Supporting Information

Photocurrent measurements

All photocurrent measurements were conducted with sodium sulphite, a sacrificial hole scavenger commonly used in photoelectrochemistry. The reaction mechanism for the oxidation of sulphite is detailed below:

\[ \text{SO}_3^{2-} + 2\text{hole} + \text{H}_2\text{O} \rightarrow 2\text{H}^+ + \text{SO}_4^{2-} \]

**Figure S1.** IPCE spectra for the different thicknesses for the MoS\(_2\) only films.

**Figure S2.** Normalized absorbance spectra (a) entire spectra, (b) 400 – 500 nm only, highlighting the red shift in absorbance peak for the thinnest films.
Figure S3. Estimated APCE for the composite films A and B (estimated by calculation of the known concentrations of MoS$_2$ dispersed into each film).

Photocurrent measurements of the MoS$_2$-TiO$_2$ hybrid photoanodes was also measured utilizing iodine/tri-iodide electrolyte. The results are presented in Figure S4. Analogous to Figure 4 a photocurrent corresponding to excitons A/B is suppressed relative to the absorbance spectrum for the thin films. We therefore verify the assertion that conduction band is approximately -0.13 V $\pm 0.05$V (against SHE reference).

Figure S4. Average photocurrent for two ratios of MoS$_2$/TiO$_2$ samples. Averages are calculated for 2 samples for each ratio and 3 measurements for each sample. Photocurrent was measured with Iodide/tri-iodide electrolyte.

To monitor the photoanodes for stability repeat runs of the same electrodes was completed. Figure S5 shows an example of three consecutive runs of a MoS$_2$ only photoanode.
**Figure S5.** Three consecutive photocurrent measurements of the same photoanode.

**Figure S6.** Approximate band structure of MoS2 and TiO2. Details of the conduction band maxima and valance band minima are given (against NHE).