Supplementary Information

Synthesis of stoichiometric rhombohedral $LaCuO_3$ thin films using oxidation effect of NaClO solution

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The oxidation of 70 nm-thick $LaCuO_{3-\delta}/SrTiO_3$ film, 11 nm-thick $LaCuO_{3-\delta}/SrTiO_3$ film, and 11 nm-thick $LaCuO_{3-\delta}/LaAlO_3$ film

I performed the same experiment as in the main article using $SrTiO_3$ substrates and $LaAlO_3$ substrates. $LaCuO_{3-\delta}$ (LCO) thin films were deposited on 10 × 10 mm^2 sized $SrTiO_3$ (STO) (001) (cubic, a = 3.905 Å) (Shinkosha Co. Ltd.) substrates and $LaAlO_3$ (LAO) (001) (pseudocubic, a = 3.79 Å) (CrysTec GmbH) by pulsed laser deposition. The deposition conditions are the same as for the LSAT substrate. Figure S1(a) shows the R-T curves of as deposited 70 nm-LCO/STO film and 70 nm-LCO/STO films treated with NaClO solution for 24, 48, 60, and 72 hours. Fig. S1(b) shows the R-T curves of as deposited 11 nm-LCO/STO film and 11 nm-LCO/STO films treated with 80 °C NaClO solution for 48 and 72 hours. Fig. S1(c) shows the R-T curves of as deposited 11 nm-LCO/LAO film and 11 nm-LCO/LAO films treated with 80 °C NaClO solution for 48 and 72 hours. To display the slope of R-T curves clearly, an enlargement of the R-T curves of NaClO treated films are shown in the insets. As in the case of the LSAT substrate, the R-T curves of 70 nm-LCO/STO, 11 nm-LCO/STO, and 11 nm-LCO/LAO thin films changed in the order of insulating, metallic, and insulating depend on NaClO treatment time. These results indicate that, regardless of the substrate type, the insulating orthorhombic $LaCuO_{3-\delta}$ changes to the metallic monoclinic $LaCuO_{3-\delta}$ due to the oxidation effect of the NaClO solution, and then the metallic monoclinic $LaCuO_{3-\delta}$ changes to the insulating rhombohedral $LaCuO_3$. The resistance of the 11 nm thick films are several orders of magnitude higher than that of the 70 nm thick films. This is thought to be an effect of stress from the substrate.

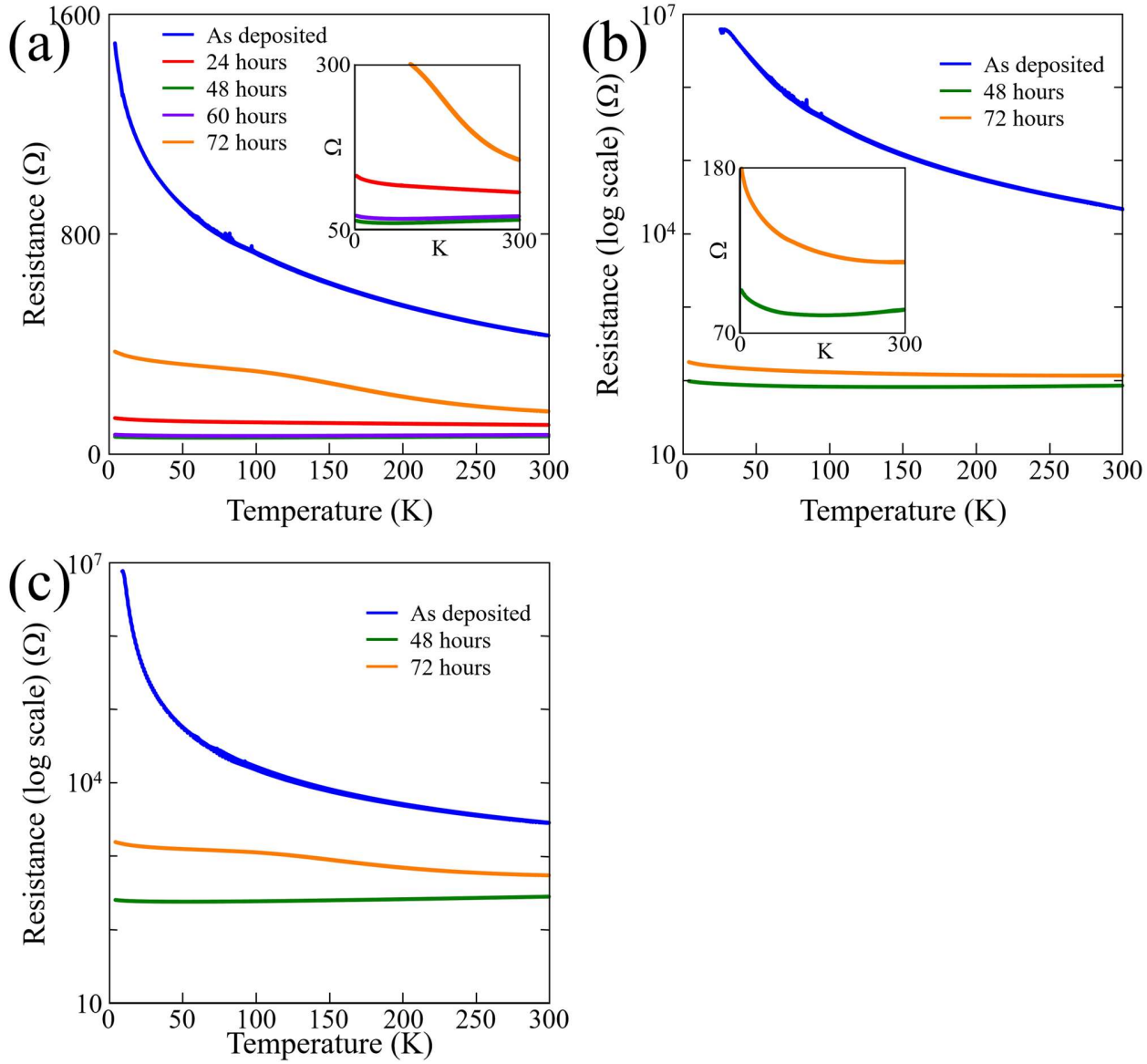

Figure S1. The R-T curves of (a) 70 nm-LCO/STO, (b) 11 nm-LCO/STO, and (c) 11 nm-LCO/LAO with different oxidation times, respectively. The inset shows the enlargement of the R-T curves of the NaClO treated films.