

# Supplemental Material

## **Extrinsic contribution to the anomalous Hall effect and Nernst effect in Fe<sub>3</sub>Co single-crystal thin films by Ir doping**

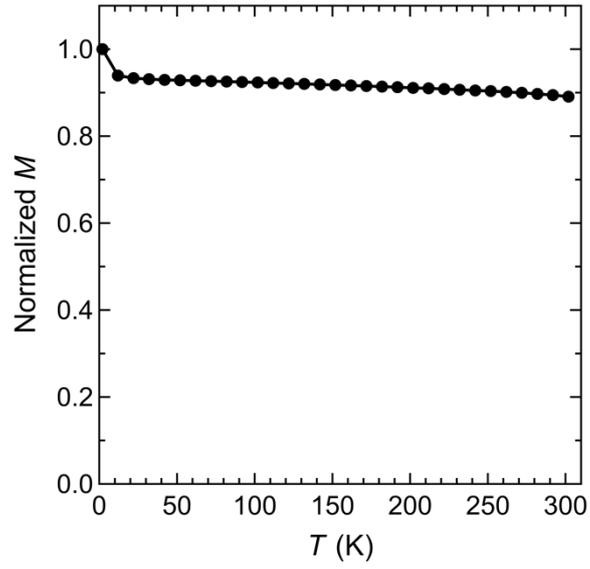
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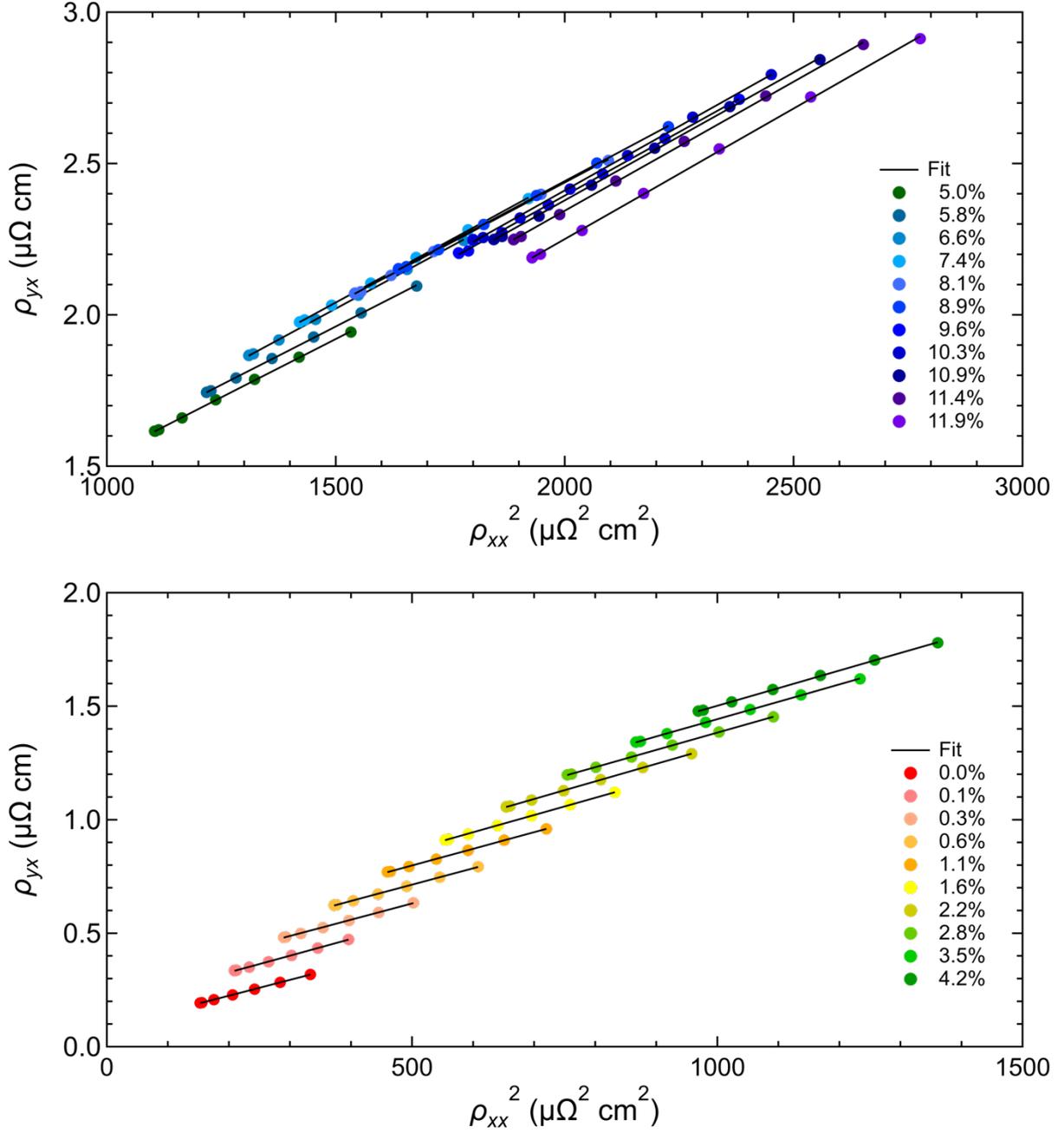
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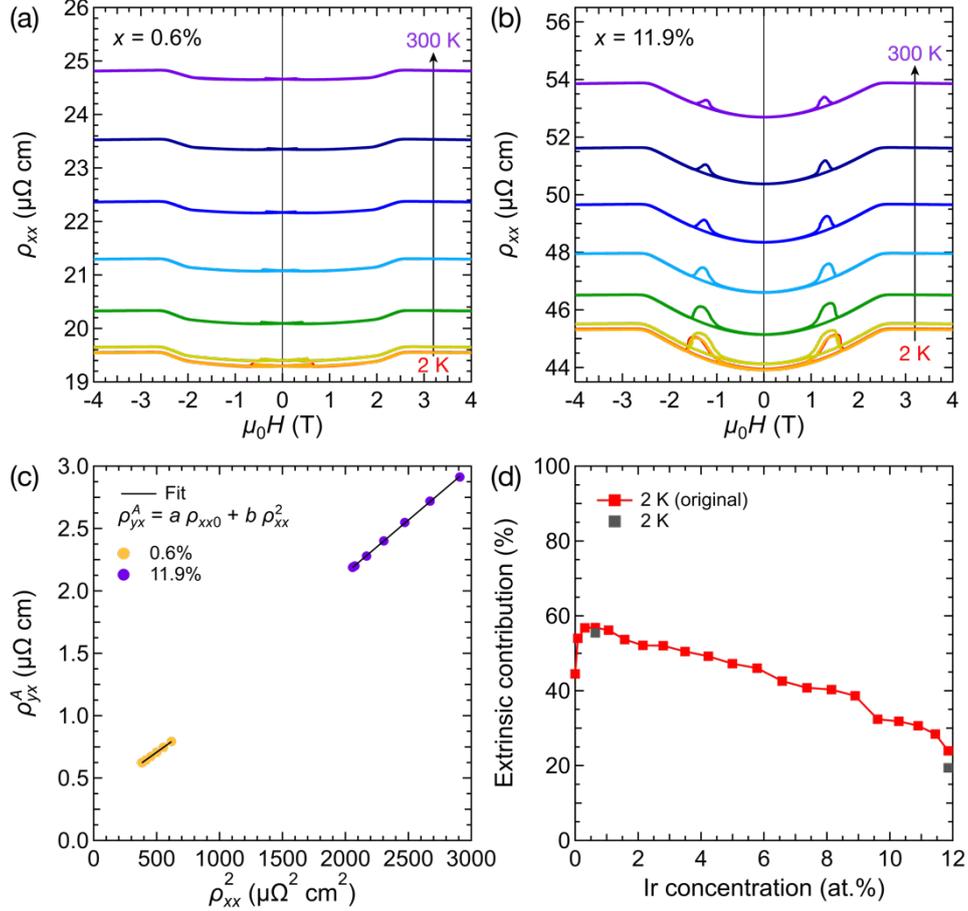
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**FIG. S1.** Temperature dependence of normalized magnetization ( $M$ ) for  $x = 12\%$  in  $(\text{Fe}_3\text{Co})_{100-x}\text{Ir}_x$  composition-spread thin films. The magnetization remained almost unchanged from 2 to 300 K.



**FIG. S2.** Magnified views of  $\rho_{yx}^A$  vs  $\rho_{xx}^2$  plots of  $(\text{Fe}_3\text{Co})_{100-x}\text{Ir}_x$  composition-spread thin films as a function of Ir concentration. The black solid lines represent fitting results using the scaling relationship  $\rho_{yx}^A = a\rho_{xx0} + b\rho_{xx}^2$ .



**FIG. S3.** External magnetic field ( $H$ )-dependent longitudinal resistivity ( $\rho_{xx}$ ) for (a)  $x = 0.6\%$  and (b)  $x = 11.9\%$ . (c) Scaling analysis between  $\rho_{yx}^A$  and  $\rho_{xx}^S$  for  $x = 0.6\%$  and  $11.9\%$ , where  $\rho_{xx}^S$  is obtained by extrapolating the saturation region of the  $H$ -dependent  $\rho_{xx}$  curves in parts (a) and (b) from positive (negative) field to zero field. (d) Extrinsic contribution ratio ( $a\rho_{xx0}/\rho_{yx}^A$ ) at 2 K when using  $\rho_{xx}$  at zero field (original; red) and  $\rho_{xx}^S$  (gray) in the scaling analysis.

The magnetoresistance (MR) should be small when the  $\rho_{xx}$  values at zero field are used for the scaling analysis between the  $\rho_{yx}^A$  and  $\rho_{xx}$ . In order to investigate the error in our scaling analysis caused by the change in  $\rho_{xx}$ , we remeasured and reanalyzed the external perpendicular magnetic field ( $H$ )-dependence of  $\rho_{xx}$  up to 4 T, where the magnetization can be fully saturated, for two Ir concentrations;  $x = 0.6\%$  showing the largest extrinsic contribution ratio of the AHE and  $x = 12\%$  expecting to show the largest change in the  $\rho_{xx}$  due to the anisotropic magnetoresistance (AMR) effect. The  $H$ -dependent MR curves for the two Ir concentrations are shown in Figs. S3(a) and S3(b). The change in the  $\rho_{xx}$  below  $\approx 2.5$  T mainly originates from the AMR effect, while only the ordinary magnetoresistance (OMR) effect appears above 2.5 T. To obtain the  $\rho_{xx}$  in the perpendicularly saturated magnetization state ( $\rho_{xx}^S$ ) without the OMR effect, we extrapolated the saturation region of the  $H$ -dependent  $\rho_{xx}$  curves from positive (negative) field to zero field. Using the  $\rho_{xx}^S$  values, we performed the same scaling analysis as shown in Fig. 4 to compare the fitting results when using the  $\rho_{xx}$  at zero field and  $\rho_{xx}^S$ , which is shown in Fig. S3(c). As a result, the difference of the extrinsic contribution ratio

when using  $\rho_{xx}$  and  $\rho_{xx}^S$  was as small as  $\approx 1.4\%$  for  $x = 0.6\%$  at 2 K [Fig. S3(d)], where a maximum extrinsic contribution ratio was observed. In contrast, for  $x = 12\%$ , the difference of the extrinsic contribution ratio was  $\approx 4.5\%$  at 2 K [Fig. S3(d)]. This slightly large difference would be attributed to a relatively large MR ratio of  $\approx 3\%$  for  $x = 12\%$ . In our previous study [Ref. 23; R. Toyama *et al.*, *Phys. Rev. Mater.* **7**, 084401 (2023)], we observed a large AMR ratio up to  $-4.7\%$  at 10 K. Thus, the MR ratio of  $\approx 3\%$  for  $x = 12\%$  could be attributed to the large AMR ratio, which leads to the difference of the extrinsic contribution ratio of  $\approx 4.5\%$ . However, this value of  $\approx 4.5\%$  can be considered as a maximum error in our analysis, especially at high-Ir concentrations. In this study, we discussed the tendency of the extrinsic contribution ratio qualitatively, and the error of  $\approx 1.4\%$  was not large at the low-Ir concentrations, which are the main claim in this study. Therefore, such an error is not significant and does not affect the conclusion of this study.