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## Phonon mode softening at the ferroelectric transition in $\text{Eu}_x\text{Ba}_{1-x}\text{TiO}_3$

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$^{151}\text{Eu}$  Mössbauer study of phonon softening in ferroelectric  $\text{Eu}_x\text{Ba}_{1-x}\text{TiO}_3$ .

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### Summary

The ferroelectric  $\text{Eu}_x\text{Ba}_{1-x}\text{TiO}_3$  system is being studied as part of a project to search for the permanent electric dipole moment of the electron [1]. Part of this work involves understanding the materials properties of the system. Doping  $\text{BaTiO}_3$  with europium drives the ferroelectric transition down from 278 K [2] at  $x=0$ , to 0 K by  $x<0.75$ . The Eu-doped materials are weakly conducting, so detecting the ferroelectric transition by either capacitive methods or bulk susceptibility is difficult, however the phonon mode softening that accompanies the formation of the orthorhombic ferroelectric phase leads to a characteristic reduction in the Mössbauer-Lamb (or  $f''$ )-factor [3].  $^{151}\text{Eu}$  Mössbauer measurements on two samples of  $\text{Eu}_{0.5}\text{Ba}_{0.5}\text{TiO}_3$  have confirmed the presence of the phonon mode softening centred at 180 K, but also revealed an unexpected result. The signal from divalent europium ( $\text{Eu}^{2+}$ ) dominates the spectra of both samples; however, we found that 9-12% of the europium was present as  $\text{Eu}^{3+}$ . While initially ascribed to unreacted  $\text{Eu}_2\text{O}_3$ , neither xrd nor neutron diffraction showed any evidence for this, or any other trivalent europium impurity. More surprisingly, the temperature dependence of the  $f$ -factor shows a much stronger response in the  $\text{Eu}^{3+}$  component than in the  $\text{Eu}^{2+}$  one, clearly indicating that the trivalent europium is present within the  $\text{Eu}_{0.5}\text{Ba}_{0.5}\text{TiO}_3$  phase and ruling out any possibility of phase separation or impurity effects. Preliminary analysis of neutron powder diffraction data rules out the possibility that some of the europium might be located on titanium sites and the origins of the enhanced phonon softening at the  $\text{Eu}^{3+}$  site remain unclear.

**Primary author:** Mr ROWAN-WEETALUKTUK, W.N. (McGill University)

**Co-authors:** Dr SUSHKOV, Alex (Yale University); Dr STUDER, Andrew (Bragg Institute, ANSTO); Dr YETHIRAJ, Mona (Bragg Institute, ANSTO); Prof. SUSHKOV, Oleg (University of New South Wales); Dr ECKEL, S (Yale University); Prof. LAMOREAUX, S.K. (Yale University); Prof. CADOGAN, Sean (University of Manitoba)

**Presenter:** Prof. CADOGAN, Sean (University of Manitoba)

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