May 10th, 11:00 AM - 1:00 PM

Understanding Photovoltaic Properties of PbS Quantum Dot Solids via Solution Contacting

Vitalii Dereviankin
Portland State University, vd2@pdx.edu

Erik Johansson
Portland State University

Let us know how access to this document benefits you.

Follow this and additional works at: https://pdxscholar.library.pdx.edu/studentsymposium

Part of the Nanoscience and Nanotechnology Commons, and the Semiconductor and Optical Materials Commons

https://pdxscholar.library.pdx.edu/studentsymposium/2017/posters/24

This Event is brought to you for free and open access. It has been accepted for inclusion in Student Research Symposium by an authorized administrator of PDXScholar. For more information, please contact pdxscholar@pdx.edu.
Understanding Photovoltaic Properties of PbS Quantum Dot Solids via Solution Contacting

Vitalii Dereviankin, Erik Johansson
Department of Chemistry, Portland State University, P.O. Box 751, Portland, Oregon, 97207

INTRODUCTION

PbS quantum dot (QD) solids are promising materials for solar-energy conversion as they combine versatility of colloidal QDs with the benefits of bulk semiconductors. PbS QDs are strong light absorbers, have easily tunable optoelectronic properties, allow for multiple excitation generation, and are readily available from low cost solution methods of synthesis. Despite high photon-to-electron conversion efficiencies (~25 mA/cm²) overall performance of QD based photovoltaics remains limited (~9.9% PCE) due to low open-circuit voltages (Voc). Both bulk and surface defects are known to affect Voc significantly. For PbS QD solids, defects at the interface between the QD solid and contacts were shown to affect photovoltaic properties. Metal contacting of PbSe QD solids to form Schottky junctions showed limited ability to control Voc via change in metal work function, which is consistent with Fermi level pinning due to defects formed at metal-QD interface. This problem was overcome for bulk semiconductors (Si, GaAs) when electrochemical contacting was implemented using liquid electrolytes, and demonstrated higher Voc values and no Fermi level pinning for solid materials. Another benefit of using liquid contacting comes from their availability in wide range of reduction potentials.

In order to efficiently contact the QD solids with an electrolyte, electrochemical contacting method may similarly allow for a better understanding of QD solids. In this paper we present our results of studying photovoltaic properties of PbS QD solids using electrochemical contacting with fast, outer sphere redox couples.

EXPERIMENTAL DESIGN

In order to efficiently contact the QD solids with an electrolyte we designed and used a "sandwich" type cell (Figure 1, b). Redox couples for electrolytes were chosen based on their observed maximum as relative to PbS QD solids (Figure 2, a). PbS QD were deposited on FTO substrate by spin-coating along with ligand exchange from native oleic acid (OA) to 3-mercaptopropionic acid (3-MPA). Once heat sealed, cells were filled with an electrolyte through infill hole in CE and their photovoltaic properties were tested using Gamry R. 600 potentiostat and ABET solar simulator (10500).

RESULTS

QDs and QD solids were characterized using UV-Vis, TEM, and XRD methods. UV-Vis spectra shows a characteristic excitonic peak at 1.3 eV of PbS QDs with the benefits of colloidal QDs. Average QD particle size is 3.1 ± 0.08 nm, as estimated from all three methods.

Figure 2. Absorption spectra of as-synthesized OA capped PbS QDs, showing explicit excitonic absorption peak at 1.34 eV.

Figure 3. (a) Transmission electron micrograph of as synthesized OA capped PbS QDs deposited on FTO and (b) as synthesized OA capped PbS QDs (blue line) along with PbS galena reference (red, vertical lines).

Figure 4. X-ray attenuation patterns of (a) 3-MPA exchanged PbS QD solids and the quantum dot solids themselves.

Table 1. Summary of experimentally measured solution potentials, open-circuit voltages, and short-circuit current densities of PbS QD solids contacted by the electrolytes.

<table>
<thead>
<tr>
<th>Redox couple</th>
<th>E(A/A–)(mV vs.Cp2Fe+/0)</th>
<th>Voc(mV)</th>
<th>Jsc(mA/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferrocene(1)</td>
<td>(Cp2Co+/0) (MV2+/+·)</td>
<td>-535.8</td>
<td>-0.429</td>
</tr>
<tr>
<td>(Cp2Fe+)</td>
<td></td>
<td>-0.010</td>
<td>0.004</td>
</tr>
<tr>
<td>Decamethylferrocene(1)</td>
<td>(Me6Cp2Fe+)</td>
<td>-1334.3</td>
<td>1.19 ± 1</td>
</tr>
<tr>
<td>(MV2+/+·)</td>
<td></td>
<td>-785.9</td>
<td>0.262</td>
</tr>
<tr>
<td>Cobaltocene(1)</td>
<td>(CpCo+)</td>
<td>-119 ± 13</td>
<td>1.036±1 0.262</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-535.8</td>
<td>0.612</td>
</tr>
</tbody>
</table>

DISCUSSION

Current–voltage data were consistent with Schottky junction formation near the semiconductor/liquid interface (Figure 6). These results are important because they show that electrochemical contacting provides a good method to probe the photovoltaic properties of quantum dot solids over a wide span of contacting energetic. Observed maximum Voc of 1.08 ± 0.04 show the importance of the results in that electrochemical contacting shows no evidence of inducing interfacial defects, and absence of Fermi level pinning. Thus, this method can be applied to investigate photovoltaic properties of PbS QD solids while reducing the impact of electrical defects at the QD solid interfaces.

CONCLUSIONS

Electrochemical contacting was shown to be a promising method for studying the optoelectronic properties of PbS QD solids. Results were consistent with electrochemical contacting not inducing surface defects at the QD solid/electrolyte interface. Furthermore, photovoltages of 0.475 V were observed, which compares well to metal contacting of PbS QD solids. Further studies are underway to fully understand the method, liquid contacting of quantum dot solids, and the quantum dot solids themselves.

REFERENCES


ACKNOWLEDGMENTS

We thank Portland State University, CLAS, for financial support of this research. We also thank Valentin Uzunov for help with sandwich cell fabrication, Sheng Kuei Chiu for help with sandwich cell fabrication, and Nanofabrication (CEMN).