In the framework of our ESRF proposal we have first developed the methodology of such time-resolved 2-D DRX studies under HPHT conditions (up to 8 Gpa and 1000 K) using Paris-Edinburg high-pressure cell developed at IMPMC. The preliminary results obtained for ZnO were very promising: we first succeeded to observe different regimes of phase transformation in ZnO, nucleation and grain growth, retarded transformation in ZnO nanoparticles, transition nano-nano which unambiguously prove martensitic character of transformation at low temperatures and subsequent recrystallization of HP phase. No other *in situ* or *ex situ* method is able to give such abundant information on a phase transition. Currently multiple challenges are to be overcome, such as expansion of p-T and compositional region (light elements), high-rate diffusional transformations, probing of 2nd order phase transformations (superconductors, ferroelectrics, etc.), increasing the "probed" regions without increasing the minimal size of detectable crystallite, quantification of absolute values of grain number and grainsize, etc. Further development and application of this methodology promises the discoveries of unusual dynamic phenomena, and fundamentally new level of understanding not only of the 1st order phase transformations under HP, but of phase transformations in ordered and partially disordered systems in general.

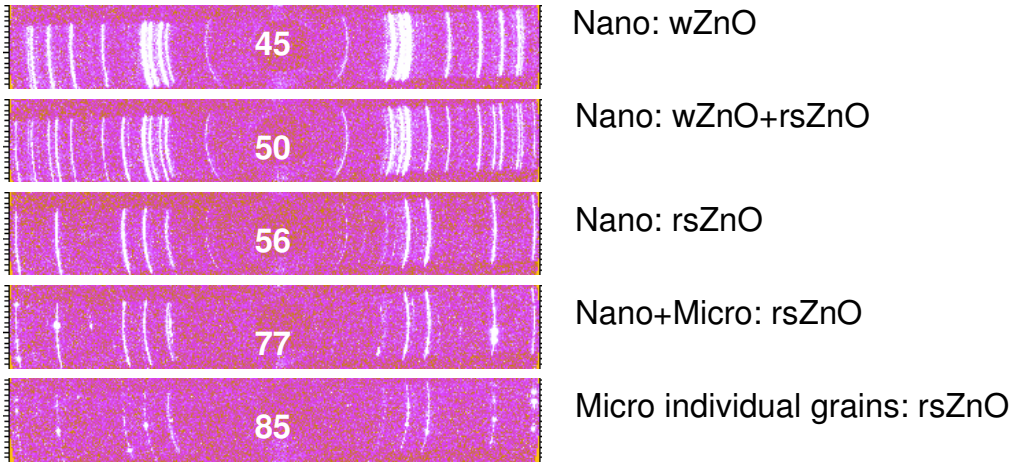

Figure. Multiscale evolution of ZnO polymorphs under HPHT conditions (continuous heating at a given pressure) observed by time-resolved 2-D XRD: initial nano- wZnO (pattern 45) directly transforms into nano- rsZnO (50 & 56), and recrystallizes into micro- rsZnO at higher temperatures. The quantitative analysis of XRD patterns opens a window into the world of extreme conditions. Simultaneous and/or subsequent studies of lattice vibration (e.g. by Raman or neutron diffraction) and interatomic bonding (by *in situ* IXS or EELS of recovered states), will allow me to probe various kinds of phase transformations in solids on different time- and space-scales.