A TiO₂ Nanotube Network Electron Transport Layer for High Efficiency Perovskite Solar Cells

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Objective

- Increase Perovskite Solar Cell (PSC) efficiency through layer optimization
- Find alternative Electron Transport Layers (ETL) structure and manufacturing method
- Gather and interpret results of novel PSC data for analysis and publication

Introduction

Perovskite solar cells (PSC) have recently attracted tremendous attention due to their superior properties and low manufacturing cost. Lately, there have been groups focusing on the improvement of the electron transport layer (ETL) because of its ability to block electron recombination and extract electrons resulting in an optimized solar cell. By introducing a mixed network of TiO₂ nanotubes instead of the traditional nanoparticle structure for the ETL, the cells have exhibited greatly improved characteristics. This was accomplished through the anodization of titanium foil followed by the process of self-decomposition, ultrasonic tube separation, and spin-coating. This presents a new technique for solar cell optimization through structure innovation in the ETL.

Methods

TiO₂ Nanotube Network Fabrication
- Ti foil cleaned in acetone, ethanol, and water
- Anodized in an ethylene glycol followed by annealing
- Anodized again and washed in de-ionized water
- Dried and sent through self-anodization process
- Ultrasonicated and spin-coated on substrate

Perovskite Solar Cell Manufacturing
- FTO cleaned with detergent, water, acetone, and ethanol
- Dried and treated with ozone and UV light
- Blocking layer spin-coated on and annealed
- TiO₂ mesoporous layer spin-coated on and annealed
- Lead iodide deposited and annealed
- Methylammonium iodide deposited and annealed to form perovskite
- Spiro-OMeTAD based hole transport layer deposited
- Left in dark environment overnight
- Silver thermally evaporated on substrate

Results

The results showed that the new transport structure resulted in an enhanced solar cell. Using an alternative ETL based on a novel TiO₂ nanotube network structure resulted in an increased efficiency and electron lifetime. This also shows the difference between the traditional and the optimized structures for PSC devices taken as an average of twenty samples. Hysteresis can also be determined using above data.

Table 1: Nanotube verse nanoparticle performance analyzed by taking the average of 20 samples.

<table>
<thead>
<tr>
<th>Average of 20 Samples</th>
<th>VOC (V)</th>
<th>JSC (mA/cm²)</th>
<th>FF</th>
<th>η (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nanoparticle Reverse</td>
<td>0.84</td>
<td>21.7</td>
<td>0.60</td>
<td>10.9</td>
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<tr>
<td>Nanoparticle Forward</td>
<td>0.82</td>
<td>19.1</td>
<td>0.48</td>
<td>7.51</td>
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<tr>
<td>Nanotube Reverse</td>
<td>0.88</td>
<td>24.8</td>
<td>0.63</td>
<td>13.8</td>
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<tr>
<td>Nanotube Forward</td>
<td>0.84</td>
<td>23.6</td>
<td>0.56</td>
<td>11.1</td>
</tr>
</tbody>
</table>

Conclusion

- As the ETL is an integral part of the solar cell it has been important to optimize its structure. Using an alternative ETL based on a novel TiO₂ nanotube network structure resulted in an enhanced solar cell.
- Due to the new transport structure, the solar cell was able to increase light absorption, improve electron extraction and collection, and decrease hysteresis. These benefits along with and increase in electron life ended up increasing the efficiency by 26.6% compared to the traditional nanoparticle ETL.
- These results prove the importance of an ETL and show that there is room for improvement in that area. Results found strong enough to be published in Phys. Chem. Chem. Phys.

Prospective

Due to the success in the area of the ETL shown by the above results, there is a potential in the following ideas for the next development of the solar cell research being conducted.

- Changing parameters of transport layer such as thickness or particle size
- Different structures of ETL such as nanocubic or use of quantum dots
- Use of Atomic Layer Deposition (ALD) in the form of TiO₂ and Al₂O₃

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