Supplementary Information

A study of the density of states of ZnCoO:H from resistivity measurements

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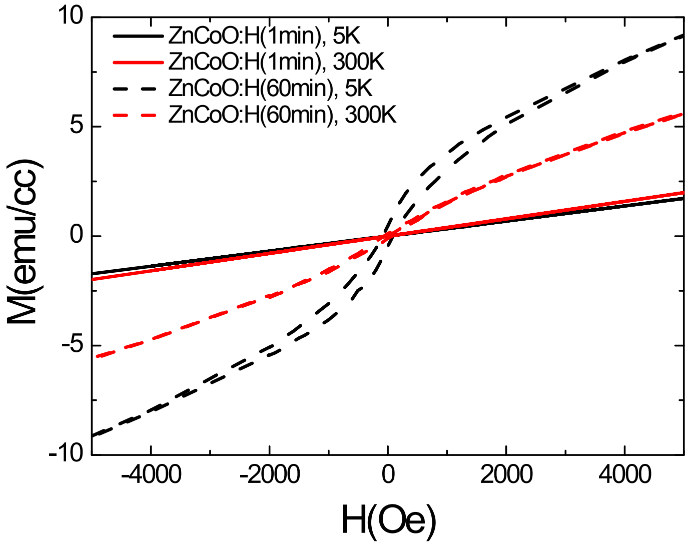

Figure S1. (a) MH curves of hydrogenated ZnCoO at 5 K and 300 K. ZnCoO:H (1 min) denotes a ZnCoO sample hydrogenated for 1 minute and ZnCoO:H(60 min) does a ZnCoO sample hydrogenated for 60 minutes.

Figure S1 shows MH curves of hydrogenated and ZnCoO:H(60 min) at low temperature (5 K) and room temperature (300 K). For a ZnCoO sample hydrogenated for 1 minute (ZnCoO:H (1 min)), no clear hysteresis loops were observed at 5K and 300 K, while hysteresis loops were observed clearly even at 300 K for a ZnCoO sample hydrogenated for 60 minutes (ZnCoO:H(60 min)). Since very small amount of hydrogens was injected into the ZnCoO:H (1 min) in this study, the sample was expected to show either very weak ferromagnetic signal or to be not ferromagnetic. It was confirmed from M-H curves with no hysteresis loop at 5 K.

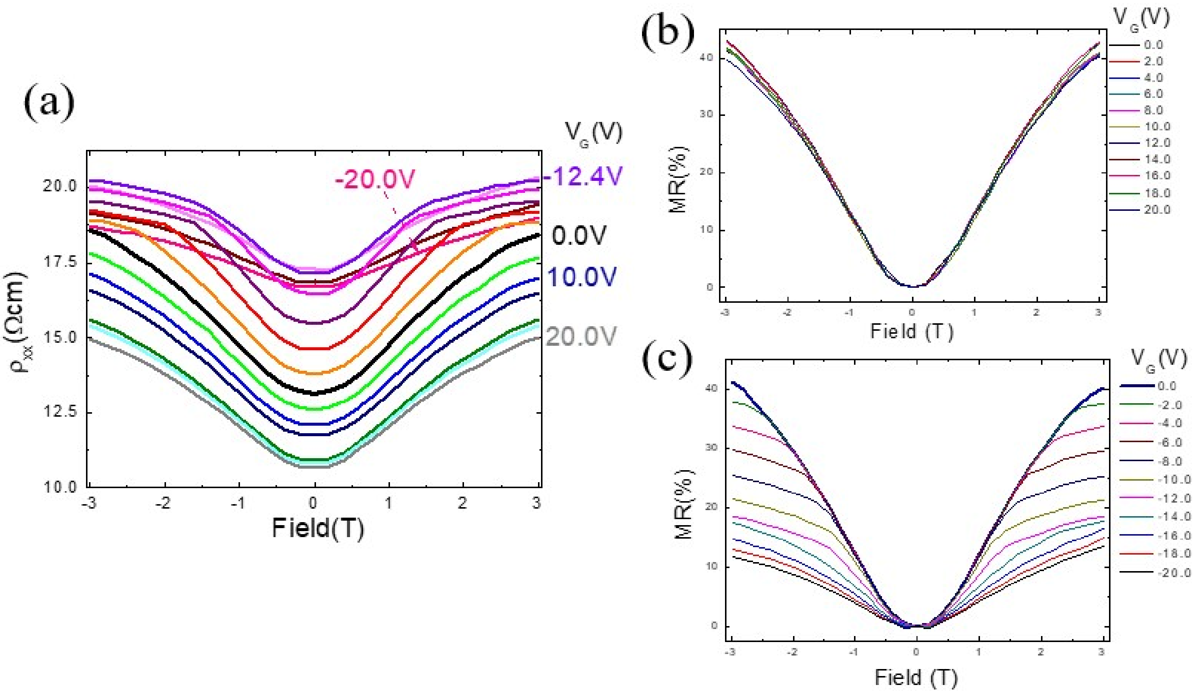

Figure S2. (a) Resistivity ρ_{xx} as a function of the magnetic field and gate voltage V_G. Magnetoresistance (MR) for positive (b) and negative (c) gate voltages. For the positive gate voltages, MR is large, positive, and independent of the gate voltages, whereas the MR decreased with negative gate voltages.

Figure S2 (a) shows resistivity ρ as a function of the magnetic field and gate voltage V_G. The resistivities increases as the strength of the magnetic field increases. These positive magnetoresistances are shown in Figure s2 (b) and (c). MR for the positive gate voltages are almost identical, independent on the gate voltages. But for the negative gate voltages, MR increases as the gate voltage increases from – 20 V to 0 V. Also, negative MR was observed near the zero magnetic field for $V_G \leq -12.4$ V.

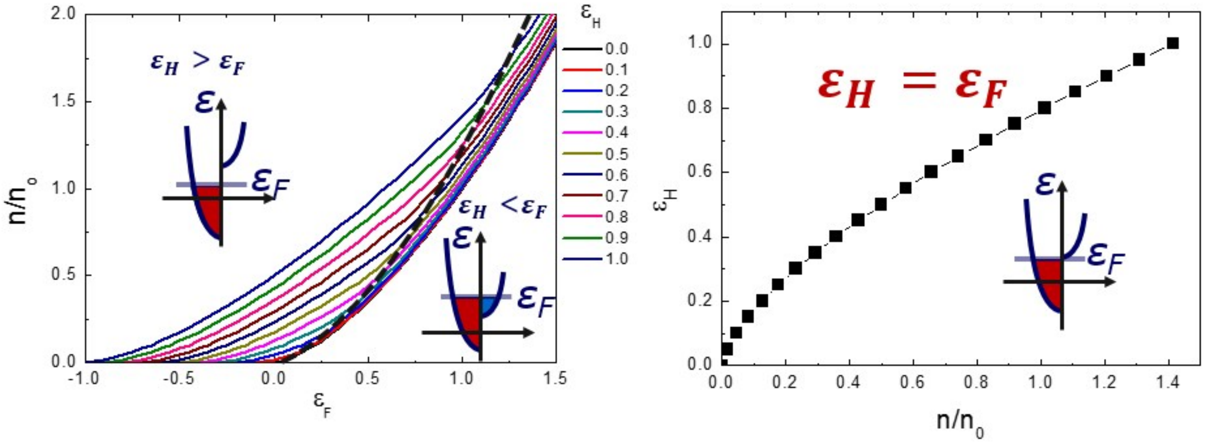

Figure S3. Total carrier density calculated with Eq. (2). (a) Normalized carrier density versus normalized Fermi energy for different magnetic field strengths. With larger magnetic field strengths, the total carrier density increased for the same Fermi energy. The dashed line represents the carrier density with $\varepsilon_F = \varepsilon_H$. (b) Normalized magnetic field where the Fermi energy is coincident with the magnetic field energy, which means that the Fermi energy locates at the conduction band minimum of the minority spin shown in the inset. This magnetic field corresponds to the knee point of the resistivity, as shown in Fig. 1(a).

Total carrier densities, calculated using Eq. (2) as a function of Fermi energy for different magnetic field strengths, are shown in Fig. 5(a). In the experiments, the total carrier density was varied by applying a gate voltage. For the same Fermi energy, the total carrier density increased with magnetic field strength. In other words, the Fermi energy decreased as the applied magnetic field increased for the same carrier density. The dashed line in Fig. 5(a) and the black squares in Fig. 5(b) represent the carrier densities in which the Fermi energy is coincident with the magnetic field energy, which means that the Fermi energy locates at the CBM of the minority spin shown in the inset of Fig. 5(b). This condition corresponds to the knee point of the resistivity, as shown in Fig. 1(a).