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Supporting materials for

Thermoelectric-Photoelectric Composite Nanocables Induced Larger Efficiency of Dye-Sensitized Solar Cells

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1. Seebeck coefficient and resistivity of $NaCo_2O_4$, TiO_2 and TiO_2-$NaCo_2O_4$ composite materials

$NaCo_2O_4$ powder, TiO_2 powder and TiO_2-$NaCo_2O_4$ composite nanocables were pressed and sintered at 900 ^oC for 4 h in air. The obtained samples were cut into bars of 2×2×11 mm^3 for Seebeck coefficient (S) and electrical resistivity (ρ) measurements using a commercial system (ZEM-3, ADVANCE RIKO, Inc., Japan). Fig. S1 shows temperature dependence of resistivity (ρ) and Seebeck coefficient (S) of $NaCo_2O_4$, TiO_2 and TiO_2-$NaCo_2O_4$ composite materials. $NaCo_2O_4$ shows a low resistivity of about 1 mΩ cm (Fig. S1A(a)) and a positive Seebeck coefficient of about 108 μV K^{-1} (Fig. S1B(a)) at room temperature, implying that $NaCo_2O_4$ is a good p-type thermoelectric oxide. TiO_2 shows a high negative Seebeck coefficient of about -350 μV K^{-1} (Fig. S1B(b)) at room temperature to indicate that it is an n-type thermoelectric oxide, but its high resistivity of about 320 mΩ cm (Fig. S1A(b)) at room temperature weakens its thermoelectric performance. As a result, the temperature gradient effect in the DSSC with pure TiO_2 photoanode is suppressed so that there is no obvious difference among their *J-V* characteristics under different ΔT, Fig. 5C and 5D. Since the mass ratio of $NaCo_2O_4$ and TiO_2 in CNCs is about 1:4, that is, the mass percentage of $NaCo_2O_4$ in CNCs is only about 20%, the TiO_2-$NaCo_2O_4$ composite material exhibits similar Seebeck coefficient and resistivity to TiO_2, but its values of both Seebeck coefficient and resistivity are smaller than those of TiO_2, (Fig. S1B(c) and S1A(c)).

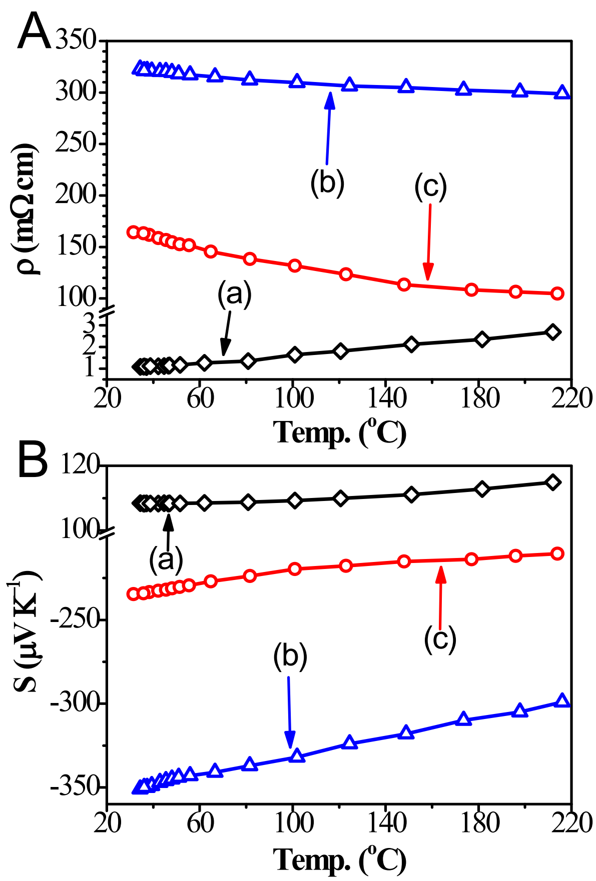

Fig. S1 Temperature dependence of (A) resistivity (ρ) and (B) Seebeck coefficient (S) of (a) $NaCo_2O_4$, (b) TiO_2 and (c) TiO_2-$NaCo_2O_4$ composite materials.

2. Microstructure of the composite photoanode film

In order to investigate the effect of TiO_2-$NaCo_2O_4$ composite nanocables on the photovoltaic properties of solar cells, different contents of the prepared CNC powders were mixed with TiO_2 nanoparticles for hybrid pastes, and then the composite photoanode films were prepared by doctor-blade coating technique. The cross-sectional SEM image of the composite photoanode film with 10 wt% CNCs is shown in Fig. S2. It is observed in the photoanode that some CNCs are randomly scattered in the TiO_2 nanocrystalline particles with an average diameter of about 30 nm, and many TiO_2 nanocrystals are attached on the surface of the CNCs, consistent with the expected design as shown in Fig. 1a. The CNCs have a much bigger size and smaller specific surface area than the TiO_2 nanocrystals, which is a possible factor to influence light scattering as well as the adsorption capacity of dye molecules.

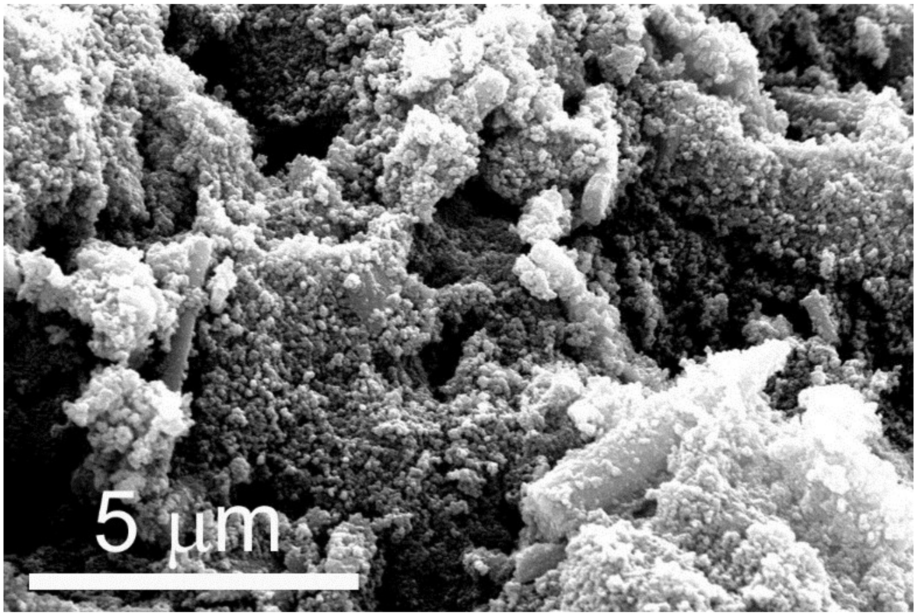

Fig. S2 The cross-sectional SEM image of the composite photoanode film with 10 wt% CNCs.