Reversible switching of the 2D electron gas of $SrTiO_3$(001) studied by HREELS and XPS

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The formation of a 2D electron gas (2DEG) at interfaces gained high interest in applied material sciences as it provided highly conductive layers for future applications. As it became accessible under oxygen-poor conditions at the TiO_2-terminated $SrTiO_3$(001) surface [1], it also opened the field for surface science techniques.
In this work, we follow the 2DEG formation by studying the change in surface coordination and dielectric properties by X-ray photoelectron spectroscopy (XPS) in combination with high-resolution electron energy loss spectroscopy (HREELS). With the latter the three distinct dipole active modes of $SrTiO_3$ could be identified as surface phonon polaritons (SPP). The coupling of these SPP to the electronic excitation of the 2DEG lead to an asymmetric line shape with extreme broadening as seen in Fig.1. By studying this broadening, we have been able to gain valuable insights into the electron-phonon coupling and the charge carrier density of the 2DEG. This allowed us to track the reversible formation of the 2DEG by manipulating the environment through heating in UHV/O_2 atmosphere or adsorbing molecular oxygen at 100 K. The dielectric response will be discussed quantitatively in terms of an extended Drude model in the surface layer on top of a bulk-like $SrTiO_3$ substrate. Our analysis reveals a strong frequency-dependent relaxation rate of the 2DEG electronic excitations responsible for the electron-phonon coupling. This discovery opens up a new way of studying the intriguing 2DEG transport phenomena.

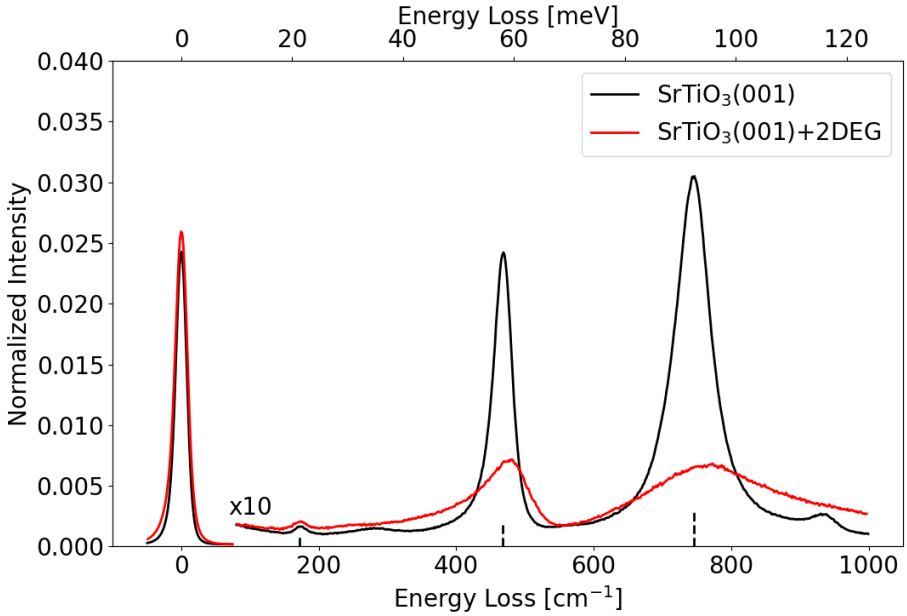

Fig. 1. Vibrational spectra (HREELS) of bulk-like terminated $SrTiO_3$ (black line) and $SrTiO_3$(001) in the presence of a 2DEG (red line). The three fundamental dipole-active modes are marked, which broaden asymmetrically by electron-phonon coupling to the 2DEG.

[1] A. F. Santander-Syro, O. Copie, A. Barthélémy, and M. J. Rozenberg, Nature 469, 189 (2011).