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Acta Cryst. (2011) A67, C60**On subgroups of hyperbolic crystallographic groups**

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The characterization of the subgroup structure of crystallographic groups is one of the problems in mathematical crystallography which is of general interest. Subgroups of crystallographic groups are essential for a number of important studies in chemical research such as providing a concise tool for classifying crystal structures. Moreover, group-subgroup relations are useful, for example, in understanding the domain structures of twinned crystals and in the study of phase transitions.

The subgroups of crystallographic groups in the Euclidean and spherical cases have been studied extensively in previous works. On the other hand, investigating the subgroups of hyperbolic crystallographic groups is still a viable topic to explore. The motivation of this work is to discuss a method of arriving at the subgroups of crystallographic groups particularly those that exist in hyperbolic 3-space. We will discuss low index subgroups and properties pertaining to normal subgroups, conjugacy classes and torsion free subgroups. Some applications of these groups will also be explained.

Examples of these groups are called Tetrahedral groups, which are groups of symmetries of tilings in space by tetrahedra, belong to the important family of discrete groups known as crystallographic reflection groups. Tetrahedral groups arise in connection with various extremal problems in hyperbolic 3-manifolds and orbifolds. Among its two dimensional subgroups are the triangle groups, which are currently finding applications in the construction of chemical networks by projecting hyperbolic tilings into triply periodic minimal surfaces. More recently, in [1], the subgroup lattice of the triangle group *642 was used to give an enumeration of crystal nets, interest of which arises from their relevance to condensed materials. Hyperbolic triangle groups also play a role in dealing with structures of the fullerene family [2].

[1] S. Hyde, S. Ramsden, V. Robins, *Acta Crystallographica* **2009**, A65, 81-108.

[2] C. Pisani, *Springer Verlag* **1996**, 67.

Keywords: mathematics, crystallography, crystallographic groups

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Acta Cryst. (2011) A67, C60**Interfaces of lanthanum and strontium manganite superlattices**

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The manganites have been investigated for applications in magnetic devices. In the simple perovskite form, LaMnO₃ and SrMnO₃ are individually antiferromagnetic insulators. An alloy of these materials, La_{1-x}Sr_xMnO₃, undergoes an antiferromagnetic-ferromagnetic transition at concentrations of 0.15 < x < 0.5 [1]. Superlattices of LaMnO₃ (LMO) and SrMnO₃ (SMO) can be grown by molecular beam epitaxy (MBE) with layer by layer control. While keeping the stoichiometry constant

but changing the film thickness, the electrical and magnetic transport of these superlattices can vary by orders of magnitude [2]. This behavior is related to the localization of electrons, presence of interfacial states [3], film abruptness [4], and the strain in the films.

We can also remove selected MnO₂ layers of the superlattice to form a Ruddleson-Popper structure. By distorting the oxygen octahedra around Mn cations, the magnetic properties can be engineered differently from the perovskites. In superlattices it has been shown that the magnetization under an applied magnetic field is asymmetric parallel and normal to the film growth direction [5].

In superlattices, the density of interfaces is comparable to film thickness. To understand the origin of the magnetization, an investigation of the nanostructure and interfaces is essential. Scanning transmission electron microscopy (STEM) has the capability to collect images, diffraction patterns, and spectroscopy on individual films. With aberration corrected optics, a probe size of 1 Angstrom, or smaller is achieved in STEM mode, which can image oxides at atomic resolution and obtain chemical and electronic structural information on the atomic scale with electron energy loss spectroscopy (EELS).

We have investigated the interfaces of manganites in both the perovskite and Ruddleson Popper phases with aberration corrected electron microscopy. For the perovskites, the films are grown with high quality and exhibit near perfect epitaxy. A magnetic transport study [4] shows the in-plane magnetization is asymmetric about the two interfaces of LMO and SMO. At one interface, the magnetization is sharply enhanced, and at the other interface, the magnetization is suppressed. Using a combination of STEM, EELS, and Nanoarea electron diffraction (NED), we investigated the origin of this asymmetry. For the Ruddleson Popper manganites, electron diffraction performed with a liquid nitrogen cooled stage shows the crystal structure is modified upon cooling to ~100 K.

[1] J. Hemberger et al., *Phys. Rev. B* **2002**, 66, 094410. [2] A. Bhattacharya, et al., *Phys. Rev. Lett.* **2008**, 100, 257203. [3] A.B. Shah et al., *Phys. Rev. B* **2010**, 82, 115112. [4] S. May et al., *Phys. Rev. B* **2008**, 77, 174409. [5] B.B. Nelson-Cheeseman et al., *Appl. Phys. Lett.* **2011**, 98, 072505. [6] Supported by DOE grant DE-FG03-02ER45996 and ANL under DOE grant DE-AC02-06CH11357 Digital Synthesis FWP.

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Acta Cryst. (2011) A67, C60-C61**Interfacial magnetism by resonant X-ray reflectivity**

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The X-ray Resonant Magnetic Reflectivity (XRMR) technique yields the magnetization density across ultra-thin magnetic samples, with specificities that establish the technique as a complement to macroscopic techniques or polarized neutron scattering. The technique is sensitive to the orientation and the amplitude of the magnetic moment with a spatial resolution below the nanometer, distinguishing contributions from different chemical elements. The presentation will have an emphasis on some experimental and analytical methodologies and then turn to two recent applications. In a first example, XRMR allowed the direct analysis of the layer resolved spin structure in the fcc Fe films on Cu(001) providing the magnetic structure in the coverage regime above four monolayers, which is commonly referred to as "antiferromagnetic", but whose detailed structure was never solved [1]. Meyerheim *et al.* found a new model characterized by