Surface metallization of $SrTiO_3$(001) by adsorption of hydrogen: Toward carrier dynamics studies

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Strontium titanate ($SrTiO_3$; STO) has attracted growing attention as next generation oxide electronics because of its unique electronic properties. For example, a 2D metallic layer with high carrier mobility is formed at the interface of the two insulating oxides STO/$LaAlO_3$ [1] or on the vacuum-cleaved STO surface [2]. Recent theoretical study [3] has proposed a novel way to create the 2D metallic layer on STO by hydrogen adsorption, which has not been evidenced by experimental studies. In this study, we report the first experimental demonstration of the 2D metallic layer on the H-adsorbed STO(001) surface using photoelectron spectroscopy (PES) and surface transport measurements.

The electronic structures of the clean and H-adsorbed STO(001) surfaces (0.05 wt% Nb, n-type) were investigated by valence band and core-level PES at the TEMPO beamline of SOLEIL and at SPring-8 BL07LSU. For the clean STO surface, no state is observed at the Fermi level in the valence band PES spectra as expected from an insulating nature of STO. Upon H-adsorption, however, a sharp new feature appears at the Fermi level. Angle-resolved PES spectra reveal that this metallic feature has parabolic band dispersion similar to the 2D metallic layer on the vacuum-cleaved STO surface. By H-adsorption, in addition, the core-level PES peaks shift to higher binding energies by a downward band bending. Therefore, surface metallization of H-adsorbed STO originates from electron accumulation at the STO surface induced by electron donation from adsorbed hydrogen to the surface. Surface transport measurements using a four terminal method reveal that the observed change in the electronic structures of STO by H adsorption, the insulator-to-metal transition, is indeed concurrent with the increase in surface conductivity. The high surface conductivity of the H-adsorbed STO surface confirms that the electrical conduction is in the metallic conduction regime.

The present results give an important step toward *real-time* studies of the carrier dynamics on the H-adsorbed STO surface using time-resolved PES. The reverse metal-to-insulator transition of the H-adsorbed STO surface is initiated by fs-laser pump and the following time evolution of electronic structures is monitored in real-time by ps x-ray probe. The time-resolved x-ray spectroscopy system recently developed at SPring-8 BL07LSU will be introduced in the talk together with examples of carrier dynamics studies on semiconductor surfaces.

References

[1] A. Ohtomo and H.Y. Hwang, Nature 427 423 (2004).
[2] A.F. Santander-Syro *et al.*, Nature 469 189 (2011).
[3] F. Lin *et al.*, Phys. Rev. B 79 035311 (2009).