Supplementary Information:

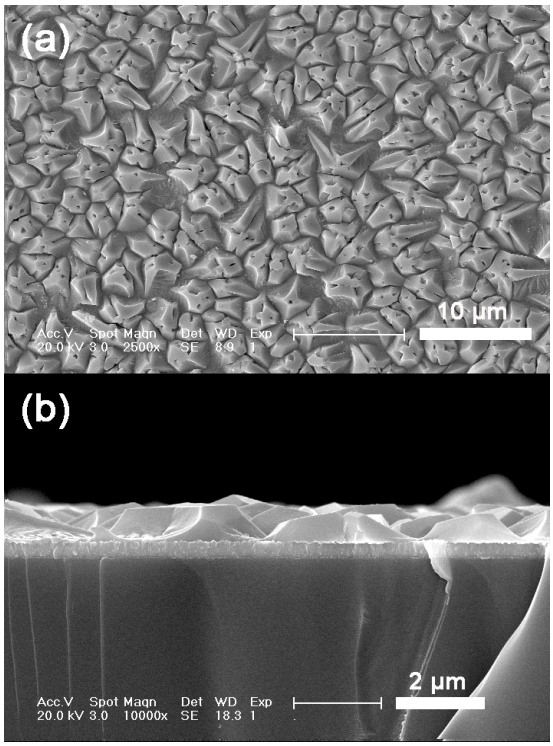

Fig. S1: SEM images of Cu_2O film. (a) Top view image of Cu_2O film; (b) cross section image of Cu_2O film.

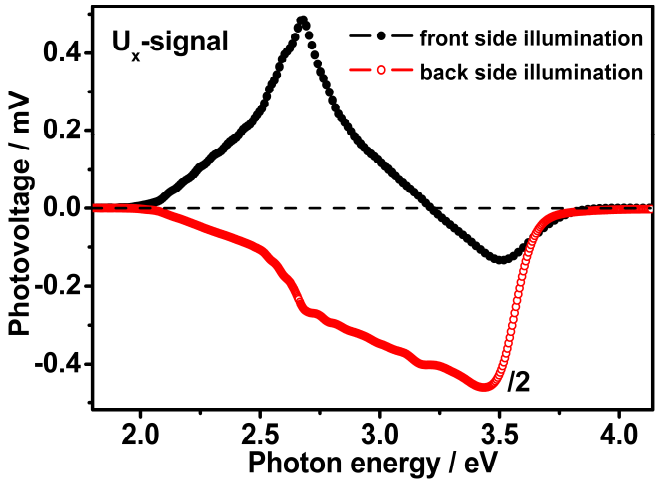

Fig. S2: SPV spectra of ZnO/Cu_2O heterostructure film under front and back side illumination measured by lock-in amplifier as the in-phase photovoltage signals [U_x, $U_x = U \times \cos(\text{phase})$].

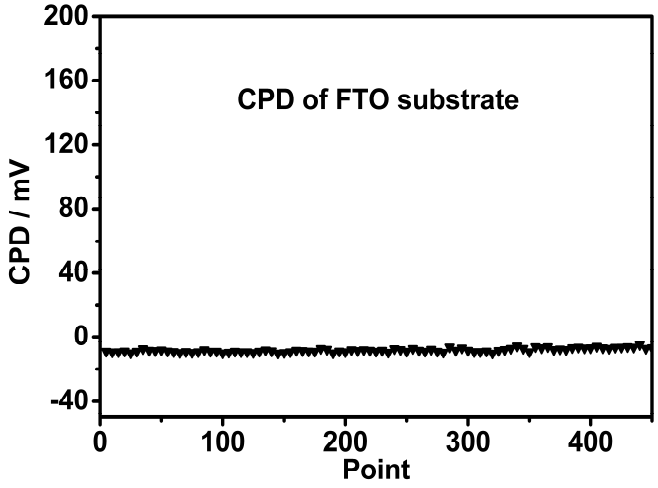

Fig. S3: CPD of FTO substrate.

In our experiment we measured the surface work functions instead of bulk work functions. For an n-type semiconductor (ZnO for instance) with upward band bending, the measured surface work function is larger than its bulk work function while lower for a p-type semiconductor (Cu_2O for instance). So when taking into account the surface band bending the interfacial electric field magnitude is larger than the difference of the measured CPDs (0.19 V). The Fermi levels of ZnO and Cu_2O under vacuum condition are necessary to confirm the interfacial electric field magnitude. However the measurement of the Fermi levels of ZnO and Cu_2O under vacuum condition is extremely difficult. Here we just make a rough estimate. The measurement of surface work functions was taken under the same atmosphere so we neglect the influence of adsorbates.