Piezoelectric materials directly couple electrical and mechanical energies. Some example applications include nano-positioning systems used in lithography, ultrasonic imaging transducers, underwater sonar and electronic fuel injectors. Figures of merit for these applications vary, however many can be tuned by a detailed understanding of the underlying actuation mechanism. Polycrystalline forms of these materials dominate the total market share, thus investigations of the grain-scale response are critical to further developing these materials for existing and emerging applications. In a series of works [1-4], we have applied 3D-XRD methods to resolve the individual response of grains in piezoelectric materials while actuating with an applied electric field. It was first shown how materials with electric-field induced phase changes could be optimised to allow the maximum amount of strain, with minimal intergranular residual strain. It is hoped this work could be used to extend the fatigue lifetimes of related materials by minimising the probability of crack initiation in the microstructure. Secondly, grain maps of a prototypical ferroelectric BaTiO$_3$ were obtained (Figure 1) and it was demonstrated that during actuation significant intergranular strains developed due to the varying orientation relationships between the ferroelectric polarisation axis and applied electric field vector. These results demonstrated the influence of grain neighbourhoods on the response, hinting at local grain-grain interactions potentially having a large impact on the overall material response. This presentation highlights the importance of grain-scale investigations of strain mechanisms in polycrystalline piezoelectric materials.

Figure 1. Grain maps of the entire sample colour coded according to the ferroelectric domain switching strain in, (a) the initial state, and (b) the electrically poled state. The poling direction is along the vertical z-axis.