Exploring Possibilities to Enhance Silicon Solar Cell Efficiency by Downconversion of Sunlight

by

Muddassar Naeem

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Master of Philosophy

The University of Adelaide
School of Chemistry and Physics
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Statement of Declaration

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Muddassar Naeem

Supervisors:

Prof. Jesper Munch
A/Prof. Murray Hamilton
A/Prof. Heike Ebendorff-Heidepriem
To my family
Abstract

Improving the efficiency of solar cells is an active area of research in photovoltaic industry. The research work presented in this dissertation is based on a quest for better and improved silicon solar cells. The current work aims to explore different possibilities by studying advance approaches for PV applications. Additionally this work is intended to seek the feasibility of new photonic concepts for improving silicon solar cells.

In this work we have investigated solar downconverters consisting of tellurite glass. Their fabrication process is discussed followed by the experimental characterization. Optical measurements such as absorption spectra, fluorescence spectra and fluorescence quantum efficiency are undertaken. These optical measurements enabled to understand physical processes associated with the materials used.

Furthermore, the work presented in the thesis is focused on the realization of a downconverter. The work can be roughly sub-divided into two parts. One part identifies the suitable energy conversion materials and the second part deals with the development and demonstration of the experimental method for characterizing a downconverter. The final part of the work extends investigation for more efficient materials prior to their use at the practical level. We also propose an architectural design for the efficient use of a downconverter with a silicon solar cell.
Acknowledgements

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I am very grateful to my co-supervisors, Murray Hamilton and Heike Ebendorff-Heidepriem, for their guidance throughout the work. I am highly thankful to Murray, for the provided support, assistance, many fruitful discussions, suggestions and corrections on thesis. I greatly appreciate Murray for his constructive ideas and provided necessary experimental equipment. Also I greatly thank to Heike for the provided samples to undertake investigation. Her help on sharing knowledge of glass materials at the early stage of the project was really useful.

I thank to Nigel Spooner for giving me access to his lab and lending me spectrometer and many optical components for the experimental measurements. I enjoyed on some occasions sharing ideas on experimental equipments.

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# List of Abbreviations

Throughout the thesis, several abbreviations will be used to represent specific short descriptions or notations, the following is a list for the readers convenience. This list is not exhaustive but every effort has been made to maintain conformity of notations used here.

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>AM</td>
<td>Air Mass</td>
</tr>
<tr>
<td>ARC</td>
<td>Anti-reflection coating</td>
</tr>
<tr>
<td>BP</td>
<td>Band-pass</td>
</tr>
<tr>
<td>CdTe</td>
<td>Cadmium tellurite</td>
</tr>
<tr>
<td>CIGS</td>
<td>Copper indium gallium arsenide</td>
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<tr>
<td>DC</td>
<td>Downconversion</td>
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<tr>
<td>DS</td>
<td>Downshifting</td>
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<tr>
<td>ECL</td>
<td>Escape cone loss</td>
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<td>EQE</td>
<td>External quantum efficiency</td>
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<tr>
<td>FQE</td>
<td>Fluorescence quantum efficiency</td>
</tr>
<tr>
<td>FTIR</td>
<td>Fourier transform infrared</td>
</tr>
<tr>
<td>IPV</td>
<td>Impurity photovoltaic</td>
</tr>
<tr>
<td>IQE</td>
<td>Internal quantum efficiency</td>
</tr>
<tr>
<td>LED</td>
<td>Light emitting diode</td>
</tr>
<tr>
<td>LP</td>
<td>Long-pass</td>
</tr>
<tr>
<td>NIR</td>
<td>Near-infrared</td>
</tr>
<tr>
<td>NPR</td>
<td>Non-radiative phonon relaxation</td>
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<tr>
<td>OFD</td>
<td>Organic fluorescent dyes</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Full Form</td>
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<tr>
<td>--------------</td>
<td>-----------</td>
</tr>
<tr>
<td>PCE</td>
<td>Photon cascade emission</td>
</tr>
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<td>Quantum splitting</td>
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<td>Visible</td>
</tr>
<tr>
<td>VUV</td>
<td>Vacuum ultraviolet</td>
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