Photocurrent Collection Length and the Fill Factor of Mixed-Composition Metal Halide Perovskite Solar Cells

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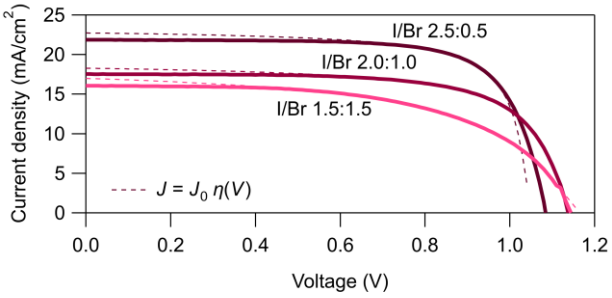
In this study, we examine the fill factor of mixed-composition perovskite ($Cs_{0.05}FA_{0.80}MA_{0.15}PbI_{3-x}Br_x$) based devices[1] as a function of the I/Br ratio. Curvature in the *J-V* data limiting the fill factor is accounted for by introducing a voltage-dependent photocurrent collection efficiency[2]. Under the approximation of uniform field and weak absorption, the collection efficiency may be defined as[3],

$$\eta(V) = X\left[1 - e^{\left(\frac{-1}{X}\right)}\right] \text{ , where } X = (L_c/D)\left[1 - \frac{V}{V_{fb}}\right] \quad . \qquad (1)$$

L_C/D is the ratio of the collection length, L_C, to the thickness of the absorbing layer, D, while V_{fb} is the flat band voltage. The collection length depends on both the mobility and the lifetime of the charge carriers. L_C therefore serves as a quick and direct evaluation of the electrical quality of the perovskite films. For example, in Figure 1, *J-V* curves for devices prepared with three different I/Br ratios are shown. The fill factors under AM1.5g simulated solar radiation, 0.73, 0.69, and 0.55, decrease as the ratio of bromine ions in the perovskite increases. The corresponding L_C/D ratios, determined using Eq. 1, above, are 17, 10, and 4. As the layer thickness, D, is comparable for all the devices, the lower fill factor is the result of shorter collection length, indicating lower charge carrier mobility and/or shorter charge carrier lifetime in the perovskite layer. The example clearly illustrates the importance of the charge collection length when adjusting the optical gap of perovskites via compositional engineering.



I/Br	FF	J_0 [mA/cm²]	L_c/D	V_{fb} [V]
2.5:0.5	0.73	23.4	17	1.05
2.0:1.0	0.69	19.2	10	1.14
1.5:1.5	0.55	19.2	4	1.17

Figure 1. *J-V* curves (AM1.5g, forward-reverse scan average) for ITO/SnO_2/$Cs_{0.05}FA_{0.80}MA_{0.15}PbI_{3-x}Br_x$ /Spiro-O-MeTAD/Au devices, together with the fitting parameters for the collection model of Eq. 1.

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