Nanopatterning of oxide heterostructures using cold ion milling

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The oxide heterostructures are extremely sensible to atomic interfaces and layer thicknesses, in this work we present a "top down" technique for the fabrication of sub-200 nm oxide nanodevices where their crystallinity, epitaxial structure and properties after the fabrication process are maintained. An intriguing oxide system is the two-dimensional electron gas (2DEG) at the interface between LaAlO3 (LAO) and SrTiO3 (STO) band insulators, that occurs only for LAO layers thicker of 4 unit cells and never for SrO termination of the STO substrate [1]. This system has attracted much attention from the oxide electronics community due to its remarkable properties such as electric field effect insulator-to-metal transition, gate-tuneable spinorbit coupling, the unconventional superconductivity and magnetism [2]. In addition, recent works show that 2DEG at interface can be spin-polarized and tuneable introducing a thin layer of a magnetic oxide between LAO and STO, as in LAO/EuTiO3/STO (LAO/ETO/STO) [3].

In this work, we will present the possibility to define some LAO/ETO/STO devices with dimensions down to 160nm with the top-down patterning technique based on Ar+ ion milling process in combination with electron beam lithography. More specifically, we will focus on demonstrating that the cold ion milling process does not damage the 2DEG properties and not introduce oxygen vacancies-related carriers in the substrate. In this sense, we have characterized in situ the electric field response of 2DEG nanodevices and compared these results with data from SQUID measurements proving the absence of extra conduction outside the patterned areas of devices. Our measurements show that the present techniques can be capable of nanopatterning all types of oxide heterostructures, interesting for the realization of future hybrid structures, where the 2DEG could be approximated also by superconducting material.