Electronic Supplementary Information (ESI):

Transparent conducting p-type thin films of c-axis self-oriented $Bi_2Sr_2Co_2O_y$ with high figure of merit

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Experimental Details

1. Thin film preparation

$Bi_2Sr_2Co_2O_y$ transparent conducting oxides thin films were deposited on $SrTiO_3$ (STO) substrates by the simple chemical solution deposition method. Bismuth acetate, strontium acetate and cobalt acetate were dissolved into propionic acid at 60 ºC, and the solution was stirred at this temperature for 20 minutes, and then stirred at room temperature for more than 12 hours. The solution concentration was preciously controlled to 0.1 M. Before the deposition process, all the substrates were ultrasonically cleaned with acetone, ethyl alcohol and deionized water, and then cleaned in a plasma-cleaner for 10 minutes. In order to obtain well-crystallized STO surfaces, the as-cleaned substrates were annealed in oxygen at 900 ºC for 60 minutes. All the thin films were fabricated by the spin-coating method with a rotation speed of 4000 rpm and a time of 1 minute, and then baked in air at 150 ºC and 400 ºC for 2 and 10 minutes, respectively. Finally, the thin films were crystallized at 850 ºC for 2 hours under following oxygen atmosphere.

2. Characterization

The crystal phase and quality were analyzed by a high-resolution X-ray diffraction with a monochromatic Cu-$K_{\alpha 1}$ radiation on a Philips X'pert Pro machine (XRD, Nickel filter and

Bragg-Brentano geometry, PANalytical B.V., Almelo, Netherlands). Surface morphology and film thickness were determined by a field-emission scanning electronic microscopy (FE-SEM, FEI-designed Sirion 200, FEI, Hillsboro, OR). The thickness for all derived thin films is about 25 nm determined by the cross-section FE-SEM. The thin films for high-resolution transmission electron microscopy (HR-TEM) were prepared by the focused ion beam (FIB). Optical transmission measurements were performed using a UV/Vis/NIR Lambda 900 spectrometer (Perkin-Elmer, California, USA). Electrical transport properties were measured on a physical properties measurement system (PPMS, Quantum-designed) using the standard four-point probe technique. Seebeck coefficient measurements were also performed on the PPMS in order to discern the type of charge carriers. Room temperature Hall measurements are also carried out on PPMS using the van der Pauw geometry.