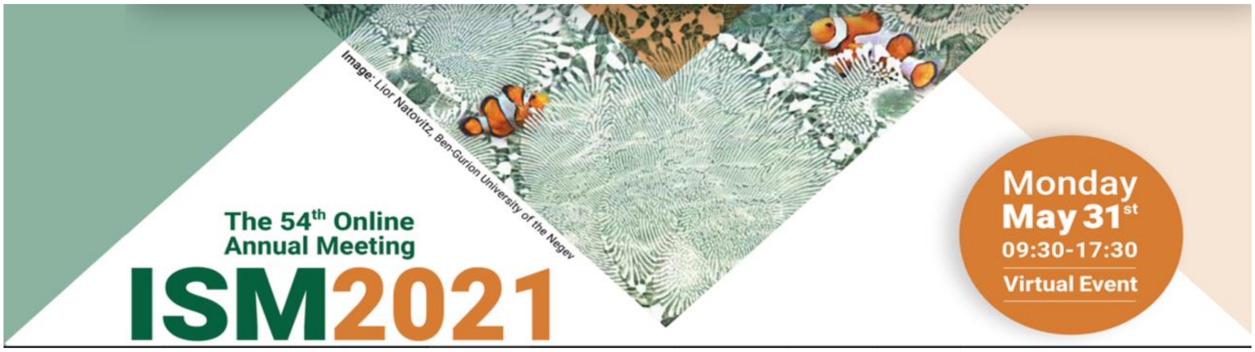

EXCITING FERROELECTRICS: WHAT DOES IT REQUIRE TO EXCITE IN SITU?

Yachin Ivry

Department of Materials Science and Engineering, Technion – Israel Institute of Technology, Israel

Ferroelectrics are functional materials with applications ranging from biomedical ultrasound imaging to cellular communication and low-power data storage. The functionality of these materials stems from a strong coupling between the electric and structural properties. That is, collective ion displacement at the picometer scale in neighboring unit cells gives rise to macroscopic polarization domains. Strong collective interactions are rather unique in nature and theoretical modelling of these system is a challenge. Hence, there is a great desire to observe the onset of this collective behavior, mainly as a function of temperature and electric field. However, such observations require not only to push the microscopy tools near their resolution limit, but there is also a need in exerting *in situ* excitations and characterize the resultant ion and domain dynamics. Here we combined advanced transmission electron microscopy (TEM) and atomic force microscopy (AFM) methods to reveal domain formation in the seminal ferroelectric, $BaTiO_3$ both at thermotropic ferroelectric phase transitions, as well as under an external electric field [1-4]. Our results show multiscale dynamics from 20-pm ion motion via 2-nm domain formation to macroscopic domain motion at the scale of a few dozens of micrometers. These results help understand the onset of ferroelectricity, while the formation of high-density domain is promising for high-throughput low-power computing devices.

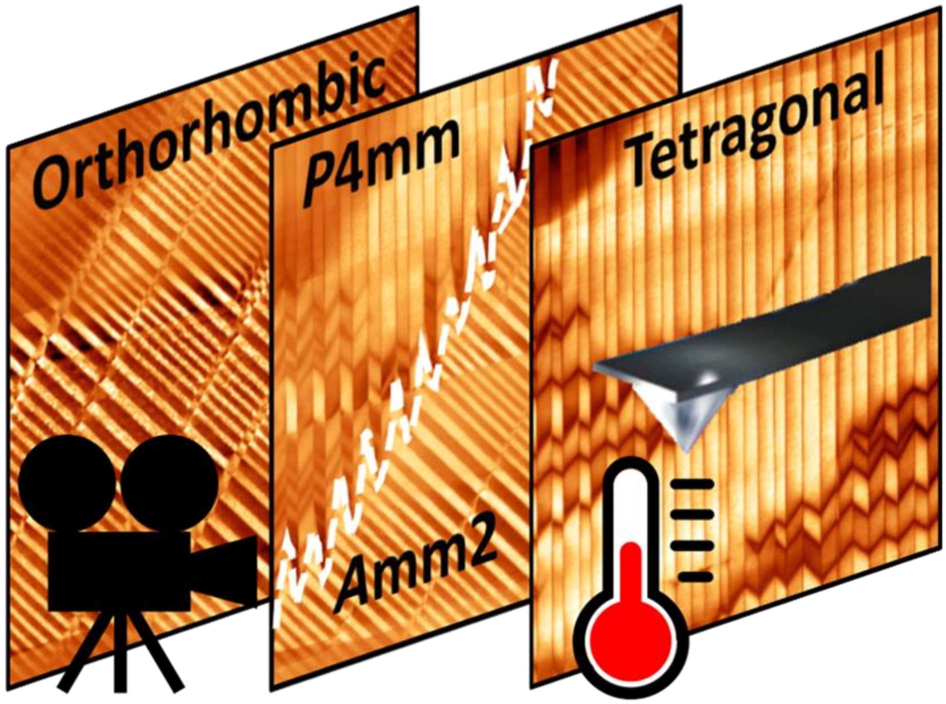

Figure 1| Ferroelectric domain dynamics during the orthorhombic-to-tetragonal transition (*in-situ* atomic force microscopy).[1]

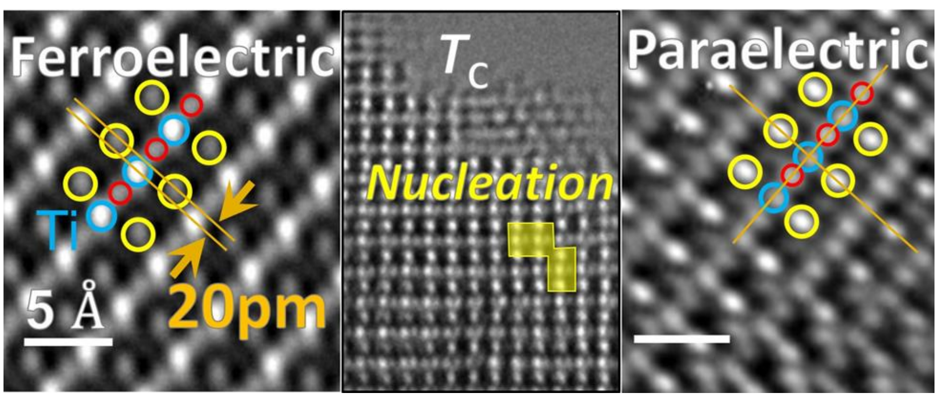

Figure 2| Dipole-moment and unit-cell dynamics during the ferroelectric-to-paraelectric transition (*in-situ* TEM) [2].

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