Strain tuning of infinite-layer nickelates membranes

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Superconductivity in infinite-layer (IL) nickelates[1] is only observed in thin-films, while bulk samples exhibit an insulating ground state, showing no indication of superconductivity even at pressures up to 50 GPa[2]. This raises the question of whether the observed superconductivity is related to the heterostructure or substrate induced strain on the thin films. Owing to the difficulties inherent in the synthesis process, strain studies investigating the superconducting properties of these new compounds are rare. Interestingly, a recent report indicates that the Tc onset can be significantly enhanced in $Pr_{1-x}Sr_xNiO_2$ films by applying hydrostatic pressure, increasing from 17 K at 0 GPa to 31 K at 12.1 GPa, with no sign of saturation before the film cracks[3]. Furthermore, the discovery of high-Tc superconductivity in the $La_3Ni_2O_7$ bilayer structure under pressure (with a maximum Tc ~ 80K above a pressure of 15 GPa) highlights the urgent need to study the electronic properties of nickelates under stress[4]. The fabrication of IL superconducting nickelate membranes, without substrate stress, presents a new approach to achieving superconductivity and uncovering the underlying physics. The structural flexibility and tunability of freestanding membranes make them well suited to study of strain. It was already shown that, freestanding membranes can be mechanically attached to an external platform to apply continuous biaxial or uniaxial stresses, enabling a stress state of up to 8% to be achieved. At the IPCMS in Strasbourg (France) in collaboration with the ICN2 in Barcelona (Spain), we are working on the possibility of excluding the effective role the STO substrate and exploring whether the IL phase (and subsequently the superconducting state) can also be obtained after release of the nickelate film[5]. This task is rather technical and it is largely depending upon the effective strain released during the membrane formation, and the successful candidate will have to handle this very carefully in order to get first and crucial information about the stress-induced effect on both the structural and transport properties in in-house experiments while dedicated experiments will be conceived by using the capability available at ESRF (ID32) to perform strain-control experiments via a piezoelectric-based strain device[6] and membranes on a flexible support and to obtain information about the low-energy elementary excitation of IL-nickelates freestanding membranes.

The successful candidate will grow the nickelate thin films via pulsed-laser-deposition technique and subsequently perform the topotactic reduction and exfoliation processes. Several substrates will be used such as LSAT, NGO and/or STO, and different capping layers will be tested for the nickelate layer. X-ray diffraction and atomic-force-microscopy techniques will be used to attest the quality of the as-grown, reduced thin films and membranes. Transport measurements will be performed by the aid of a Dynacool of Quantum Design and synchrotron radiation will be used to obtain the requested information about the electronic structure of the several samples.

References

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