Supplementary information

A monolithic and standalone solar-fuel device having comparable efficiency to photosynthesis in nature

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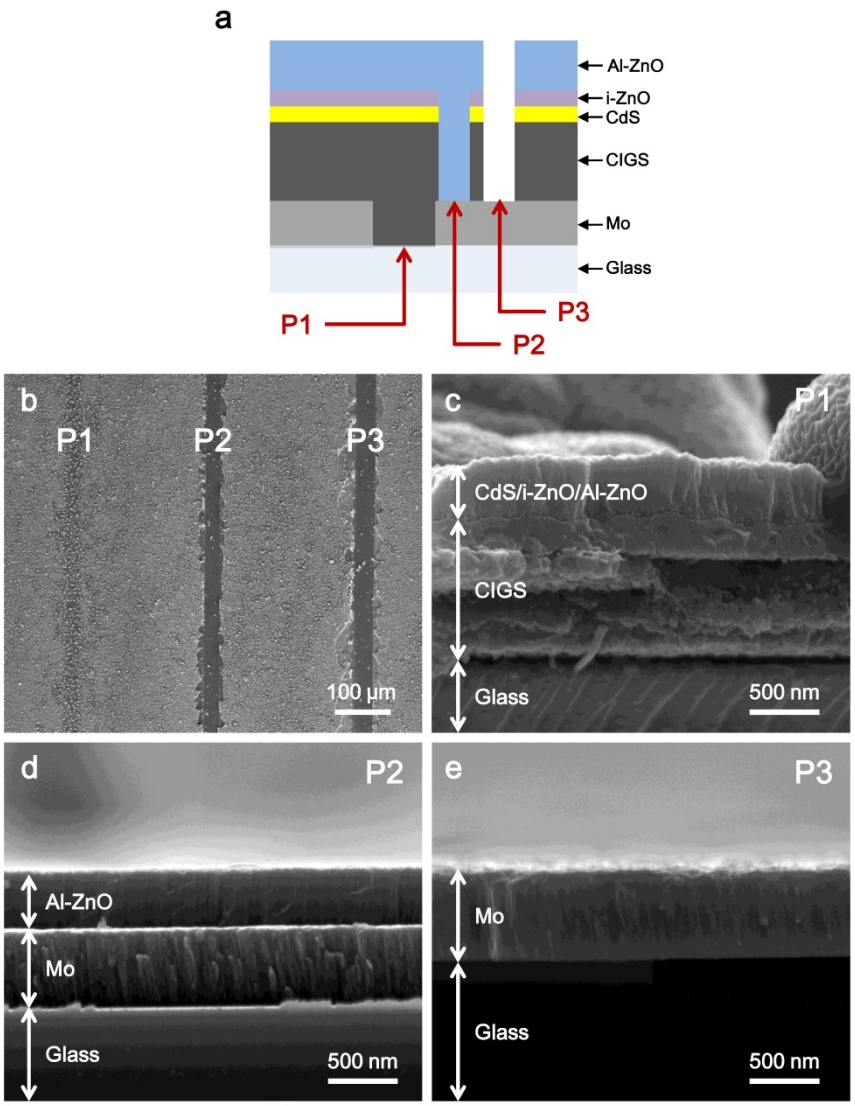

Fig. S1. Schematic diagram (a) and SEM images (b-e) of CIGS module via patterning process. (a) The schematic diagram of the patterns (b) Top view image of scribing region of the CIGS film. (c-e) Cross sectional SEM images of P1 (c), P2 (d), and P3 (e).

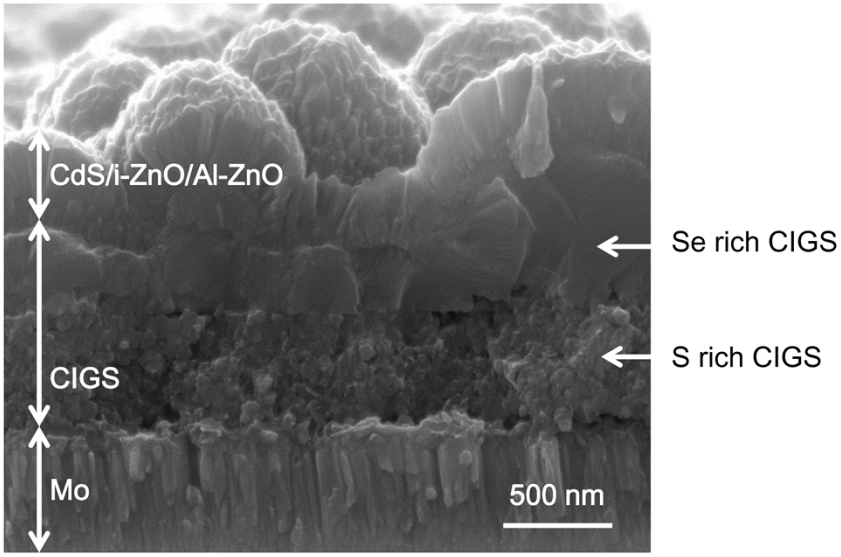

Fig. S2. Detailed cross sectional SEM image of Fig. 3b indicating S and Se rich region in CIGS absorber layer.

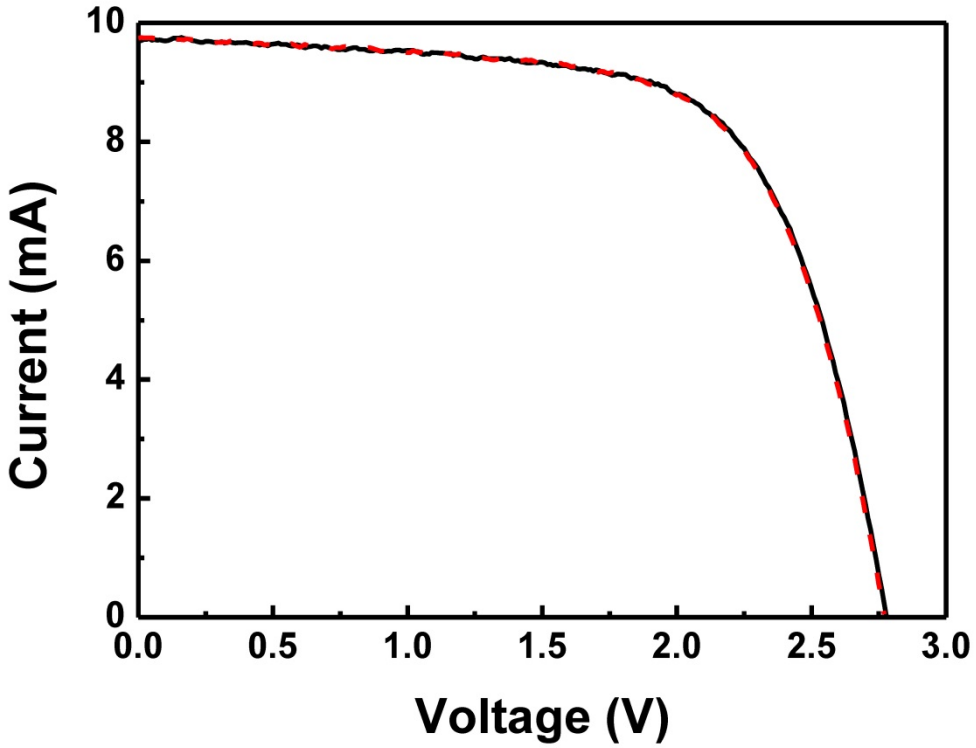

Fig. S3. Current – Voltage (I-V) characteristics of the CIGS module of before (black solid line) and after (red dashed line) the Co_3O_4 catalysts deposition on the rear side of the substrate confirming that the performance of the CIGS module was intact by the Co_3O_4 deposition process.

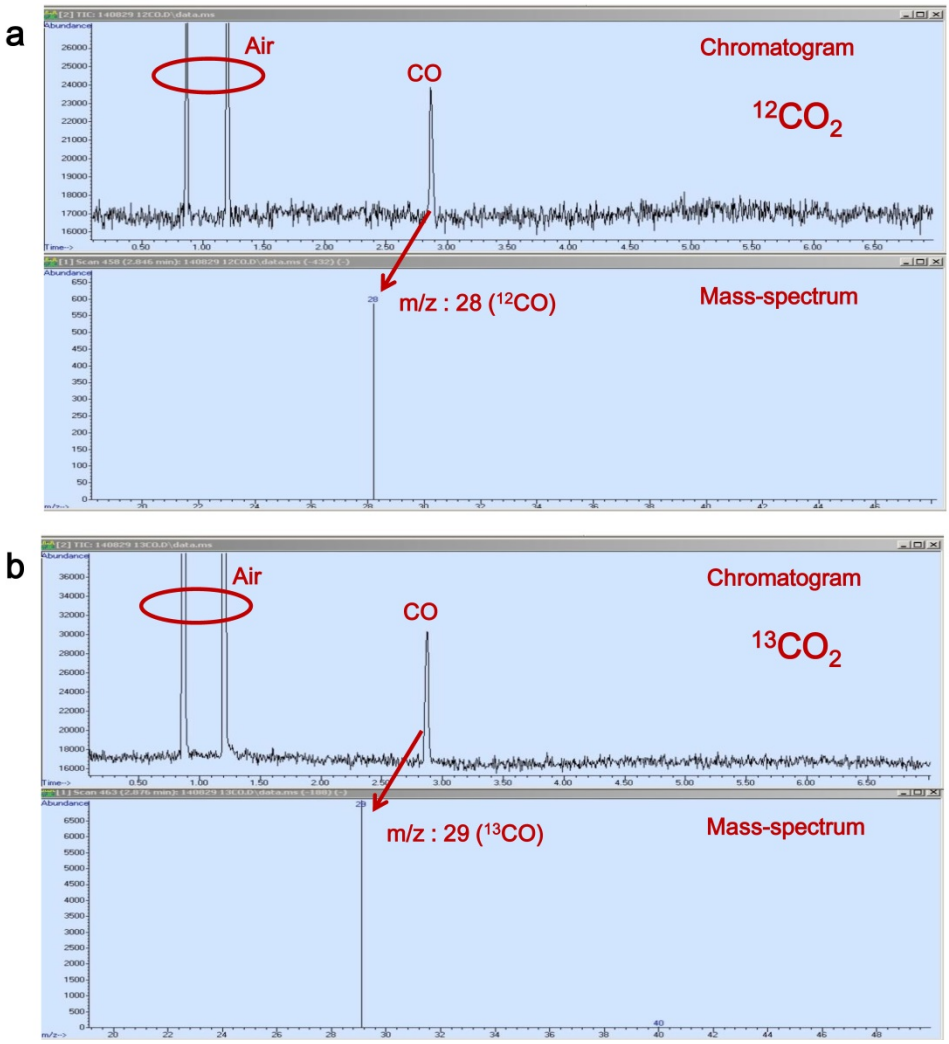

Fig. S4. ^{13}C isotope experiment results. GC-MS spectra of the gas products taken from the cathodic compartment using (a) $^{12}CO_2$, and (b) $^{13}CO_2$ gases confirming that CO_2 gas was the carbon source of the produced CO from our solar-fuel device. In order to avoid confusion of overlapping mass-spectrum for ^{12}CO and N_2, mass spectrum of air was subtracted.

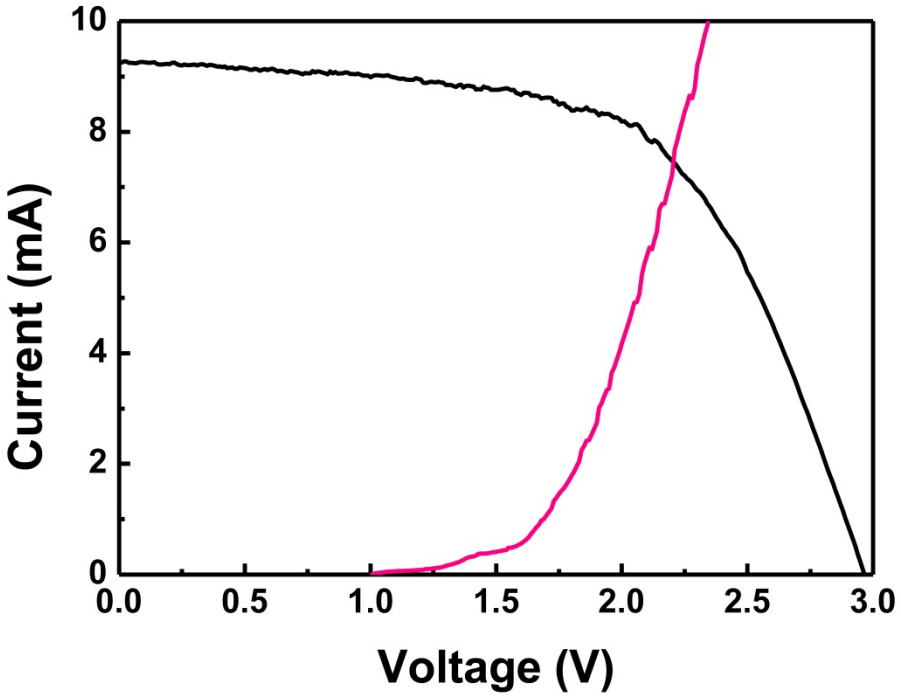

Fig. S5. Two-electrode I-V curve for hydrogen generation from solar water splitting. Black line is CIGS module which had an efficiency of 7.66 % with an open circuit voltage (V_{oc}), short circuit current density (J_{sc}), and fill factor of 2.95 V, 9.22 mA, and 59.2 %, respectively. The pink line is the electrolysis I-V curve with two-electrode configuration with a Co_3O_4 NPs film anode and a Pt cathode.

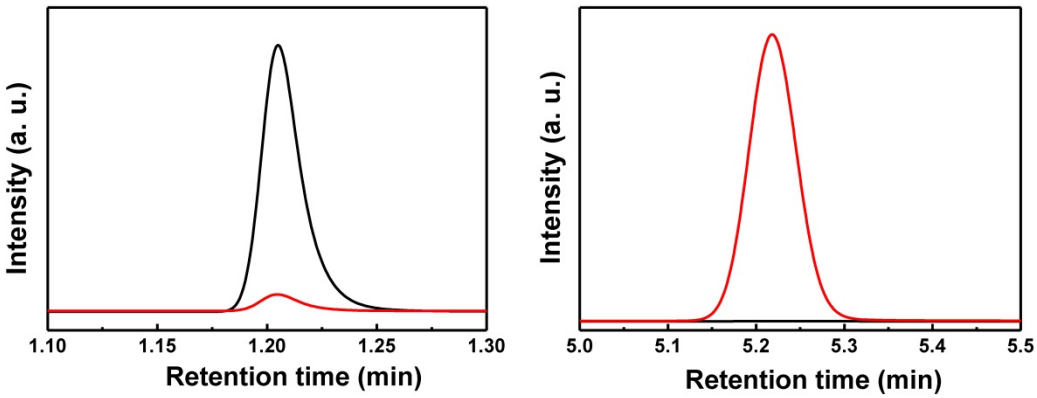

Fig. S6. A typical chromatogram from GC analysis. The red line is a chromatogram from the CO generation device from CO_2 reduction (Fig. 5), and the black line is a chromatogram from the hydrogen generation device from water splitting (Fig. S5).

Table S1. Representative reports of solar-to-hydrogen (STH) conversion efficiency via solar water splitting. (The data are taken from Ronge *et al.*)[37]

Year	Photo-electrode	Type	Electrolyte	STH Eff.	Ref.
1976	TiO_2-GaP	PEC	$0.1MH_2SO_4$	0.25 %	38
2008	TiO_2-CuTiO	PEC	1MKOH(anode) + 0.1M Na_2HPO_4(cathode)	0.30 %	39
1998	($GaInP_2$ |1jn-GaAs |)-Pt	PV+PEC	3M H_2SO_4	12.4 %	16
2010	(WO_3 |2jn-Si |)-Pt	PV+PEC	0.33M H_3PO_4	3 %	40
2012	(WO_3- |1xDSSC |)-Pt	PV+PEC	1M $HClO_4$	3.1 %	41
2013	(Co-Pi/W:$BiVO_4$- |2jn-Si |)-Pt	PV+PEC	0.1M K-Pi	4.9 %	42

Movie S1. The movie shows the solar-fuel device in operation

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(a) An overview of the solar-fuel device for experiment in the dark.

(b) A lamp is switched on.

(c) Close up of the cathode for CO generation. CO gas is evolved at the electrode. (The gas product was identified by measuring gas chromatograph).

(d) Close up of the anode for O_2 generation. The evolved O_2 bubbles attach on the electrode surface.

Supplementary References

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