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

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## 1. Introduction

Strontium titanate ($SrTiO_3$; STO) has attracted growing attention as a material of next generation oxide electronics because of its unique electronic properties. For example, a two dimensional (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, 3]. Recent theoretical study [4] has proposed a novel way to create the 2D metallic layer on STO by chemical doping (hydrogen adsorption), which has not been evidenced by experimental studies. In this report, we present the first experimental demonstration of the 2D metallic layer on the H-adsorbed STO(001) surface using photoelectron spectroscopy (PES) [5].

## 2. Experimental

The PES experiments were carried out at SPring-8 BL07LSU. The STO(001) surface (0.05 wt% Nb, n-type) was cleaned by annealing at 873 K in $6x10^{-4}$ Pa $O_2$ gas. Before introduction into the ultrahigh vacuum (UHV) chambers, the sample was treated with buffered HF solution (pH 3.5) for 30 s, followed by rinsing with distilled water. This preparation is known to produce a $TiO_2$-teminated STO(001) surface. The cleanness and orderliness of the surface were checked with low energy electron diffraction and PES, respectively. Hydrogen adsorption was carried out by exposing the sample to atomic hydrogen, which was produced by cracking hydrogen molecules with a hot tungsten filament under the atmosphere of hydrogen gas; $p(H_2)= 6x10^{-4}$ Pa.

## 3. Results and discussion

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 (Figure 1). 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. The surface metallization of STO by H adsorption, the insulator-to-metal transition, is further confirmed by a separate surface transport measurements using a four terminal method. The high surface conductivity of the H-adsorbed STO surface shows that the electrical conduction is in the metallic conduction regime.

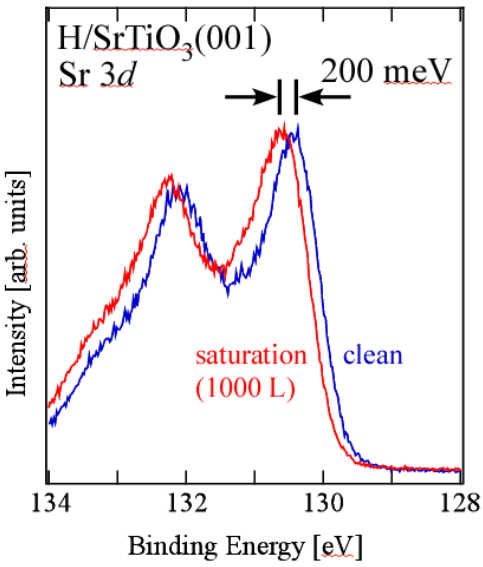


**Figure 1:** Sr 3*d* core level spectra of the clean and hydrogen-adsorbed $SrTiO_3$(001) surfaces.

In summary, by a combined PES and surface transport study, we have demonstrated the formation of the 2D metallic layer on the STO surface using surface chemical doping (hydrogen adsorption). The present result opens up the possibilities to study carrier dynamics using time-resolved photoelectron spectroscopy, where the metal to insulator transition of the H-adsorbed $SrTiO_3$ 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.

## References


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