Tuning Opto-Electronic Properties of Lead-Free Perovskite $CsSnI_3$ Solar Cells by Incorporation of BiI_3

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ABSTRACT

Solar energy offers great potential in the drive to switch from conventional fossil fuel energy sources to clean, renewable and efficient ones. Third generation in perovskite photovoltaic technologies are highly promising due to low cost, ease of fabrication, and high efficiencies. The toxicity of the lead element, however, motivated a new direction towards alternative lead-free perovskite materials. Caesium tin iodide ($CsSnI_3$) serves as an attractive candidate due to its excellent optical features such as high absorption coefficient and favorable band gap. Past experimental results showed low photovoltage for this material, which could be due to high p-type carrier density even with the addition of tin fluoride (SnF_2). Therefore, this research aims to modulate the opto-electronic properties of $CsSnI_3$ through addition of bismuth iodide (BiI_3). $CsSnI_3$ was synthesized using a simple solution method with an addition of 20 mol% SnF_2. Thereafter, different amounts (0 – 10 mol%) of BiI_3 were added and the resultant sample solutions were deposited onto titania (TiO_2) substrates via spin-coating. The perovskite films were characterized and the devices were subsequently tested. The results showed an increase in open-circuit voltage (V_{OC}) to 0.211 V for the 5 mol% BiI_3 added sample. This was supported by the high shunt and recombination resistance observed, which could be due to reduced recombination sites. Power conversion efficiencies of devices with BiI_3 added, however, were relatively poor due to much lower photogenerated current. This could be ascribed to lower absorption coefficient and poorer film coverage, which led to lesser charge generation and collection. It was also noted that Bi was not successfully doped into the perovskite structure, but could have formed a separate amorphous phase. However, band gaps of Bi-containing samples remained unchanged and close to the original value of 1.3 eV, making them suitable absorber materials. Future work will then focus on improving the photocurrent of BiI_3 added $CsSnI_3$ by increasing the thickness of the perovskite layer or adding a dye such as N719 for enhanced light absorption and better device performance.