A tunable two-dimensional electron system created at the surface of $SnO_2(110)$

J. Dai[a], E. Frantzeskakis,[a] F. Fortuna,[a] P. Le Fèvre,[b] F. Bertran,[b] R. Yukawa,[c] H. Kumigashira,[c] P. Lömker,[d] M. Müller,[d,e] and A. F. Santander-Syro[a*]

a. CSNSM, Université Paris-Sud, CNRS/IN2P3, Université Paris-Saclay, 91405 Orsay Cedex, France

b. Synchrotron SOLEIL, L'Orme des Merisiers, Saint-Aubin-BP48, 91192 Gif-sur-Yvette, France

c. Photon Factory, Institute of Materials Structure Science, High Energy Accelerator Research Organization (KEK), 1-1 Oho, Tsukuba 305-0801, Japan

d. Peter Grünberg Institut (PGI-6), Forschungszentrum Jülich GmbH, D-52428 Jülich, Germany

e. Fakultät Physik, Technische Universität Dortmund, D-44221 Dortmund, Germany

* andres.santander@csnsm.in2p3.fr

Tin oxide (SnO_2) is an important transparent binary oxide widely used as a gas sensor material and believed to remain insulating even in the presence of oxygen vacancies [1]. We report that a new 2D electron system (2DES) can be created and controlled at the (110) surface of SnO_2, see Figure 1. We characterize its electronic structure using angle resolved photoemission spectroscopy (ARPES), and show that it is formed out of the bulk s-like conduction band minimum of SnO_2 confined at the surface. The carrier density of such 2DES increases by an order of magnitude when cooling down from room temperature to 15 K, and can be further enhanced to $n_{2D} = (2.15 \pm 0.04) \times 10^{13}$ cm^{-2} after thermal deposition of an atomic layer of Eu, linking the origin of this 2DES to the oxygen vacancies created at the SnO_2 surface after the redox reaction with Eu.

[1] L. R. Merte, et al., Phys. Rev. Lett. **119**, 096102 (2017).

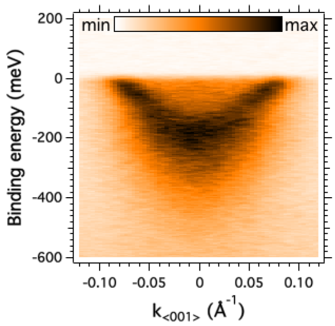

Figure 1: Energy-momentum ARPES intensity map at the $SnO_2(001)$ surface, along the in-plane $k_{<001>}$ direction. The measurement temperature is $T = 15K$.