High-density 2D electron system induced by oxygen vacancies in ZnO

T. C. Rödel1, 2, J. Dai1, F. Fortuna1, E. Frantzeskakis1, P. Le Fèvre2, F. Bertran2, M. Kobayashi3, R. Yukawa3, T. Mitsuhashi3, M. Kitamura3, K. Horiba3, H. Kumigashira3, and A. F. Santander-Syro1

1CSNSM, Univ. Paris-Sud, CNRS/IN2P3, Université Paris-Saclay, 91405 Orsay Cedex, France
2Synchrotron SOLEIL, L’Orme des Merisiers, Saint-Aubin-BP48, 91192 Gif-sur-Yvette, France
3Photon Factory, 1-1 Oho, Tsukuba, 305-0801, Japan

1 Introduction

The transparent semiconductor ZnO stands out for its numerous applications, notably due to its optoelectronic properties, which are also determined by electron density and dimensionality [1, 2]. The realization of a highly doped 2D electron system (2DES) in ZnO would be highly desirable for, e.g., high-power applications, as ZnO is cheaper, easier to process, and non-toxic compared to other transparent semiconductors such as In2O3. However, so far, only moderate electron densities of 2x1013 cm2 had been achieved in ZnO, while the contribution of oxygen vacancies to its n-type conductivity remained controversial. This work reports the creation of a high-density 2DES in ZnO.

2 Experiment

ARPES experiments were performed at BL-2A of KEK-PF and at synchrotron SOLEIL (France). The AlOx/ZnO interface was obtained by in situ surface preparation as described in Ref. [3]. The sample temperature during measurements was 20 K. Variation of the photon energy in the range 30-110 eV revealed no changes in the energy-momentum dispersion, demonstrating the 2D character of the band structure. The pressure was below 10^-11 mbar during measurements, and no degradation of the spectra quality was observed.

3 Results and Discussion

We observed (Fig. 1a) that the evaporation in ultra-high vacuum of an atomic layer of aluminum on ZnO creates a 2DES with electron densities up to 100 times higher than in previous studies. The 2DES results from oxidation of the Al layer and concomitant doping with oxygen vacancies of the underlying ZnO surface. The 2DES is composed of two subbands (Fig. 1b) with different effective masses. The self-energy of the 2DES (Figs. 1c-d) can be accurately described using a 2D Fermi liquid coupled to a Debye distribution of phonons. Thus, the inner band is wholly renormalized due to the proximity of its bottom with the phonon cutoff energy, whereas the outer band, dispersing deeper in energy, shows only a kink due to electron-phonon interaction.

References


Research Achievements


* andres.santander@csnsm.in2p3.fr