Optimization of Tin(IV) Nanoparticles for Improved Performance in Dye-Sensitized Solar Cells

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Introduction

Dye-sensitized solar cells (DSSCs) are a possible alternative tool to harvest solar energy instead of the traditional silicon-based solar cells. DSSCs offer various advantages, such as good energy conversion efficiencies in low-light conditions, simple fabrication, low cost, and the ability to modify key properties of the solar cell such as the absorbance wavelengths. In this study, we examine the performance of DSSCs constructed using tin(IV) oxide semiconductors. Tin(IV) oxide offers a wide band gap and higher electron mobility compared with the more widely used titanium dioxide. Two nanoparticle (NP) morphologies of tin(IV) oxide, spherical and flower-like NPs, are synthesized, and these two types of tin(IV) oxide NPs and mixtures of both at various ratios are used to fabricate DSSCs.

Method

SnO₂ nanospheres are synthesized from SnO₂ colloids in water using a hydrothermal method (240 °C, 60 hours). PEG and PED polymers are added (2.5% wt) to the resulting solution to make the SnO₂ nanoparticles paste. SnO₂ nanoflowers are synthesized from SnO₂•5H₂O using hydrothermal method (180 °C, 48 hours). PEG and PED are added (2.5% wt) to the resulting solution to make the SnO₂ nanoflowers paste. The photoanodes are prepared by spreading the paste on to a conducting side of the FTO glass to form a uniform layer. Each photoanode is subjected to UV-Vis spectroscopy. Then, a DSSC is constructed by putting the photoanode and a platinum-containing cathode together with their conducting sides facing each other. The photovoltaic performance of the DSSC is recorded by a multimeter.

Photovoltaic Performance

Current density vs. voltage plot of DSSCs using different types of semiconductor layers: mixture of nanoflowers and nanospheres at 1:1 ratio (red), mixture of nanoflowers and nanospheres at 1:2 ratio (black), mixture of nanoflowers and nanospheres at 2:1 ratio (blue), only nanoflowers (green), and only nanospheres (cyan).

<table>
<thead>
<tr>
<th>Cell types</th>
<th>Mean Jsc (mA.cm⁻²)</th>
<th>Mean Voc (V)</th>
<th>Mean Pmax (mW.cm⁻²)</th>
<th>Mean Fill Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spheres</td>
<td>2.6 ± 0.6</td>
<td>0.30 ± 0.03</td>
<td>0.3 ± 0.1</td>
<td>(41 ± 9)%</td>
</tr>
<tr>
<td>Flowers</td>
<td>0.23 ± 0.07</td>
<td>0.41 ± 0.01</td>
<td>0.06 ± 0.02</td>
<td>(62 ± 2)%</td>
</tr>
<tr>
<td>Flowers:Spheres = 1:2</td>
<td>2.2 ± 0.2</td>
<td>0.38 ± 0.01</td>
<td>0.38 ± 0.07</td>
<td>(50 ± 4)%</td>
</tr>
<tr>
<td>Flowers:Spheres = 1:1</td>
<td>1.8 ± 0.5</td>
<td>0.36 ± 0.02</td>
<td>0.29 ± 0.07</td>
<td>(45 ± 4)%</td>
</tr>
<tr>
<td>Flowers:Spheres = 2:1</td>
<td>1.8 ± 0.1</td>
<td>0.399 ± 0.002</td>
<td>0.40 ± 0.04</td>
<td>(44 ± 5)%</td>
</tr>
</tbody>
</table>

Mean short circuit current density, open circuit voltage, maximum power, and fill factor, along with their uncertainties, of five DSSC types with different semiconductor layer.

Conclusion

- The mixture of tin(IV) oxide nanospheres and nanoflowers increase the performance of the solar cell overall.
- Future approach: study DSSCs made by the aforementioned mixture that are further modified by a titanium coating on the SnO₂ surface and evaluate how good these DSSCs are in performing water-splitting reactions.

References