

Supporting information:

The phase composition and structure of the as-prepared sample were determined by X-ray diffraction (XRD, RIGAKU, Dmax22000) with Cu K α radiation ($\lambda = 1.5406$ nm) over the 2θ range of $10-80^\circ$. The morphology of the sample was investigated by scanning electronic microscopy (SEM, FEI, America, Hitachi S4800). Light absorption property was examined using a UV-vis diffuse reflectance spectrophotometer (Shimadzu, Japan, UV-3600). The separation characteristics of photogenerated charge carriers on spectrum were examined by a lock-in-based surface photovoltage measurement system. And the SPV spectroscopy instrument was assembled by Jilin University. The system consists of a source of monochromatic light by a monochromator (SBP300, China) and a 500 W xenon lamp, a lock-in amplifier (SR830, Stanford) with a light chopper (SR540), and a photovoltaic cell. The powder sample was sandwiched directly between a blank ITO (indium tin oxide) glass electrodes and conductor substrate installed inside the photovoltaic cell for measurement. The effective overlapping area of the two electrodes in the test is about 1 cm^2 . The monochromatic light intensity on spectrum depended on the Xeon lamp spectral energy distribution, where the highest intensity was less than $80\text{ }\mu\text{W cm}^{-2}$. The positive electrode of the lock-in input was connected to the pole on the light incident side of the sandwich-like configuration. External dc bias provided by the lock-in amplifier could be applied onto the electrodes to obtain an enhanced SPV response. The SPV spectroscopy measurement was carried out under ambient conditions and the raw data were not treated further.

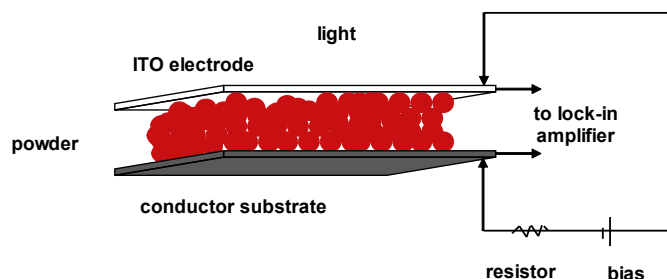


Fig. S1 The sandwich-like structure of SPV measurement