

## Highlights

Activity B - Superconducting and correlated low dimensional materials and devices for quantum electronics and spintronics - 2021

### Size-Controlled Spalling of LaAlO<sub>3</sub>/SrTiO<sub>3</sub> Micromembranes

R. T. Dahm <sup>1,2</sup>, R. Erlandsen <sup>1,2</sup>, F. Trier <sup>1</sup>, A. Sambri <sup>3</sup>, E. Di Gennaro <sup>4</sup>, A. Guarino <sup>3</sup>, L. Stampfer <sup>1</sup>, D. V. Christensen <sup>2</sup>, F. Miletto Granozio <sup>3</sup>, T. S. Jespersen <sup>1</sup>

<sup>1</sup>Center for Quantum Devices, Niels Bohr Institute, University of Copenhagen, 2100 Copenhagen, Denmark

<sup>2</sup>Department of Energy Conversion and Storage, Technical University of Denmark, 2800 Kgs. Lyngby, Denmark

<sup>3</sup>CNR-SPIN, UOS Napoli c/o Complesso di Monte S. Angelo, via Cinthia 21, 80126 Napoli, Italy

<sup>4</sup>Physics Department "E. Pancini", University of Naples "Federico II", Monte S. Angelo 80126 Naples, Italy

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Some of the authors recently demonstrated a route for forming conducting heterostructure membranes of LaAlO<sub>3</sub> (LAO) and SrTiO<sub>3</sub> (STO), the canonical system for oxide electronics. There, the producing freestanding membranes had random sizes and locations. Here we extend this work by introducing a new concept for pregrowth substrate preparation allowing for control of where the LAO/STO membranes form on the substrate as well as their individual lateral dimensions. The method relies on patterning the stress discontinuities in the LAO/STO epitaxial hetero-structure by locally altering the growth substrate using argon milling prior to the growth. The process is schematically illustrated in Fig.1 and relies on a combination of lithography and Ar<sup>+</sup>-ion milling to define trenches in the STO substrate prior to LAO deposition. The dimensions of the squares  $L_x, y = 0.5-20 \mu\text{m}$  were varied between each field. Our results show that: 1) the size control is constricted by an upper and lower limit with respect to the yield and reproducibility of membranes; 2) the capability of direction fracture formation along directions different from [100]/[010] otherwise strongly preferred without the pregrowth patterning; 3) the membranes can be manipulated in a controllable manner with a micromanipulator needle and transferred onto a silicon substrate (Fig.2). This method opens up the possibility to study and use the two-dimensional electron gas in LAO/STO membranes for advanced device concepts.

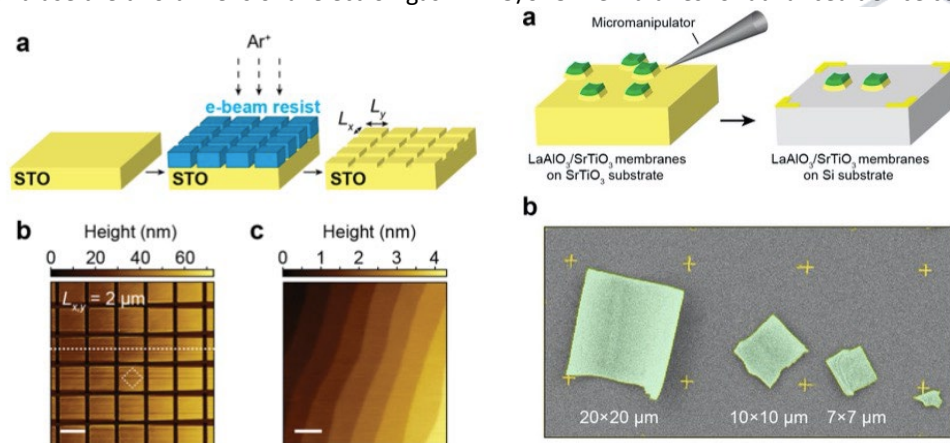


Fig. 1: (a) Schematic illustration of the surface patterning by Ar<sup>+</sup>-ion milling. (b) AFM topography map of the STO surface following Ar<sup>+</sup>-ion milling for a field with  $L = 2 \mu\text{m}$  squares (scale bar is  $2 \mu\text{m}$ ). The dashed square  $x, y$  and line correspond to the zoomed image in (c). (c) High-resolution AFM image of the area in (b) showing STO-TiO<sub>2</sub>-terraces (scale bar is  $200 \text{ nm}$ ).

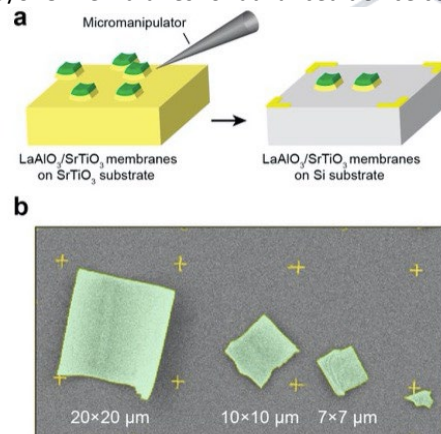


Fig. 2: (a) Schematic illustration of the controllable manipulation and transfer of LAO/STO membranes with a micromanipulator needle onto a silicon substrate. (b) SEM image of transferred membranes arranged into a row on the prepatterned silicon substrate.