Single crystal growth of $EuGa_{12}O_{19}$ by the floating zone method.

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Magnetism is a fascinating research area, because it is a nice playground to study many body physics and statistical mechanics, with potential uses in electronics and energy applications. Frustrated magnets are magnetic materials where all the magnetic interactions cannot be simultaneously satisfied and thus compete with each other. In these materials a large variety of magnetically ordered states and disorder states are possible, often with very small energy differences between them. It was recently proposed that interacting electric dipolar moments may also lead to similar frustration in compounds with the magnetoplumbite crystal structure [1][2]. Some of the materials in the family contain both frustrated electric and frustrated magnetic moments and we have recently observed that the dielectric properties of $NdMgAl_{11}O_{19}$ can be influenced by an applied magnetic field, implying so called magnetoelectric coupling. Magnetoelectric coupling in this family, along with the electric and magnetic frustration, leads to the possibility to tune between energetically similar magnetic states using applied electric fields, or between electric states using magnetic fields. Such possibilities are fascinating to explore, with very few model materials available to probe both frustration and multiferroic coupling simultaneously.

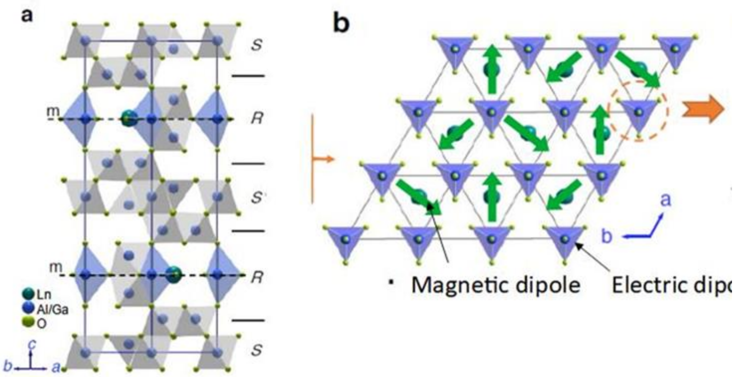

Figure 1 : (adapted from Reference [1]) (a) Crystal structure of the hexaaluminates and hexagallates.

(b) view from the top showing the nested lattices of magnetic dipoles (green arrows) and electric dipoles (double pyramids).

Investigating the ground-state properties of these materials is best performed using single-crystals. The work will initially consist of growth attempts of single crystal $EuGa_{12}O_{19}$ by the floating zone technique [3]. Either using optical heating through focusing of IR light using parabolic mirrors, or by laser heating. The total synthesis involves several preparative steps to first pre-synthesise polycrystalline material through solid-state reactions of the oxides ; prepare precursor rods through cold pressing ; sinter the precursor rods to increase density whilst also increasing structural strength ; and finally shape them for mounting within the floating zone furnace. Gallium oxide has a relatively low vapor pressure, so the growth attempts may need to be performed under a high gas pressure to reduce evaporation.

After the growth, the crystals will be characterized by x-ray diffraction and composition analysis to confirm crystal quality, before characterisation of the magnetic and electric properties are undertaken.

References:

[1] S.-P. Shen, J.-C. Wu, J.-D. Song, X.-F. Sun, Y.-F. Yang, Y.-S. Chai, D.-S. Shang, S.-G. Wang, J. F. Scott, and Y. Sun, *Nature Communications* 2016 , **7** .

[2] M. Ashtar, Y. X. Gao, C. L. Wang, Y. Qiu, W. Tong, Y. M. Zou, X. W. Zhang, M. A. Marwat, S. L. Yuan, and Z. M. Tian, *Journal of Alloys and Compounds* 2019, **802** , 146.

[3] Alemayehu S. Admasu and Durga Sankar Vavilapa, https://arxiv.org/abs/2103.05587.