A detailed study was carried out of the mechanical properties under compression of potassium niobate, a ferroelectric perovskite that has the potential to replace lead-based materials in electromechanical (piezoelectric) applications. Potassium niobate (KNbO$_3$) has recognized excellent optical properties and is widely used in optical mechanisms, e.g. for laser frequency doubling. However, its mechanical response to conditions such as it might see in electromechanical applications has not been widely studied. These conditions include both mechanical and thermal loading, in an uncontrolled atmosphere. A series of compression tests over a range of temperatures between room temperature and 900°C was performed on single crystals of potassium niobate and the specimens were subsequently examined at multiple length scales.

The results reveal the interesting and very complex behaviour of the potassium niobate material. The stress-strain response was unexpectedly consistent with temperature (Fig. 1). Macroscopic characterization of the compressed crystals revealed cracking in all the specimens tested above 200°C. The cracking coexisted with plasticity; dislocations were observed in all tested specimens (Fig. 2). At all temperatures the dominant slip system was $\{110\}<1-10>$. Finally, domain walls were observed in large numbers only in the specimens tested between 300°C and 500°C, indicating that unlike the cracking and plasticity responses, the strain accommodation through domain change was not consistent with temperature. The tests performed in this study have turned out to be an excellent first step in understanding the mechanical behaviour of this material. They have provided valuable data on the material’s response to compressive loading and have established the important areas for further study and the critical conditions for useful further modelling work.

Acknowledgement: This work was supported by DFG Project MR 22/4-2 and the EU Seventh Framework Programme [FP7/2007-2013] - grant 312483 (ESTEEM2). The authors gratefully acknowledge U. Salzberger for TEM specimen preparation and S. Kühnemann for SEM images. MCR acknowledges a JAE/DOC contract from the Spanish Consejo Superior de Investigaciones Científicas and the European Social Fund.
Fig. 1: Critical flow stress of potassium niobate single crystals strained in compression at constant cross-head speed, at various temperatures.

Fig. 2: TEM BF image of potassium niobate deformed at 400°C showing dislocations and domain walls. Arrow indicates direction of $g = [001]$. 