Highlights

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Giant Oscillating Thermopower at Oxide Interfaces

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Thermoelectric spectroscopy, is a formidable tool to investigate the electronic structure of the $LaAlO_3/SrTiO_3$ interface [1] and achieve full comprehension of charge confinement in oxide heterostructures. In this work, we explore thermopower in $LaAlO_3/SrTiO_3$ at low temperature as a function of gate field, in order to monitor the electronic properties at varying doping concentration (see experimental configuration in Figure a). Under large negative gate voltage, corresponding to the strongly charge depleted regime, thermopower displays record-high negative values of the order of 10^4-10^5 μV/K, oscillating at regular intervals as a function of the gate voltage (see figure b). The huge thermopower magnitude can be attributed to the phonon-drag contribution, which is boosted by 2D electron confinement. Indeed, in the low temperature limit, the coupling of acoustic phonons with 2D confined electrons is enhanced by the loss of crystal momentum conservation in the interface-orthogonal direction, enabling the interaction of the electron gas with many more phonon frequencies. On the other hand, the thermopower oscillations map the Fermi level descent across a dense array of localized states lying at the bottom of the Ti 3d conduction band (see in Figure c and d the model electronic band structure of the two-dimensional electron gas (2DEG) which allows to reproduce the experimental results, as shown in Figure e). This study is the first direct evidence of a localized Anderson tail in the $LaAlO_3/SrTiO_3$ two-dimensional electron liquid.

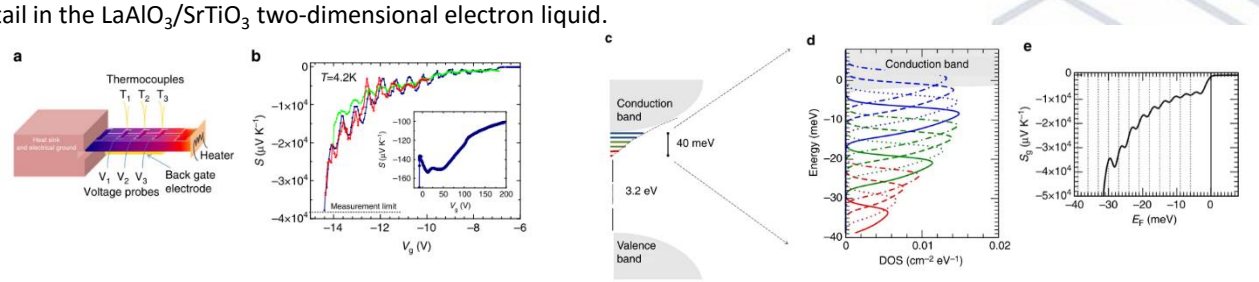

Figure : Seebeck measurement configuration and behavior under gate field of a $LaAlO_3/SrTiO_3$ interface. a) Sketch of the sample and experimental configuration for the Seebeck measurements. b) Seebeck coefficient versus gate voltage measured in a $LaAlO_3/SrTiO_3$ interface at 4.2 K. In the main panel, the different traces correspond to different thermal and Vg cycles. In the inset, a blow-up of the accumulation regime (Vg>0) is shown. c) Sketch of the model band structure purposely built to reproduce the experimental results. Gray areas indicate valence and conduction states; the colored lines below the conduction states represent a tail of localized states. d) Actual Density of States (DOS) of the model band structure considered for the calculations. The shaded gray area is the DOS relative to the conduction band bottom (CBB) of t_{2g} d_{xy} orbital character. Below the CBB lies a tail of 12 localized states, placed at regular intervals of 3 meV from each other, indicated by different colors and type of lines. From the bottom: red solid, dotted, dashed, dot-dashed, and then the same sequence repeated in green and blue. Zero energy is fixed at the CBB. e) Phonon-drag calculated for the model DOS. The dotted vertical lines indicate the bottom energy of each localized state, the solid line is the CBB. S_g oscillates at each intersection of E_F with the bottom energies.

[1] Ohtomo, A. and Hwang, H. Y., *"A high-mobility electron gas at the $LaAlO_3/SrTiO_3$ heterointerface"*, Nature 427, 423–426 (2004)