| ESRF | **Experiment title:** Electric and Magnetic Field effects on Nematic Suspensions of Hematite | **Experiment number**: SC-2793 |
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**Report:**


**1 Abstract -** The proposed experiment was focused on the electric field response of nematic phases formed by anisotropic pigment particles in suspensions. The Iron-III-oxide pigment (Sicotrans Red) CI: Pigment Red 101 was dispersed in various solvents (1-octanol, dodecane and 5CB) using commercially available stabilisers. The aim of the experiment was to determine the cause of a previously observed electro-optic effect (absorption decrease). WAXS measurements were made to measure a Bragg peak at Q=2.5Å$^{-1}$, which enables an orientational order parameter to be determined as a function of concentration and field. SAXS measurements also enabled an orientational order parameter from the particle form scatter at Q=0.04Å$^{-1}$ to be determined.


**2 Experimental details -** The electric field was delivered by a high voltage amplifier driven by an arbitrary waveform generator. An electric field cell that was developed at Bristol was used as a stage to hold the sample as the field was applied. For each solvent a range of concentrations (0.1wt % to 40wt %) was studied with applied fields from 0 to 5V/μm. Time resolved measurements were performed to determine the response and relaxation times. This was carried out using two camera lengths. The short camera length was used to capture the Bragg peaks from internal planes of the particles (WAXS). The long camera length was used to record the particle form scattering (SAXS).

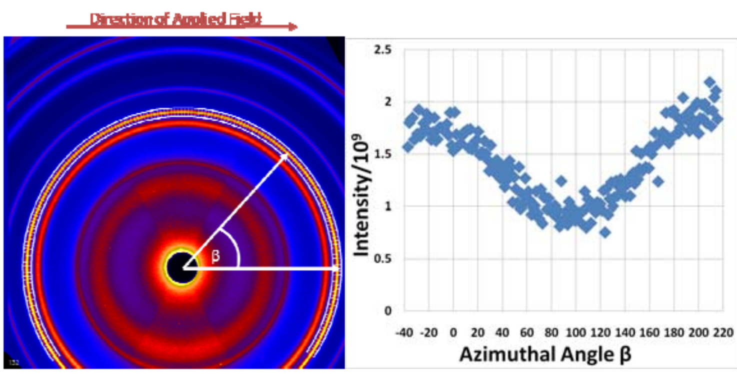


*Figure 1: Azimuthal distribution of the Bragg intensity with angle β*

**3 Results -** From the WAXS data an order parameter was determined by dividing the intensity of a Bragg peak into a number of data bins (Figure 1). The azimuthal distribution of the

Bragg intensity at Q=2.5Å[-1] (lattice plane spacing, d=2.51Å) has been extracted and used to determine the orientational order parameter by the integration shown below in equation 1:

$$\overline{P_2} = \frac{1}{z}\int_0^{180} I(\beta)\left(\frac{3}{2}\cos^2\beta - \frac{1}{2}\right)\sin\beta d\beta \qquad (1)$$

This is then plotted as a function of applied field for various concentrations. An example, for particles in dodecane, is shown in Figure 2. It is clear from these results that there is a small degree of alignment with applied electric field with 40wt% sample showing the greatest re-orientation.

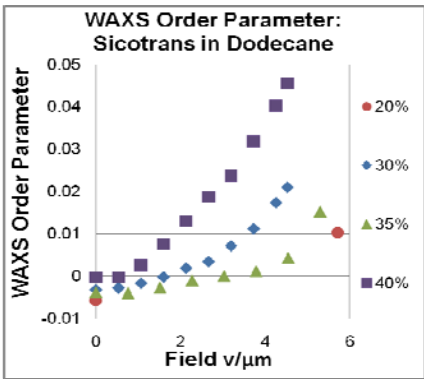


*Figure 2: WAXS order parameter as a function of applied field*

Analysis of this particle form scattering confirms that the long dimension of the particle tends to orientate parallel to the field. The order parameter was determined by a similar method to that of the Bragg scattering. This was achieved by taking a similar ring of the intensity and plotting as a function of azimuthal angle after first subtracting a background as shown in Figure 3.

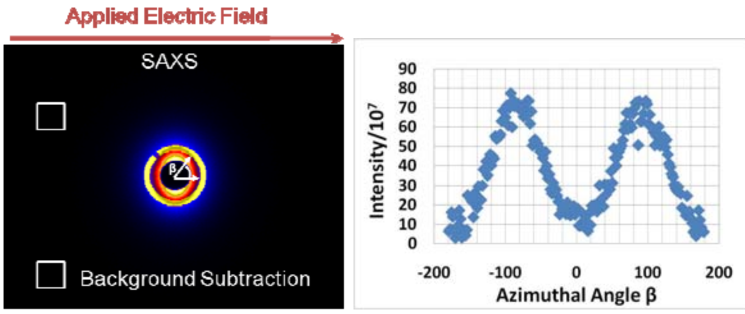


*Figure 3: Azimuthal distribution of the particle form intensity*

The order parameter, determined using equation 1, was plotted as a function of applied field for different concentrations as shown in Figure 4 (a). The particles show similar behaviour in both 1-octanol and dodecane with the largest order parameter at 40wt%.

From knowing the direction of re-orientation of both the particle form and Bragg scattering it can be concluded that the 2.51Å lattice planes of the particle are perpendicular to the long axis of the rod and the rod axes tend to align parallel to the field. It can be shown that for a simple model that the order parameter of the particles calculated from SAXS can be related to the decrease in absorption and account for the electro-optic effect.

The particles were also studied in two mesogenic solvents, E7 and 5CB. They show markedly different behaviour as shown in Figure 4(b). It is shown that the particles do not align in 5CB however in E7 they align in the opposite direction to the alignment in non mesogenic solvents.

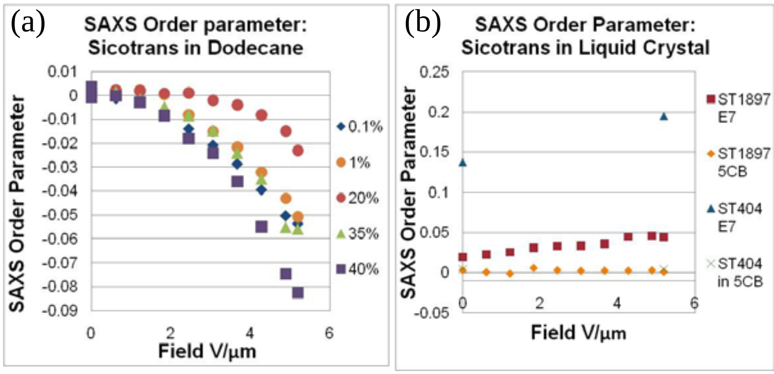


*Figure 4: SAXS orientational scattering order parameter as a function of applied in both dodecane and mesogenic solvent for different concentration as wt%*

## 4 Conclusions and Further Work -

We have established a method for the determination of the orientational order parameter of particles using the Bragg diffraction from internal crystal planes. The particle form scattering has also been measured with a longer camera length and indicates that the long dimension of the particles is oriented along the field direction. Each system showed a small response to the field at a number of concentrations with different solvents (e.g. 1-octanol and dodecane) showing a similar behaviour. The field induced orientational order of these particle in non mesogenic solvents has been able to account for the observed electro induced optic effect using a simple model.

However, the small reverse orientation of the particles in E7 does suggest that director anchoring on the particle surface is important.

Further work will include stabilisation using mesogenic stabilisers and X-ray characterisation of different pigment particles in isotropic and anisotropic solvents as well as reduction in the poly-dispersity of these systems. Computer modelling will also be carried out to try to understand the differing behaviour of the particles in mesogenic and organic systems.