An Antiferroelectric Twist Grain Boundary Phase

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In 1972 de Gennes described the nematic–smectic transition in liquid crystals in analogy to the conductor–superconductor transition in metals. As a result of this analogy the introduction of chirality to a smectic phase has a similar effect as the application of a magnetic field to a superconductor. As it is known for type-II superconductors, a mixed state, i.e. a state with a periodic lattice of line singularities (magnetic flux lines), appears before the superconducting state breaks down at higher magnetic field. In the liquid crystal case, the mixed phase is a double-periodic structure with singularities arranged in a strange geometry.

In 1989 Renn and Lubensky worked out the possible geometric features of this liquid crystal structure which they called the Twist Grain Boundary (TGB) phase. Shortly thereafter the first such material was synthesised by Goodby and in the years following, several TGB materials were investigated by X-ray scattering and their singular properties verified.

Whereas the vortex (or Abrikosov) phase in superconductors consists of a two-dimensional lattice of vortex lines, the liquid crystal analog phases are geometrically much more complicated as the singular lines can only be parallel along one direction, but sets of such directions twist to create a three-dimensional periodic structure containing blocks or slabs of a two-dimensional liquid. Thus the TGB phase is a helical structure which combines the seemingly contradictory features of layering and twist.

Subsequently different TGB phases were predicted and discovered which belonged to either the orthogonal smectic category (SmA*) or to the tilted smectic category (SmC*). These phases were denoted TGBA and TGBC, respectively. Whereas SmA* and SmC* are synclinic structures (the molecular directions are parallel or essentially parallel from layer to layer) other chiral tilted smectics exist which have an anticlinic organisation with the molecular tilt direction being opposite in adjacent layers. Such smectics are denoted SmC_a^* and have antiferroelectric properties.

In this thesis the first TGB phase derived from the anticlinic SmC_a^* phase is described. It is denoted $TGBC_a$. The internal anticlinic structure was deduced from textural, X-ray and electro-optic studies. As the anticlinic structure is not compatible with the previous topological description of the grain boundaries valid for TGBA and TGBC, built on a periodic pattern of screw dislocations, a new structure had to be worked out, built on unit screw dislocations in combination with half-unit disclinations of alternate sign. This structure is described in detail.

Keywords: twist grain boundary phase, antiferroelectric liquid crystals, liquid crystals