nature nanotechnology

SUPPLEMENTARY INFORMATION

DOI: 10.1038/NNANO.2011.139

Solution processed core-shell nanowires for efficient photovoltaic cells

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1. CdS nanowire growth and SEM, XRD

CdS nanowires grown by the PVT method are shown in Figure S1. CdS nanowires ranged from 100nm to 400nm in diameter and up to 50μm in length. The XRD pattern matches very well with hexagonal phased wurtzite CdS; the strong (101) peak indicates the preferred growth direction while (100) and (002) orientated nanowires are also observed under our growth condition.

2. HRTEM, FFT and selected inverse FFT image

Core-shell nanowires were examined by HRTEM. Figure S2 (a) shows the typical HRTEM image of a core-shell nanowire. The corresponding FFT image from Figure S2 (a) is shown in Figure S2 (b). Here we selected the growth direction (white arrow) to obtain the inverse FFT image as marked by yellow spots. Figure S2 (c) is the pattern we used for the inverse FFT image, the other FFT spots were removed from Figure S2 (b). The corresponding selected FFT image is shown in figure S2 (d). Along the growth direction, the crystal phase in the core (yellow area) and shell (red area) parts are both continues. Along the core-shell interface, the most of the crystal fringes match each other, which indicate that the resulting core-shell nanostructure has coherent interface. The lattice mismatches are marked by green spot on the interface. Less than 10% lattice distortion is observed along the nanowire direction, which confirmed the low defects density of the core-shell nanowire.

3. CdS nanowire conversion to CdS-Cu_2S core-shell nanowire

The CdS nanowire was dipped in 0.5M CuCl solution at 50 ℃ for a given period of time. Immediate color change from bright yellow to dark brown was observed after dipping. The corresponding XRD patterns in Figure S3 show the increase of the Cu_2S peaks and the decrease of the CdS peaks with the reaction length, which indicates cation exchange of the CdS to Cu_2S.

4. Nanowire PV cell degradation test

In order to test the degradation of our nanowire solar cell, the as-made CdS-Cu_2S core-shell nanowire solar cell was tested under standard 1 sun (AM 1.5G) illumination at 32 ℃. The cell operated at the short circuit condition for highest copper ion diffusion. During the illumination, the light was turned off for 8-10 hours repeatedly to test the efficiency recovery under dark environment as

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reported previously[1]. As shown in Figure S4, over ~40 hours of continuous operation, the overall efficiency slowly decreased by ~4% below its original value. This efficiency decease is mainly due to the V_{OC} loss. Furthermore, almost complete recovery of efficiency was observed after setting in dark for a few hours and no obvious long term efficiency loss can be identified during our test period.

Reference:

1 Partain, L. and Sayed, M., presented at the Electron Devices Meeting, 1973 International, 1973 (unpublished).

Figure S1

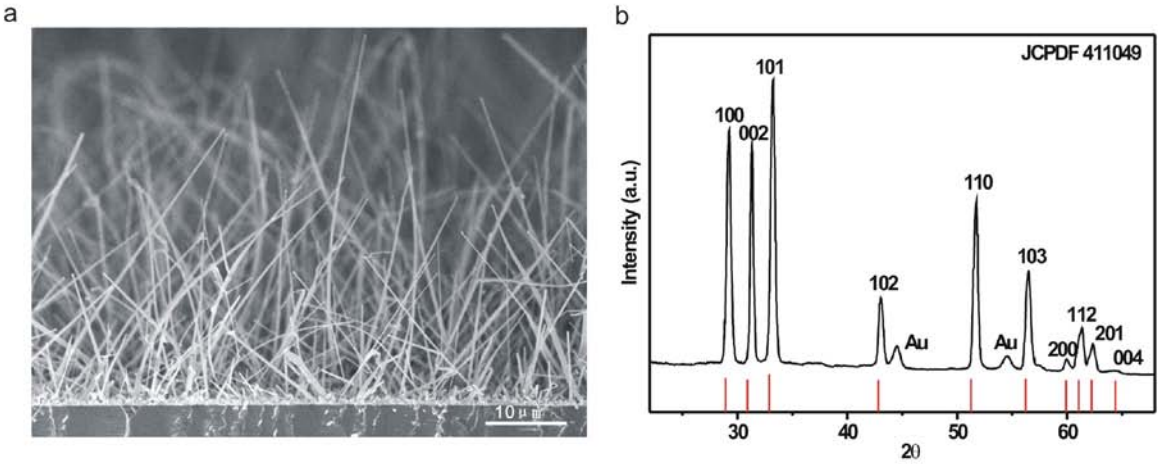

Figure S1. SEM and XRD of the as-grown CdS nanowires. a. SEM image of the as-grown CdS nanowires with diameters 100nm-400nm and lengths up to 50μm. b. corresponding XRD of CdS nanowires. The (101) peak is strongest, which is consistent with the growth direction shown in Figure 1b.

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Figure S2

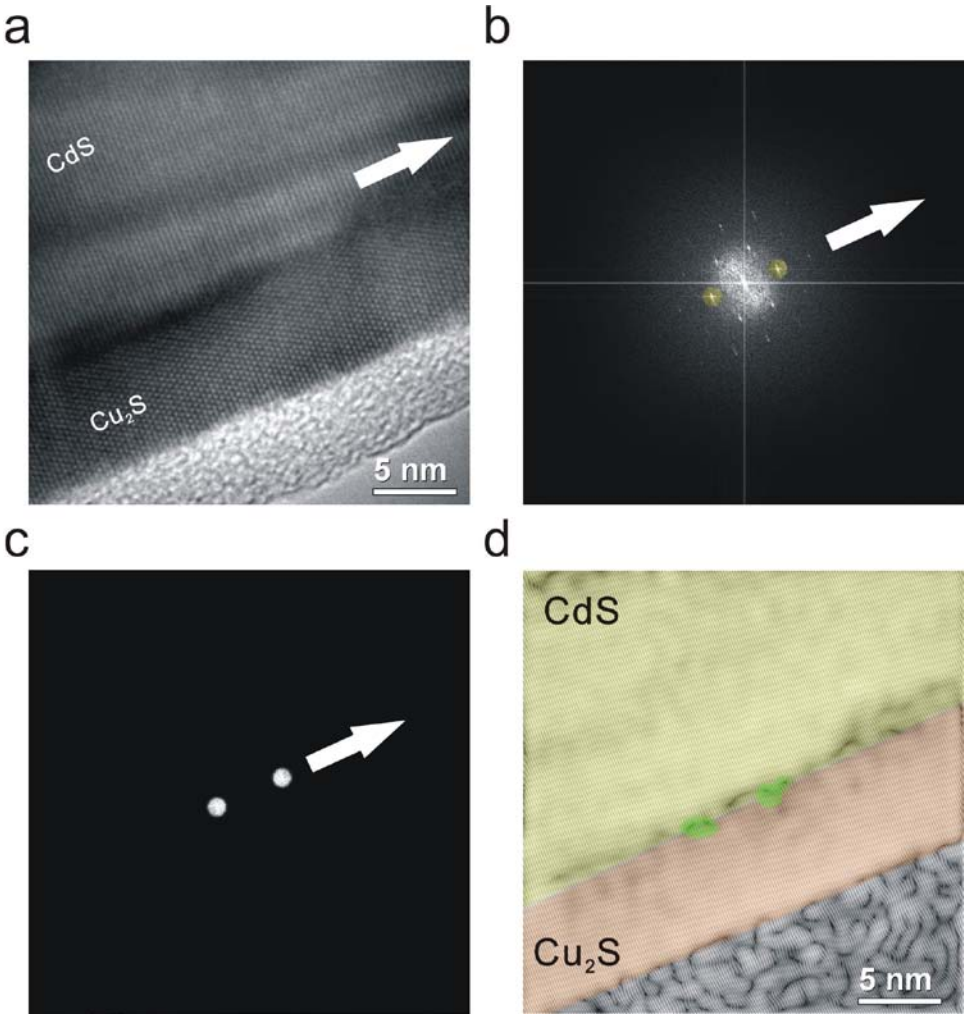

Figure S2. a. HRTEM image of a CdS-Cu_2S nanowire. The white arrow direction indicates the growth direction. b. Coresponding FFT image from figure S2 (a). The selected FFT spots are marked in yellow. c and d, the seleted FFT spots and corresponding inverse FFT image. The yellow area in figure S2(d) is the CdS core, while the red area is the Cu_2S shell. The lattice distortion at the interface is marked by green spots.

Figure S3

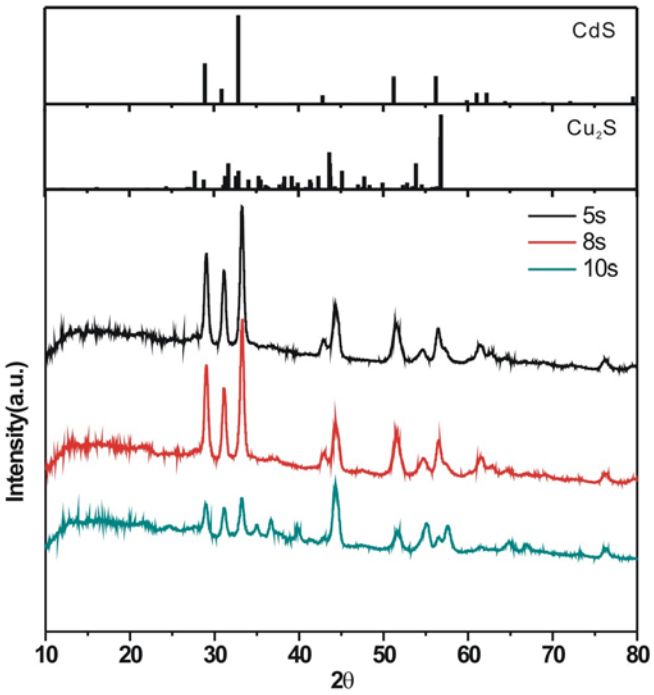

Figure S3. XRD patterns of the CdS-Cu_2S core-shell nanowires with different ion-exchange reaction times. With longer reaction time, the CdS peaks decrease and the Cu2S peaks increase, indicating growth of the shell over time.

DOI: 10.1038/NNANO.2011.139

Figure S4

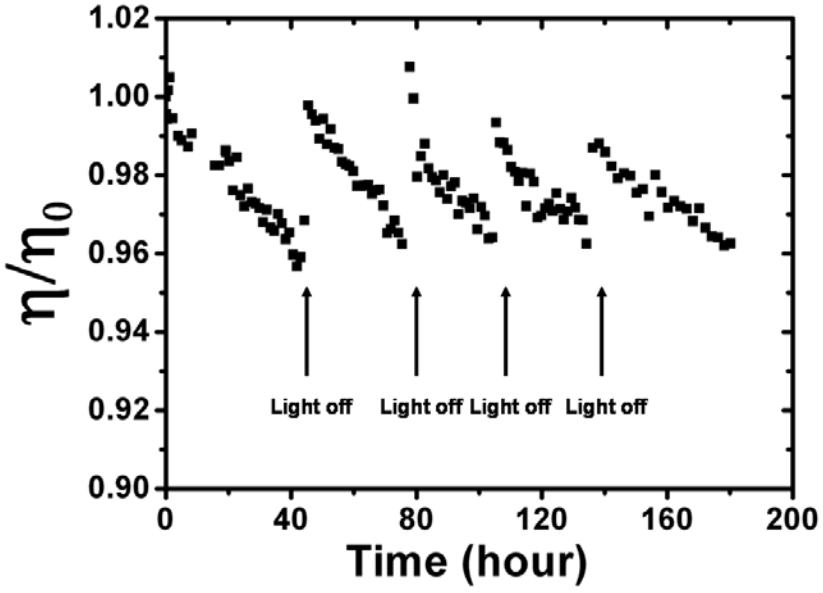

Figure S4. Lifetime test of a CdS-Cu_2S core-shell nanowire solar cell. The nanowire cell operating under 1-sun (AM 1.5G) illumination at the short circuit conditon shows about 4% efficiency loss after ~40 hours and almost complet recovery under dark.