In-situ manipulation of ferroelectric structures at the atomic level

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Ferroelectric materials are characterised by the existence of a finite electric polarization in absence of an external field below the Curie temperature. These materials tend to form domains, i.e. areas with the same direction of polarization. The application of an electric field can change the spontaneous polarization of these materials. Therefore, control over the switching of the domains, i.e. the polarization direction is essential for future applications in electro-mechanical devices.

Recently, micro-electro-mechanical systems have been developed for transmission electron microscopy (TEM), allowing ferroelectric materials to be electrically biased and/or heated in-situ, producing real-time information on the specimen under controllable electrical /temperature conditions. Additionally, it is possible to directly correlate atomic level dynamics to electrical properties and temperature.

The main objective of the project is the *in-situ manipulation of ferroelectric structures at the atomic level*. This will require a combination of Scanning Transmission Electron Microscopy (STEM) and mapping algorithms to carry out polarization analysis of the material with and without biasing at different temperatures.

The successful applicant will join an active collaboration that has published widely in this area in recent years [1-3], and which involves Prof. Sanchez's group as well as Prof. Marin Alexe's team at the University of Warwick. All aspects of sample growth, device fabrication and theoretical and computational analysis are carried out in-house. This PhD position will focus on in-situ electron microscopy, with exposure to these other areas of materials physics. The successful candidate will also develop skills in operating advanced aberration corrected-TEM/STEM and spectroscopy with sub-Å resolution and focused ion beam with standard lift-out procedure, sought-after skills in the current technology market.

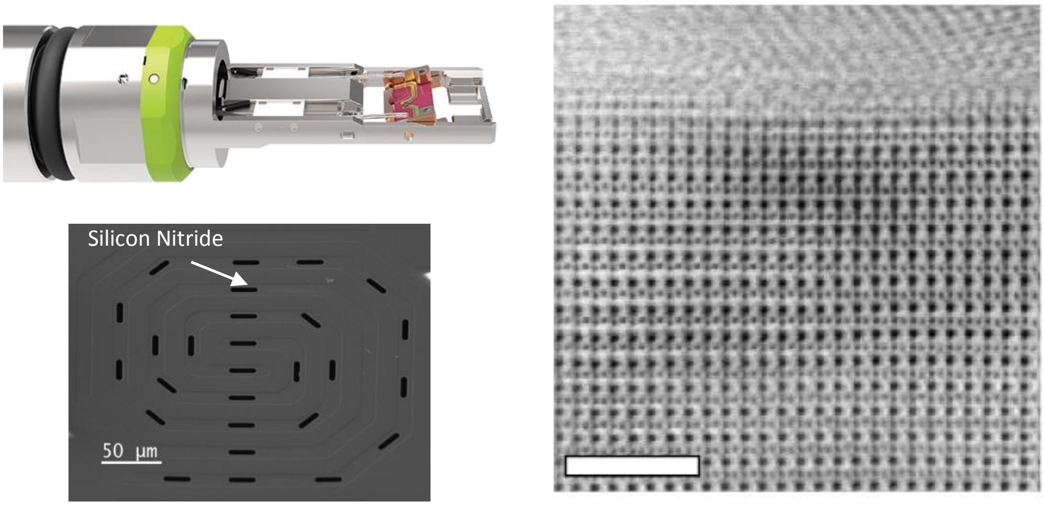

Figure – In-situ holder and MEMS (left) and annular bright field (right) atomic resolution image of a $La_{0.7}Sr_{0.3}MnO_3$-$PbTiO_3$-Co heterostructure. The scale bar is 2 nm. (Courtesy of J.J.P. Peters)

References

[1] *"Polarization curling and flux closures in multiferroic tunnel junctions"* J. J. P. Peters, G. Apachitei, R. Beanland, M. Alexe, A. M. Sanchez, Nature Communications 7 (2016)

[2] *"Antiferroelectric Tunnel Junctions"* G. Apachitei, J. J. P. Peters, A. M. Sanchez, D. J. Kim, M. Alexe, Advanced Electronic Materials 3 (2017)

[3] *"Bi-ferroic properties of multiferroic tunnel junctions"* Z. D. Luo, G. Apachitei, M. M. Yang, J. J. P. Peters, A. M. Sanchez, M. Alexe, Applied Physics Letters 10 (2018)