## Supplementary Information for

## Proximity-Induced Magnetism and Anomalous Hall Effect in Bi<sub>2</sub>Se<sub>3</sub>/LaCoO<sub>3</sub>: A Topological Insulator/ Ferromagnetic Insulator Thin Film Heterostructure

Shanna Zhu<sup>1,2</sup>, Dechao Meng<sup>3,4</sup>, Genhao Liang<sup>3</sup>, Gang Shi<sup>1,2</sup>, Peng Zhao<sup>1,2</sup>, Peng Cheng<sup>1</sup>, Yongqing Li<sup>1</sup>, Xiaofang Zhai<sup>3,5</sup>, Yalin Lu<sup>3,5,6</sup>, Lan Chen<sup>1,2\*</sup> and Kehui Wu<sup>1,2,7\*</sup>

<sup>1</sup>Beijing National Laboratory for Condensed Matter Physics, Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China

<sup>2</sup>School of Physical Sciences, University of Chinese Academy of Sciences, Beijing 100049, China <sup>3</sup>Hefei National Laboratory for Physical Sciences at the Microscale, University of Science and Technology of China, Hefei 230026, China

<sup>4</sup>Microsystem and Terahertz Research Center & Institute of Electronic Engineering, CAEP, Mianyang 621900, China

<sup>5</sup>Synergy Innovation Center of Quantum Information and Quantum Physics, University of Science and Technology of China, Hefei 230026, China

<sup>6</sup>National Synchrotron Radiation Laboratory, University of Science and Technology of China, Hefei 230026, China

<sup>7</sup>Collaborative Innovation Center of Quantum Matter, Beijing 100871, China

\* To whom correspondence should be addressed. E-mail: <u>lchen@iphy.ac.cn</u>, <u>khwu@iphy.ac.cn</u>



**Figure S1**. A comparison of the surface morphology between Bi<sub>2</sub>Se<sub>3</sub> samples grown on LaCoO<sub>3</sub>/SrTiO<sub>3</sub>(001) and as-treated SrTiO<sub>3</sub>(001) at different substrate temperatures, respectively. (a) Large-scale AFM image of the Bi<sub>2</sub>Se<sub>3</sub> film grown on LaCoO<sub>3</sub>/SrTiO<sub>3</sub>(001) under the optimal conditions where  $T_{sub} = 150$  °C, with scan size 5×5 µm<sup>2</sup>. (b) AFM image of a control sample of Bi<sub>2</sub>Se<sub>3</sub> film grown on as-treated SrTiO<sub>3</sub>(001) substrate under the same conditions as (a), with scan size 5×5 µm<sup>2</sup>. (c) AFM image of a Bi<sub>2</sub>Se<sub>3</sub> film sample grown on LaCoO<sub>3</sub>/SrTiO<sub>3</sub>(001) at higher substrate temperature than that in (a) where  $T_{sub} = 225$  °C, with scan size 1×1 µm<sup>2</sup>. (d) AFM image of a Bi<sub>2</sub>Se<sub>3</sub> film sample grown on as-treated SrTiO<sub>3</sub>(001) substrate under the same conditions as (c), where  $T_{sub} = 225$  °C, with scan size 1×1 µm<sup>2</sup>.



**Figure S2**. MR measured at 1.7 K in ±10 kOe perpendicular magnetic field of four  $Bi_2Se_3/LCO$  samples grown at  $T_{sub} = 150$  °C, 175 °C, 200 °C, 225 °C, respectively, and two control samples of  $Bi_2Se_3/STO$  grown in the same conditions with  $T_{sub} = 150$  °C and 225 °C.

**Table S1**. The detailed fitting parameters obtained from the HLN equation, where  $\alpha$  is a dimensionless coefficient, and  $l_{\varphi}$  is the phase coherence length.

Sample	Bi <sub>2</sub> Se <sub>3</sub> on LCO/STO				Bi <sub>2</sub> Se <sub>3</sub> on STO	
$T_{sub}$ (°C)	150	175	200	225	150	225
α	0.423	0.392	0.385	0.361	0.478	0.526
$l_{\varphi}(\mathrm{nm})$	259	218	197	147	417	799



**Figure S3**. MR hysteresis as a function of applied magnetic field in the low-field range of a typical  $Bi_2Se_3/LCO$  sample measured at 1.7 K, when the field sweeps from opposite directions. The hysteretic feature of MR in magnetic samples is a result of the proximity effect as well.



**Figure S4**. Magnetization versus temperature of a 30 u.c. LaCoO<sub>3</sub> film on STO (001) substrate with magnetic field applied parallel to the film surface measured during field cooling with 500 Oe.



Figure S5. Magnetization curves of a 20 QL  $Bi_2Se_3$  film grown on 40 nm  $LaCoO_3/STO$  measured at 100 K with magnetic field applied parallel to the film surface.