Spontelectrics: a unique form of the solid state

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A new form of the solid state has been discovered at the ASTRID laboratory (ISA) at Aarhus University, exemplified by cryofilms of common-or-garden chemicals such as propane, nitrous oxide or toluene. These so-called spontelectric films have the property that they are spontaneously polarised, supporting electric fields which can exceed 10^8 V/m, without any external stimulus such as an applied field [1-6].

The spontelectric effect is unique in solid state physics and quite distinct from any other known phenomenon, such as the ferroelectric effect. The spontelectric effect arises from both local and infinite range interactions due to the permanent dipoles of the constituent molecules. On deposition to form a film, crystallization apart, species move under thermal agitation such that dipoles should tend to be aligned on average in head to tail configurations, that is, $\delta+$ to $\delta-$, where $\delta+$ and $\delta-$ refer to opposite dipolar ends of the species. However thermal fluctuations may give rise to temporary configurations in which are found local average excess of $\delta+$ close to $\delta+$ rather than $\delta-$ and similarly an excess of $\delta-$ close to $\delta-$, that is, net dipole alignment. Here, fluctuations play the role of the externally applied field in the standard description of dielectric polarization. Dipole aligned configurations are evidently accompanied by an energy deficit due to repulsions between molecules. Such configurations will create a fleeting and spatially localised electric field which tends to oppose the alignment. There are now two possibilities. In the first place, the effect could remain a local fluctuation which continually both dies away and is resurrected, with dipole alignment averaging to zero over time and space. In the second, given a large enough local fluctuation, dipole alignment propagates via the opposing electric field throughout the system, taking over the entire film of material, becoming macroscopic and generating the observed spontelectric effect. A spontelectric state, essentially metastable, is then formed supporting powerful electric fields. The system is non-local and characterised by feedback, since dipole alignment gives rise to the electric field which itself feeds the degree of alignment. There is an analogy with laser action and, further, spontelectrics may be likened to a classical equivalent of a Bose-Einstein condensate.

The spontelectric effect is detected through the presence of potentials at the surface of films, measured using a low current and high resolution electron beam, Spontelectric potentials may be of tens of volts. Here we show (i) the negative dependence of the spontelectric field on the temperature of deposition of N_2O, between 38K and 65K (ii) the Curie point for a film of isoprene (iii) the remarkable behaviour of methyl formate which shows an increase of the spontelectric field for temperatures of deposition >80K (iv) a simple phenomenological model for the spontelectric effect.

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