ZnO-CuO Backbone-Branch Heterostructure for High-Efficiency Organic-Inorganic Hybrid Perovskite Solar Cells

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Abstract
Population growth has led to an unsustainable demand in energy consumption. Due to its renewable, sustainable, and clean nature, solar energy remains as one of the most promising sources of energy. Dye-sensitized solar cells (DSSCs) and perovskite solar cells (PSCs) have emerged as an attractive alternative technology to silicon-based devices, due to their ease of fabrication, low material cost, and versatility of application. However, the absorption materials in these solar cells cannot absorb near-infrared (NIR) light, which inherently limits their efficiency. In this work, CuO is used as a secondary absorption layer to utility NIR light for improving device efficiency. ZnO nanorods (NRs) on fluorine-doped tin oxide (FTO) substrate are synthesized by chemical vapor deposition. CuO is synthesized on ZnO NRs by thermal oxidation. Properties of the synthesized materials are characterized by SEM, XRD, and UV-Vis-NIR photospectroscopy.

Background
Photovoltaic Principle
Solar cells consist of two electrodes, an absorber layer, an electron and a hole transport layer (ETL and HTL, respectively). In short, electrons are excited at the absorber layer by incoming photons. The excited electrons are collected by the negative electrode. The wavelength range of the absorbed light depends on the band gap of the absorber material being utilized.

Electron-Transfer Processes
ETL
2
Perovskite
3
Sunlight
4
Perovskite
5
ETL
6
Photoelectron
7
Electron
8
Electron
9
HTL
Figure 2: Schematic of electron transfer processes
For higher performance of solar cell devices, processes 4-7 must be minimized, while 1-3 should be maximized.

Limitation of Perovskite
In this work, CuO is used as a secondary absorption layer to utility NIR light for improving device efficiency. ZnO nanorods (NRs) on fluorine-doped tin oxide (FTO) substrate are synthesized by chemical vapor deposition. CuO is synthesized on ZnO NRs by thermal oxidation. Properties of the synthesized materials are characterized by SEM, XRD, and UV-Vis-NIR photospectroscopy.

Experimental Process & Results
Figure 3: Solar spectrum distribution
Non-absorption of near-infrared light limits efficiency of perovskite-based solar cells.

CuO Synthesis on FTO glass

Table 1: ZnO NR diameter with respect to process gas ratio

### CuO Synthesis on FTO glass

<table>
<thead>
<tr>
<th>Sample</th>
<th>N$_2$ (sccm)</th>
<th>Ar (sccm)</th>
<th>O$_2$/N$_2$ (sccm)</th>
<th>Diameter (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 1</td>
<td>30</td>
<td>80</td>
<td>0/0</td>
<td>150</td>
</tr>
<tr>
<td>Sample 2</td>
<td>20</td>
<td>90</td>
<td>1/1</td>
<td>135</td>
</tr>
<tr>
<td>Sample 3</td>
<td>10</td>
<td>100</td>
<td>2/2</td>
<td>120</td>
</tr>
<tr>
<td>Sample 4</td>
<td>5</td>
<td>105</td>
<td>3/3</td>
<td>115</td>
</tr>
<tr>
<td>Sample 5</td>
<td>0</td>
<td>110</td>
<td>4/4</td>
<td>110</td>
</tr>
</tbody>
</table>

Figure 6 shows that the diameter of ZnO NRs increase with higher oxygen ratio during CVD synthesis (from 24 to 175 nm). This result indicates that the diameter of ZnO NRs can be controlled during growth.

Conclusion
In this work, we have successfully synthesized ZnO-CuO nanoscale, core-shell structures by using two-step synthesis process; 1) chemical vapor deposition, and 2) thermal oxidation. From the XRD results, crystallinity of ZnO and CuO-compounds are determined, and the grain size of CuO-compounds are calculated by using Scherrer’s equation. The diameter of ZnO NRs increases with higher oxygen ratio. CuO-compound nanocrystals are synthesized when the grain size of the compounds is small. In order to synthesize many nanostructures of CuO, we will research advanced thermal oxidation method (two-step method). In the future, perovskite solar cells (PSCs) using synthesized ZnO-CuO backbone-branch structure, as a photoelectrode, will be fabricated. Performance of the PSCs using various photoelectrodes structure will be compared to understand the effect of CuO material as a branch on ZnO.

Reference

Acknowledgements
This research was partially funded by the University of California Advanced Solar Technologies Institute (UC Solar).