Potential-well depth at amorphous-$LaAlO_3$/crystalline-$SrTiO_3$ interfaces measured by optical second harmonic generation

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The discovery[1] of a two-dimensional electron gas (2DEG) formed at the interface between the two band insulators $LaAlO_3$ (LAO) and $SrTiO_3$ (STO) has driven a lot of attention to this material system. In particular, the origin of the charge carriers immediately emerged as a highly debated question, since different doping mechanisms can be at play in this oxide heterostructure. By using second harmonic generation (SHG) we have investigated various aspects of the physics of LAO/STO interfaces.[2] Here, by combining SHG and transport measurements, we have studied interfaces formed by either crystalline (c-) or amorphous (a-) thin films of LAO grown on TiO_2-terminated STO(001) substrates. The comparison between these two interfaces allows disentangling the relative role of intrinsic and extrinsic doping mechanisms in the formation of the 2DEG, with the latter being dominant in the case of amorphous LAO over layer. For the first time, we have measured the depth of the quantum well formed at the interface of both systems, finding that the value of this depth is almost constant above the threshold for the onset of conduction found in c-LAO/STO samples (4 crystalline unit cells). These findings point to the existence of a universal depth of the interfacial potential well, despite the fundamentally different doping mechanism acting in these two material systems. **This result was highly unexpected.**

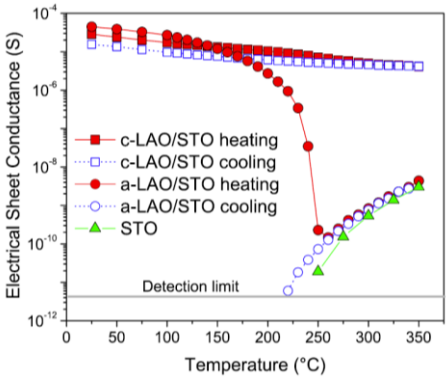

Fig. 1: Sheet conductance measured in air for the two a- and c-LAO/STO samples as a function of temperature during a heating-cooling cycle. Note the irreversible change occurring in a-LAO/STO upon heating because of the oxygen vacancies refilling in air.

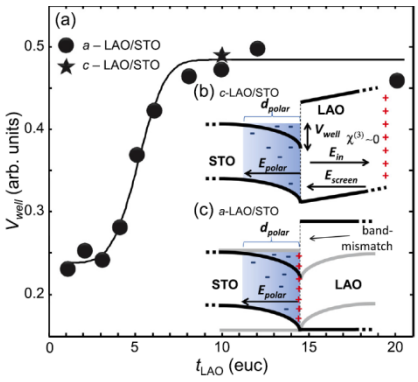

Fig. 2: The potential-well depth for a-LAO/STO and c-LAO/STO determined from SHG as a function of LAO thickness. Note the almost equal values of V_{well} for the c-LAO/STO and a-LAO/STO samples above 7 euc. In the inset a tentative band diagram for the two electron systems is shown.

[1]A. Ohtomo and H. Hwang, Nature 427, 423 (2004).
[2]A. Rubano, C. Aruta, U. S. di Uccio, F. M. Granozio, L. Marrucci, T. Günter, T. Fink, M. Fiebig, and D. Paparo, Phys. Rev. B 88, 245434 (2013).