

Transport Study of Small Polaron Trapping in TiO₂-based two-dimensional electron gases (2DEGs)

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The emergent superconductivity observed in RuO₂ thin films on TiO₂ substrates presents a puzzling question regarding its underlying mechanism. A striking parallel can be drawn with the case of monolayer FeSe on SrTiO₃, where strong interfacial electron-phonon coupling—particularly involving substrate phonons—was shown to play a crucial role in enhancing superconductivity. Motivated by this, we explored whether similar interfacial effects could be relevant in the RuO₂/TiO₂ system. To probe the electron-phonon properties from the TiO₂ substrate, we induced a two-dimensional electron gas (2DEG) at its surface through two methods: sputtering an amorphous SiO₂ (a-SiO₂) overlayer and ion milling. Both approaches introduce oxygen vacancies that dope electrons into the Ti 3d conduction band of TiO₂, forming a 2DEG. We have then patterned the 2DEG into Hall bars using photolithography. Transport measurements reveal that, unlike the metallic 2DEGs in STO or KTO, the TiO₂ 2DEG exhibits a metal-to-insulator crossover near 30 K. This insulating behavior at low temperature is attributed to small polaron trapping—a phenomenon closely related to electron-phonon coupling. Intriguingly, as the mobile carrier density approaches zero near the ground state, the Hall mobility remains finite, suggesting potential for low-carrier-density quantum devices such as quantum dots. Fitting the temperature dependence of the carrier density to Arrhenius behavior yields a small polaron trap energy of 4.4 meV. Our results shed light on the complex interplay between interfacial charge doping and polaron physics in TiO₂, providing a new perspective on the possible origins of superconductivity in RuO₂ heterostructures.

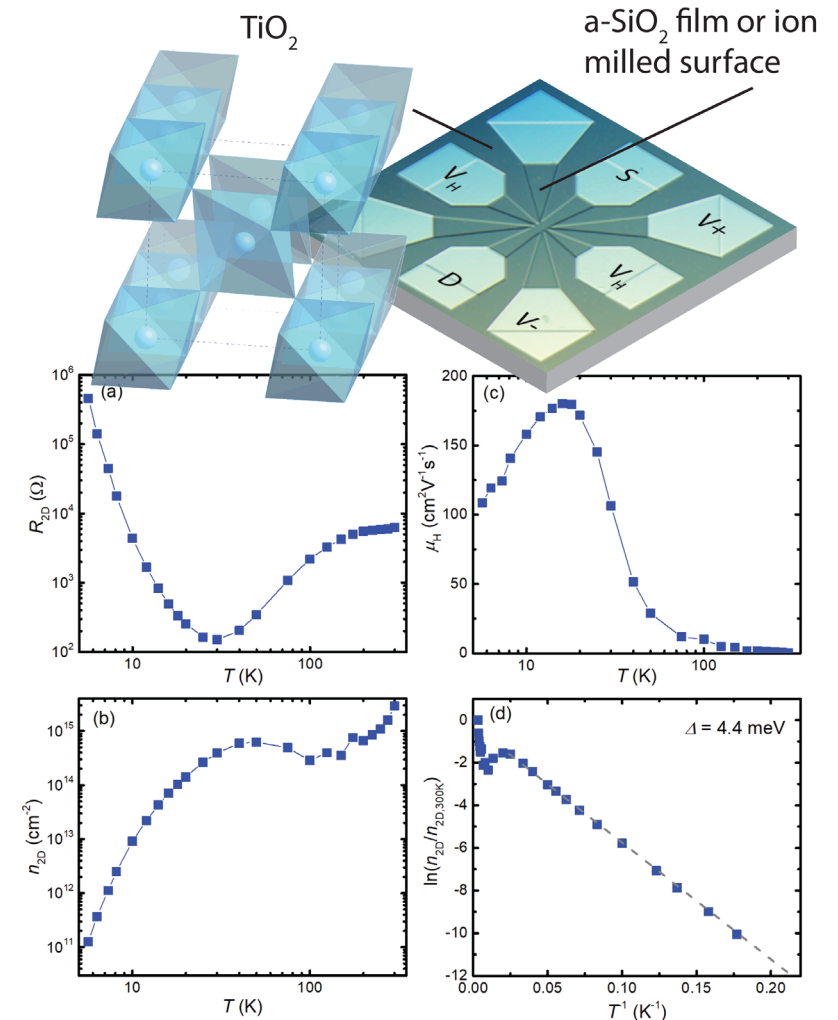


Image of of TiO₂-based 2DEGs device and transport characterization showing small polaron trapping.