Supplementary Information:

- **Film Deposition procedure**:

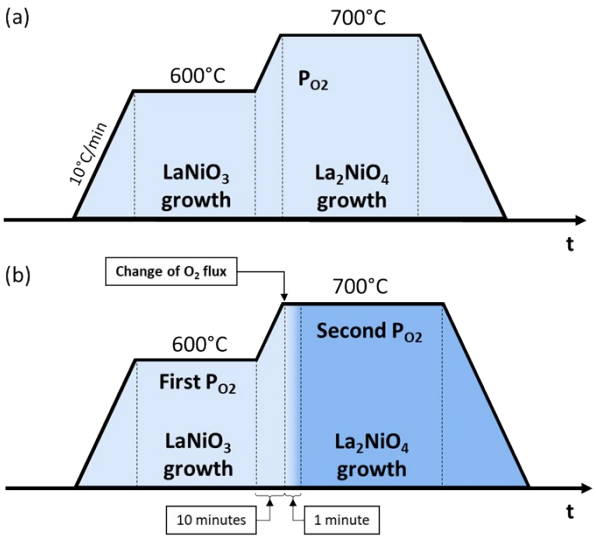

Figure S.1.: Scheme of the growth conditions depicting the deposition temperature profile and oxygen pressure during growth of (a) L/L and H/H samples, (b) L/H and H/L samples. Note that for the second layer deposition the pO_2 conditions are only established once the corresponding temperature is attained.

Growth of $LaNiO_3$ and La_2NiO_4 single layers:

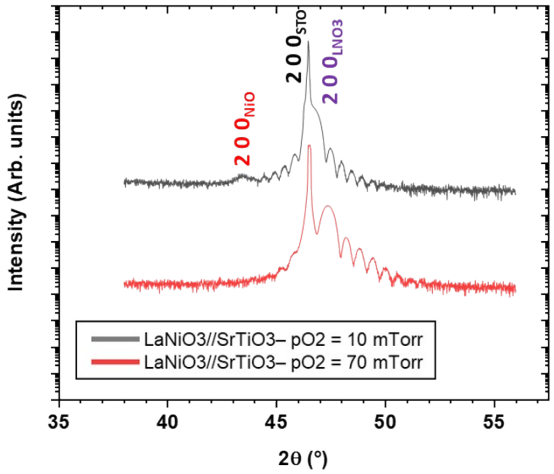

Figure S.2: High resolution XRD scans of $LaNiO_3$ single layers (~20nm thick) deposited at T=600 °C on $SrTiO_3$ under different pO_2 (70mTorr and 10mTorr) 200 $LaNiO_3$ and 200 $SrTiO_3$ peaks can be observed along with corresponding thickness fringes. The $LaNiO_3$ film deposited at low pO_2 shows a weak peak at 2θ~43° close to that of the 006 reflection of $c_{\perp}$-La_2NiO_4 or 200 of NiO, which could correspond to an incipient decomposition of $LaNiO_3$.

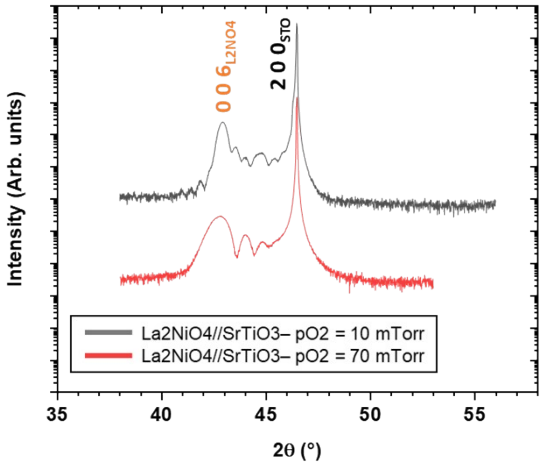

Figure S.3: High resolution XRD scans of La_2NiO_4 single layers deposited on $SrTiO_3$ under two different pO_2 (70mTorr and 10mTorr). 006 La_2NiO_4 and 200 $SrTiO_3$ reflections can be observed. In both cases the film grows with $c_{\perp}$-La_2NiO_4 orientation.

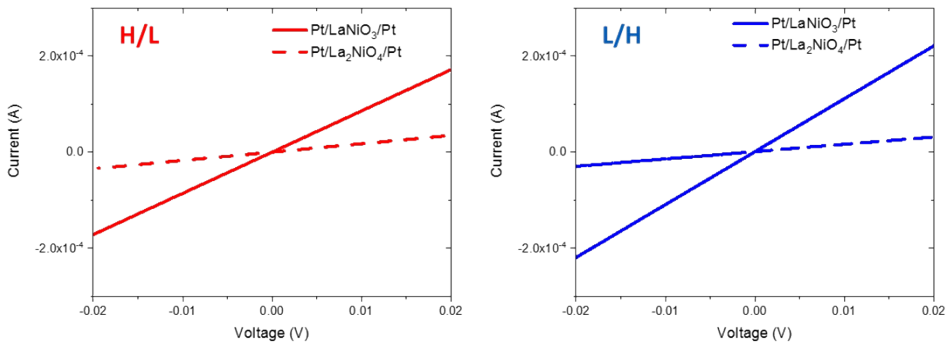

Figure S.4: I(V) curves measured between two Pt contacts placed either on the top La_2NiO_4 and on the bottom $LaNiO_3$ layers for the two cases: H/L and L/H bilayers (left and right, respectively). Regardless the deposition conditions, high or low pO_2, the curves show a linear dependence indicating an ohmic behaviour of Pt/La_2NiO_4 and Pt/$LaNiO_3$ junction. Note that the corresponding resistances are about 100 Ω and 500 Ω, for $LaNiO_3$ and La_2NiO_4, respectively. These values are much lower than those of the Pt/$LaNiO_3$/La_2NiO_4/Pt bilayers (in Fig. S6) indicating the main contribution to the resistance of the bilayers does not correspond to the regions in contact with Pt.

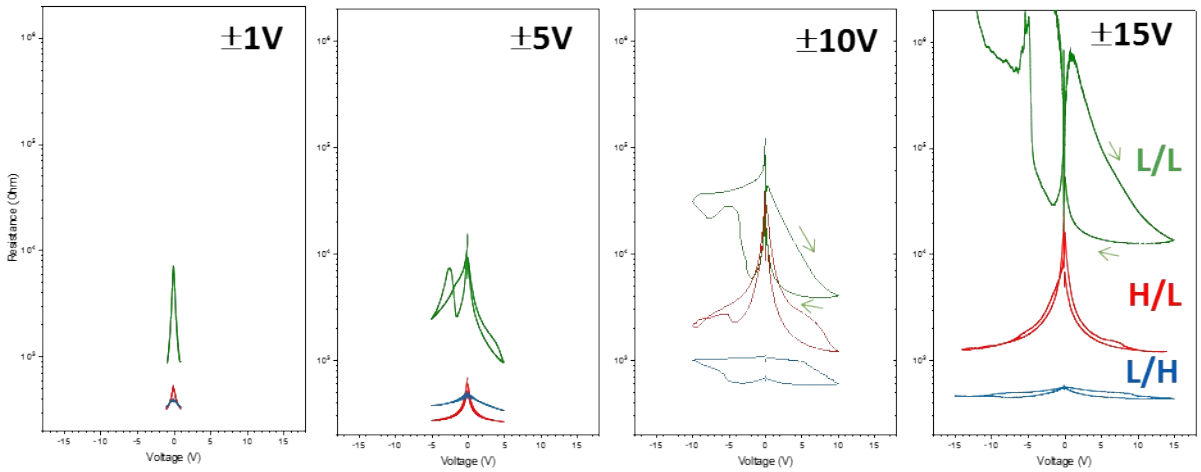

Figure S.5 Resistance versus Voltage for the three different bilayers showing the building up of an hysteretic behaviour upon voltage increase, which only remains stable at V_{max}=±15V for the L/L sample. (The arrows indicate the direction of the sweep)

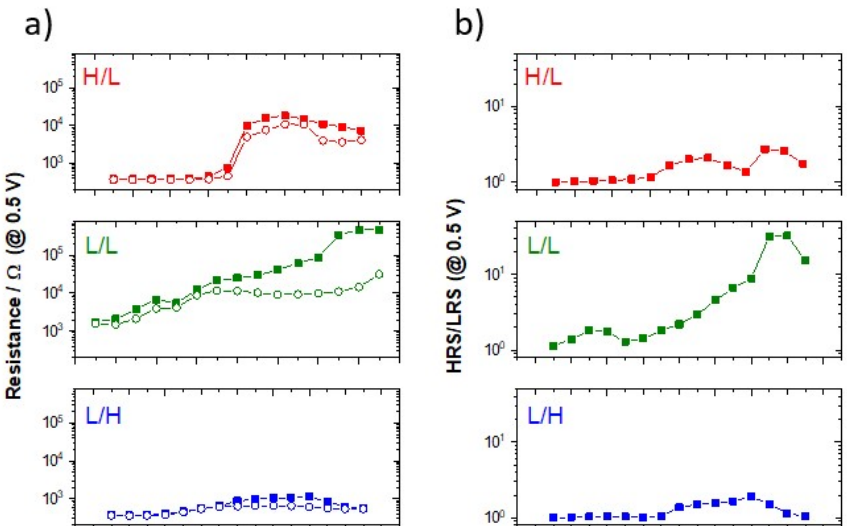

Figure S.6 Left: HRS (filled symbols) and LRS (empty symbols), measured at V=0.5 V, for the three bilayers as a function of the maximum voltage amplitude. Right: Evolution of the HRS/LRS ratio (measured at V=0.5 V) as a function of the maximum voltage amplitude.