Electronic Supplementary Information

Fabricating flexible wafer-size inorganic semiconductor devices

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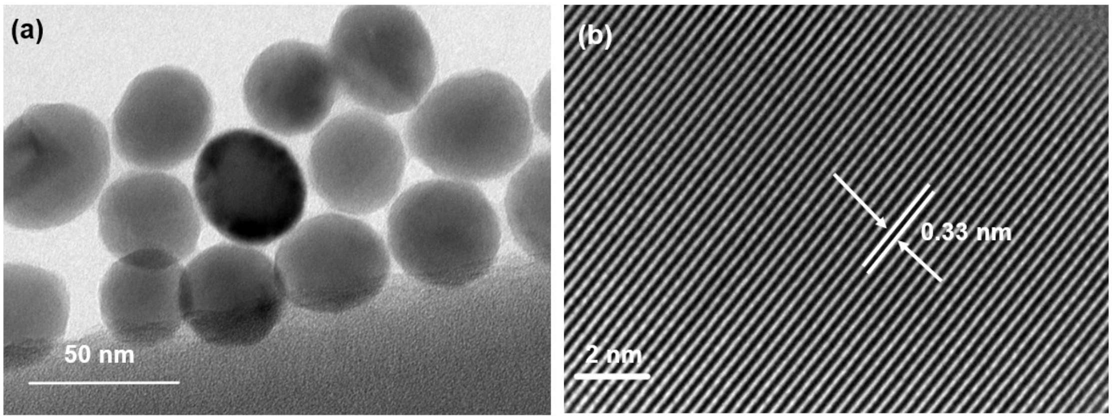

Fig. S1 The morphology of the $Cu_{2-x}Se$ NCs. (a) Transmission electron microscopy (TEM) image and (b) high-resolution TEM (HRTEM) images of the nanoparticles.

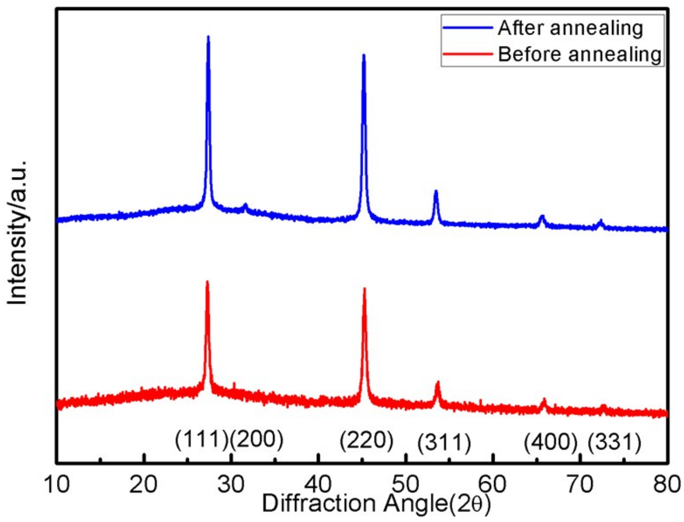

Fig. S2 XRD patterns of NCs before and after annealing.

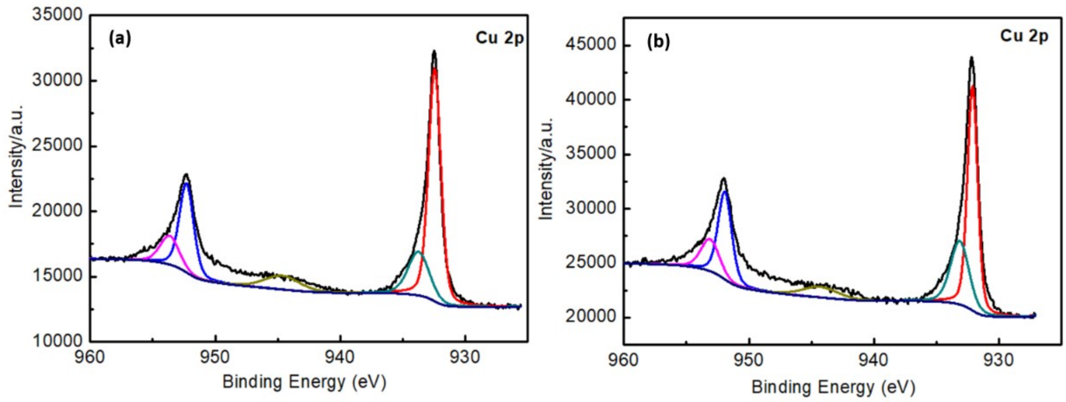

Fig. S3 The binding energy of Cu 2p (a) before and (b) after annealing.

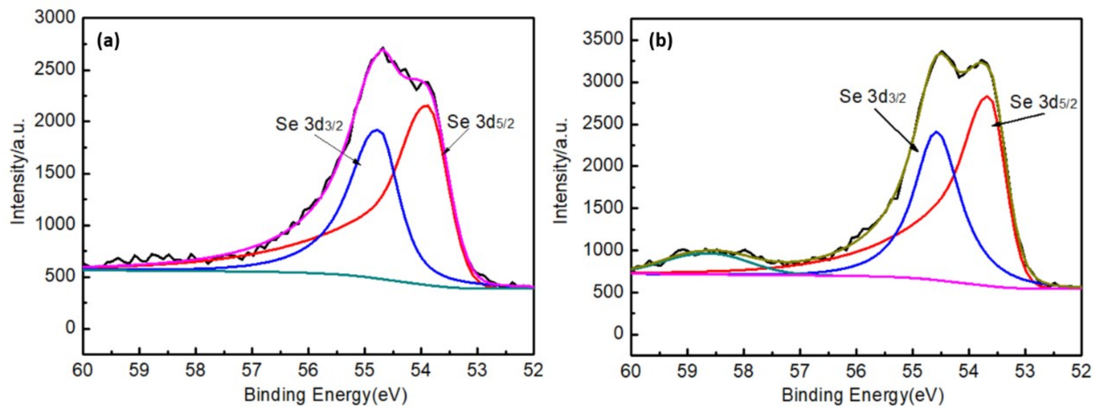

Fig. S4 The binding energy of Se 3d (a) before and (b) after annealing.

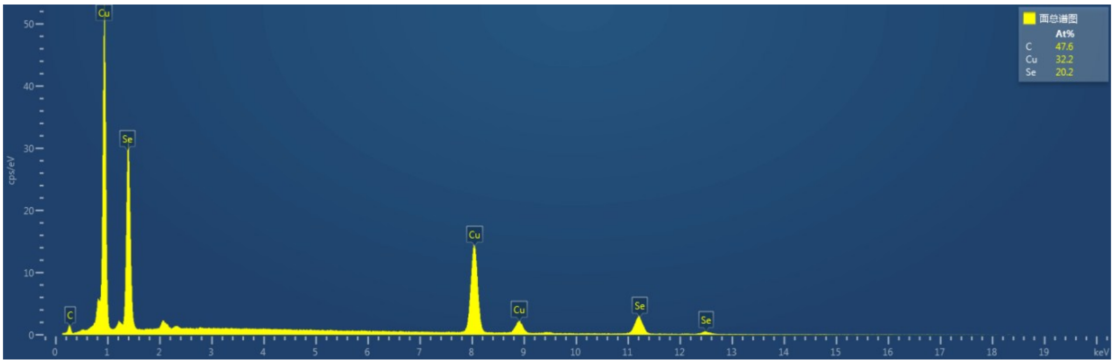

Fig. S5 Scanning electron microscopy (SEM)-energy-dispersive spectroscopy image of the $Cu_{2-x}Se$ NCs.

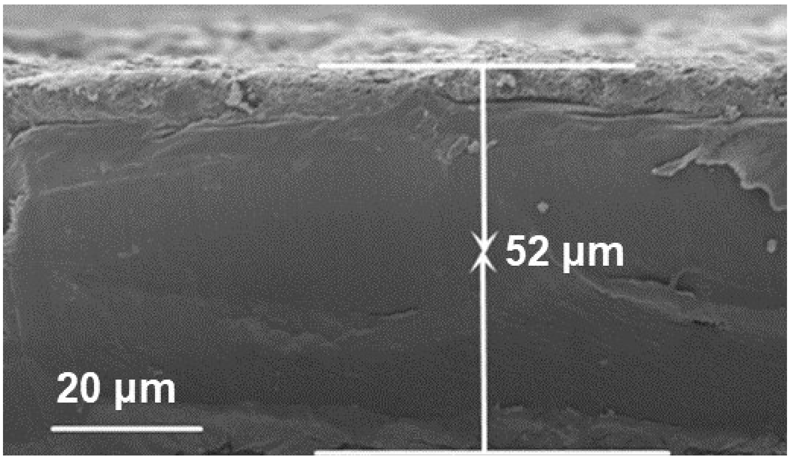

Fig. S6 The interface image and thickness of the whole film (substrate and $Cu_{2-x}Se$ film).

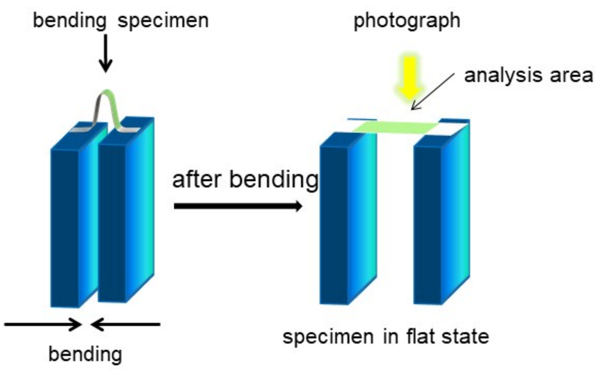

Fig. S7 The sample for Digital image correlation (DIC) analysis.

Supplementary Note 1.

We also measured the absorption characteristics and Cu/Se ratio of $Cu_{2-x}Se$ NCs solution obtained at different reaction time (Fig. S8 and Table S1). As the reaction time increases, $Cu_{2-x}Se$ NCs show a blue-shift in LSPR absorption, indicating the deepening of copper deficiency. The changes in Cu/Se ratio and resistance prove that $Cu_{2-x}Se$ NCs tend to become heavily self-doped semiconductor with time (Table S1). From these phenomena, the enhanced conductivity of $Cu_{2-x}Se$ NCs can be explained that with reaction continues, the deficiency of copper will be intensified, leading to the formation of heavily self-doped $Cu_{2-x}Se$ NCs.

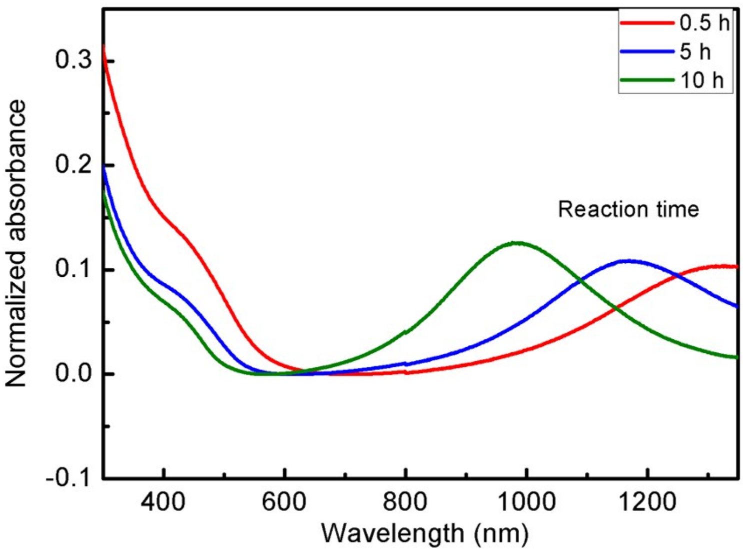

Fig. S8 The absorption spectrum of $Cu_{2-x}Se$ NCs obtained at different reaction time.

Table S1 The absorption characteristics, Cu/Se ratio and resistance of $Cu_{2-x}Se$ NCs solution obtained at different reaction time.

Reaction time	0.5 h	5 h	10 h
Average resistance	non-conductive	69.5 Ω	7.69 Ω
absorption peaks	No peak	1176 nm	985 nm
Cu/Se ratio	1.86	1.74	1.59

Table S2. Comparison of the flexibility of silver electronics and inorganic semiconductor films.

Materials	Bending radii/ angle/ rate	Bending times	Resistance increases	Ref.
Silver lines	0.5 mm	10,000	3.2 times	*Adv. Mater.,* 2011, **23**, 3426
Silver lines	1 mm	8,000	2.4 times	*ACS Appl. Mater. Interfaces,* 2014, **6**, 1306
Cu/Ag electronics	330°	3,000	4 times	*RSC Adv.,* 2016, **6**, 62236
Silver conductor	2.7 mm	200	Basically unchanged	*Nanoscale,* 2018,**10**,6806
Ag/polymers electrodes	< 1 mm	1,000	Basically unchanged	*Nat. Commun.*, 2015, **6**, 6503
Silver tracks	90°	1,000	1.27 times	*Sci. Rep.,* 2016, **6**, 21398
Ag/polymers	75 %	10,000	1.05 times	*Adv. Funct. Mater.,* 2018, **28**, 1704671
carbon/silver nanocomposites	5 mm	15,000	1.2 times	*ACS Appl. Mater. Interfaces,* 2016, **8**, 16907
Copper selenide film	3 mm	**100,000**	2.83 times	This work

Supplementary Note 2.

Copper sulfide (CuS) is a semiconductor exhibiting great potential for electronic and optoelectronic applications. Herein, CuS solution was synthesized through a hydrothermal method.[1] In detail, two precursor solutions were prepared in the first place, namely solution 1 and solution 2. In solution 1, 28 ml of deionized water was mixed with 12 mmol of $CuCl_2$ and 14 ml of ethanol, while in solution 2, 28 ml of deionized water was mixed with 12 mmol of Na_2S and 14 ml of ethanol. In the experiment, solution 1 was slowly added to solution 2 and stirred thoroughly. Black suspension would appear once the stirring was completed. Then, the mixture was placed in a 100 mL Teflon-lined autoclave for 12 hours, with the temperature being set to 140 ºC. After centrifugation and drying, the material was dispersed in ethylene glycol to produce the ink. Then, copper sulfide film was obtained by drop-casting the ink on a paper and annealing in air. In detail, copper sulfide was dispersed in ethylene glycol with a concentration of 15 mg mL^{-1} by ultrasonic treatment for 5 min. Subsequently, 120 μL ink was evenly deposited on the paper by using a dropper. Finally, the film was annealed at 60 °C for 4 h in air.

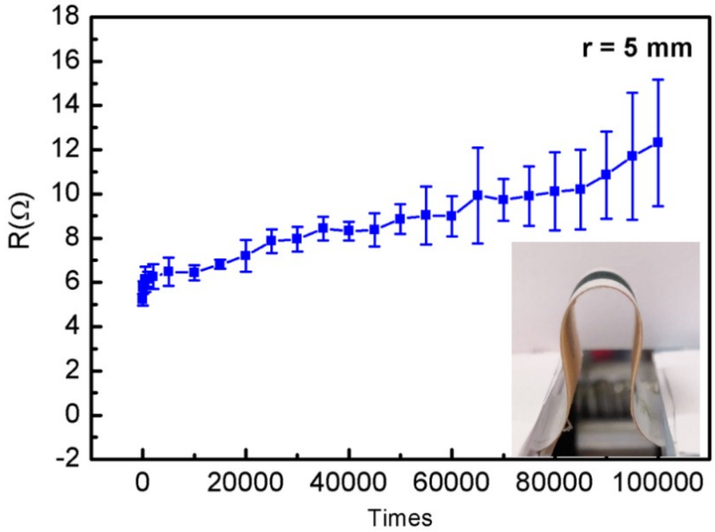

Fig. S9 The resistance changes of the copper sulfides films with bending number times.

Supplementary Note 3.

To test the effect of compressive stress on thin films, we performed a bending experiment after rotating the sample for 180 degrees (Fig. S10 a). This caused the film to be subjected to compressive stress during the bending process. As shown in Fig. S10 b, after the film was bent for 100,000 times at a bending radius of 3 mm, the resistance increased 2.34 times, which was close to the results obtained in experiments under tensile stress. So, it can be concluded that compressive stress has similar effect on the electrical properties of the film as tensile stress.

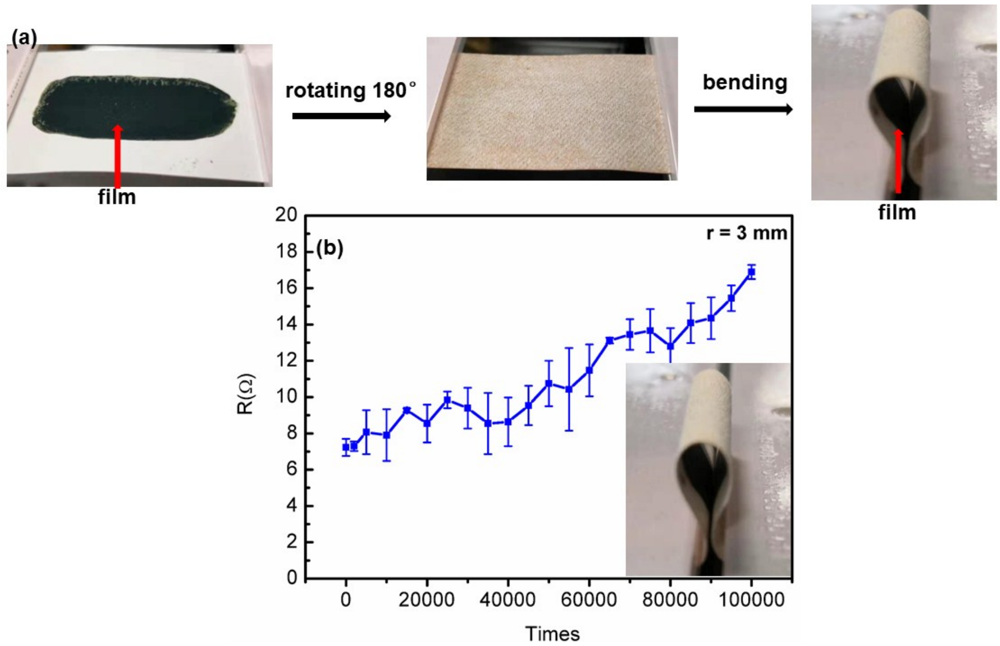

Fig. S10 (a) Rotating the sample for 180° to perform a bending experiment. (b) The resistance changes of the $Cu_{2-x}Se$ films with bending number times.

References

[1] M. R. Wang, F. Xie, W. J. Li, M. F. Chen, Y. Zhao, *J. Mater. Chem. A*, 2013, **1**, 8616-8621.