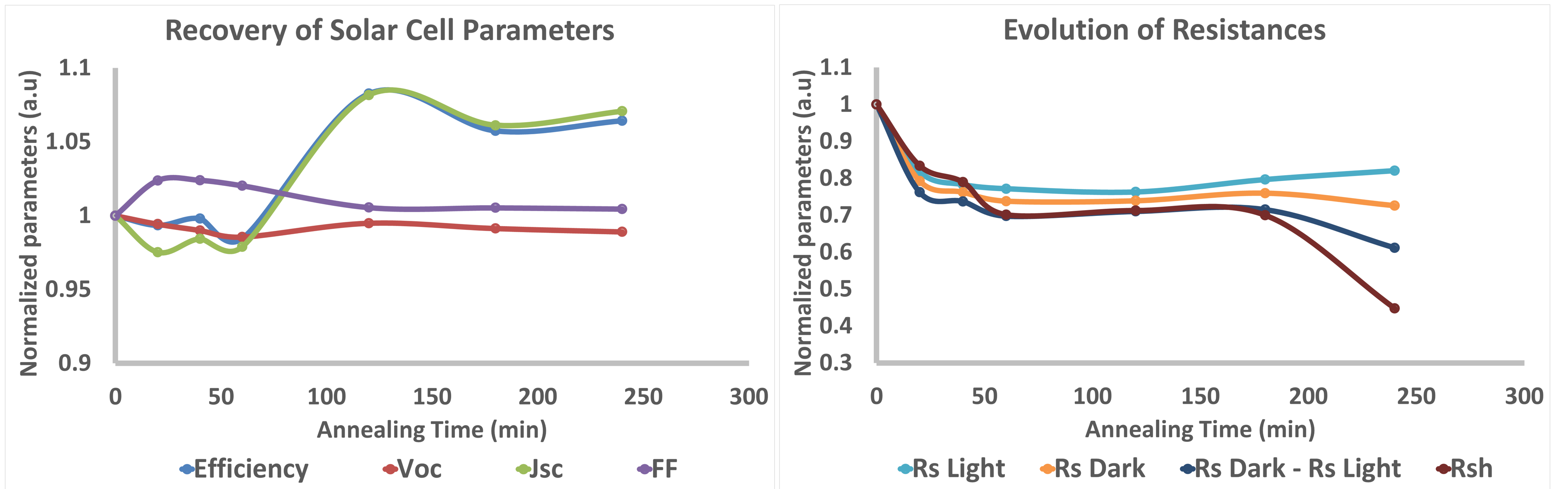

Figure 4: *Solar cell parameters as measured all along the recovery through annealing*

CONCLUSIONS

- APT results do not suggest any significant movement of the alkali atom when comparing the pictures before and after ageing. Instead, in the present case the inclusion of water into the grain boundaries seems to be the major culprit when it comes to the degradation of the solar cell efficiency. This confirms some of the conclusions drawn by Theelen et al. [1].
- IV results suggest that the degradation of the solar cells is mainly due to a degradation of the window and/or the buffer layer. This is indicated by the heavy correlation between the degradation of the efficiency and the resistances without immediate degradation of the Jsc and Voc.
- Recovery through annealing does not seem possible at this point.

ACKNOWLEDGEMENTS

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[1] Theelen et al., the impact of alkali elements on the degradation of CIGS solar cells, Prog. Photovolt: Res. Appl. 2015; 23:537–545

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