

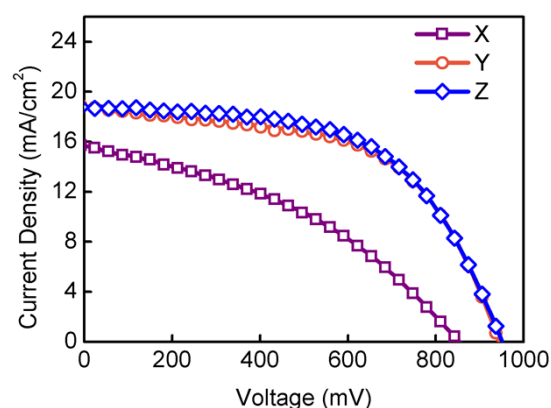
## Supporting Information

### All-carbon counter electrode for highly efficient hole-conductor-free organo-metal perovskite solar cells

**Yueyong Yang<sup>a</sup>, Junyan Xiao<sup>a</sup>, Huiyun Wei<sup>a</sup>, Lifeng Zhu<sup>a</sup>, Dongmei Li<sup>a</sup>, Yanhong Luo<sup>a</sup>, Huijue Wu<sup>a</sup> and Qingbo Meng<sup>a\*</sup>**

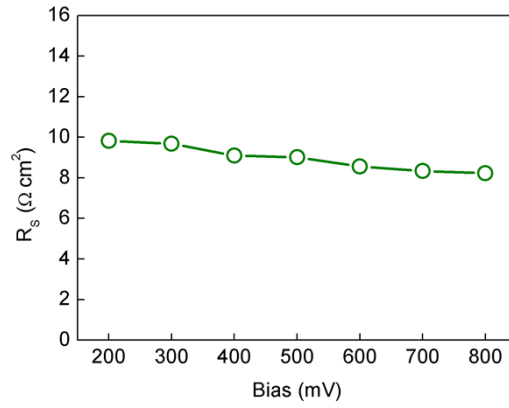
<sup>a</sup> Key Laboratory for Renewable Energy, Chinese Academy of Sciences; Beijing Key Laboratory for New Energy Materials and Devices; Institute of Physics, Chinese Academy of Sciences, Beijing, 100190, People's Republic of China.

\* Corresponding author. Email: qbmeng@iphy.ac.cn



**Fig. S1**  $J$ - $V$  characteristics of perovskite cells based on CEs with different weight ratios between graphite and CB. Sample X: 20% graphite and 75% CB; Sample Y: 47.5% graphite and 47.5% CB; Sample Z: 75% graphite and 20% CB. 1  $\mu\text{m}$  graphite was used in all these samples. The other 5% content in these samples is the binder.  $\text{PCE}_X=5.17\%$ ,  $\text{PCE}_Y=10.08\%$ ,  $\text{PCE}_Z=10.20\%$ .

The  $J$ - $V$  characteristics of perovskite cells based on CEs with different weight ratios between graphite and CB were tested. In a wide range of weight ratio between graphite and CB, the performances were quite close. However, for CEs with too much CB, the quality of the carbon film become quite poor, as the film often easily cracked into many small pieces, which consequently influenced the performance.



**Fig. S2** Fitted results of  $R_s$  for the cell with CE D at different applied bias.

**Table S1** Fitted results of  $R_s$  for cells with different CEs at 600 mV forward applied bias.

CE sample	A	B	C	D	Au
$R_s$ ( $\Omega \text{ cm}^2$ )	8.3	8.1	7.7	8.5	4.1

Fig. S1 shows the typical fitted results of  $R_s$  for the perovskite cell at different applied bias. The  $R_s$  does not change significantly with the increasing applied bias. Table S1 shows the fitted results of  $R_s$  for cells with different CEs. The  $R_s$  values for all the CEs are quite small. The  $R_s$  values of carbon CEs are higher than the Au CE. However, the differences between  $R_s$  values of carbon CEs are not significant.