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INVESTIGATIONS OF SMECTIC POLYSILOXANES 2 - FIELD INDUCED DIRECTOR REORIENTATION

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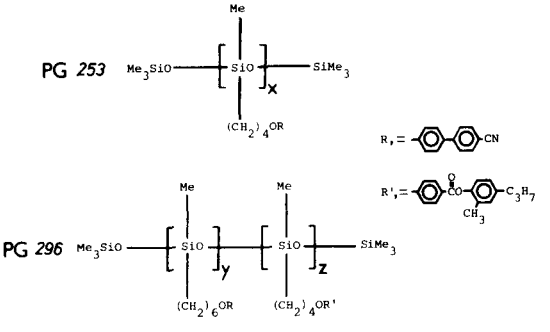
ABSTRACT

The electro-optic properties of two side chain smectic polysiloxanes subjected to high frequency (>1KHz) electric fields are discussed. Field induced homeotropic orientation is achieved for applied voltages of sufficient magnitude, and the parameters affecting the optical response times for this effect are examined.

INTRODUCTION

In the previous paper of this series[1], the effect of DC and low frequency (<1KHz) AC electric fields on a smectic polysiloxane were discussed. In this letter we report on the extension of these measurements to higher frequencies for both the original homopolymer and a structurally related copolymer. Both polymers, denoted PG253 and PG296 below, are smectogenic polysiloxanes.



These polymers, synthesised by Gray, Lacey and Gemmell[2], possess a positive dielectric anisotropy and, by comparison with a low molecular weight smectic (e.g. 8 CB, octylcyanobiphenyl) should align with their mesogenic segments parallel to an applied AC field of sufficient magnitude. From differential scanning calorimetry[2], the polymers exhibit the following transitions.

PG296 g 4.0 s 85.9 i °C

PG253 g 28.3 s 132.5 i °C

where g, s and i, are respectively the glassy, smectic and isotropic phases, for y+z=x=50.

EXPERIMENTAL

Samples were held between transparent, electrically conducting In/SnO_2 coated glass plates, separated by spacers varying between 30-70μm, and maintained at constant temperature on the heating stage of a polarising microscope. High frequency AC fields (up to 300 V rms) were provided by a low voltage waveform generator amplified using a linear high voltage amplifier. Photomicrographs were obtained using an Olympus BH-2 microscope plus OM2 camera attachment.

Thermo-optic analysis, by means of a photodiode and X-Y recorder, was used to optically monitor the transition points of the polymers.

RESULTS

Figure 1 shows thermo-optic traces for the polymers PG253 and 296. At low temperature both polymers are opaque and therefore show a low transmission in the microscope. As the smectic A to isotropic phase transition is approached the transmission suddenly increases at T' and reaches a maximum at T_m. This increase corresponds to a texture change from anisotropic but opaque, region A (see figure 2(a)), to highly birefringent and therefore transmitting region B. The changing light level with increasing temperature corresponds to a growth of the optically birefringent texture. The maximum T_m defines the temperature at which the isotropic phase first appears. Because the isotropic phase shows extinction between crossed polars

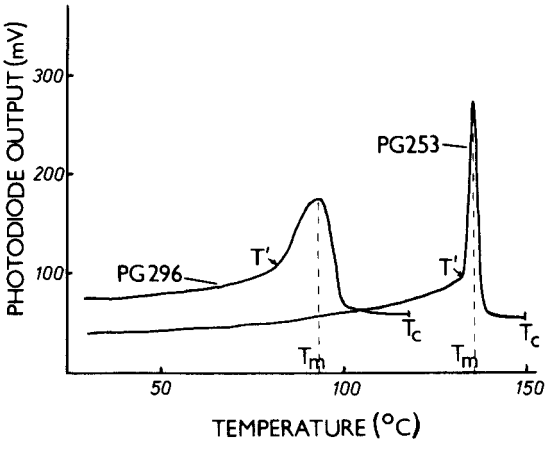
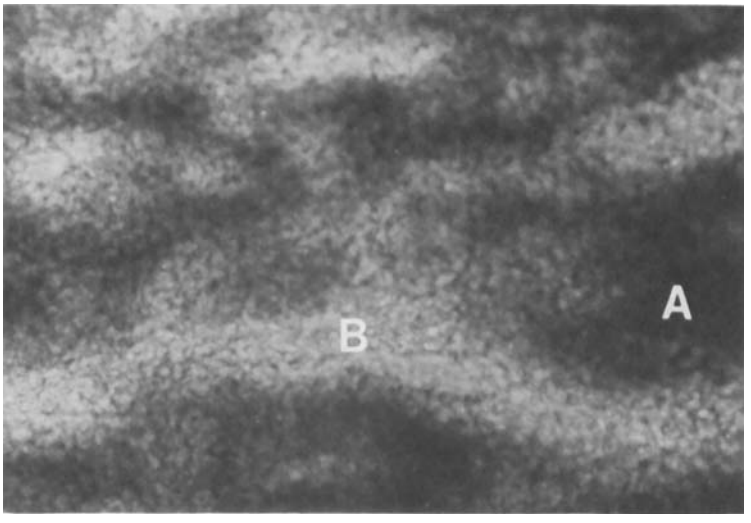


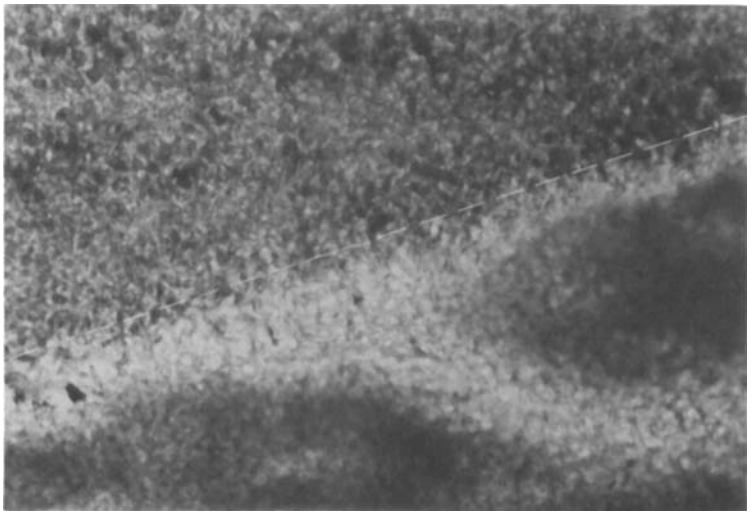
FIGURE 1 Thermo-optic analyses of the polymer samples.

further increases in temperature result in a decrease in light level as the isotropic regions increase in size. The clearing temperature T_c, usually 15° to 35°C above T_m, corresponds to the last appearance of any birefringent structures in the polymer melt. The two phase region between T_m and T_c appears to be typical of smectic polymer liquid crystals. The transition temperatures as defined by T_m from optical microscopy are:- PG296: 93.1°C (85.9) and PG253: 133.0°C (132.5) and the numbers in brackets give the temperatures of the maxima recorded in the corresponding DSC traces.

Application of high frequency AC fields (in the range 1-5KHz) to samples of both polymers, at temperatures within a few degrees of T_m, gives rise to a marked change of the optical texture. This change results in a decrease of the optical transmission in the region of the cell electrodes to a minimum. The texture change, which arises from a realignment of the polymer is illustrated in figure 2(b) for PG253 at 130°C. At this temperature, between T' and T_m, the polymer exhibits a mixture of A and B rich regions, figure 2(a). The electric field induced texture change, figure 2(b) was obtained by applying a 276 Vrms, 1.5KHz alternating voltage for 15 minutes.

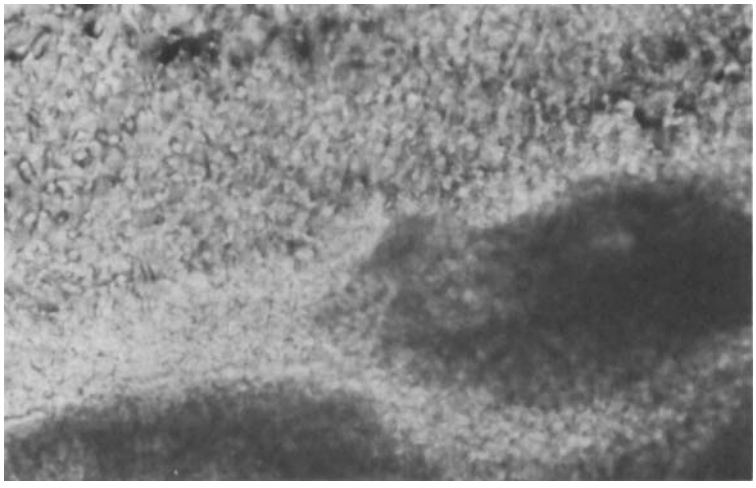


2(a)



2(b)

FIGURE 2 (a) Initial texture of PG253 at 130°C showing the opaque but anisotropic region A and the birefringent region B, (b) change in texture on application of electric field (dotted line depicts electrode edge), and (c) decay of the induced texture after one hour (see overleaf). See Color Plates V, VI, and VII, Volume 102, issue 10.



2(c)

Removal of the field at this temperature results in a very slow relaxation of the induced texture, and figure 2(c) shows this effect one hour after removal of the field. Although microscopically the field induced texture is not uniformly homeotropic when observed using crossed polars, macroscopically without polars the texture appears clear. This is in marked optical contrast to the non field aligned scattering texture. These field induced changes are readily observed for temperatures between T' and T_c.

At temperatures between T' and T_m, the polymers become more fluid resulting in a much quicker response to applied electric fields. The optical response of PG296 to alternating applied voltages at a temperature of 90°C (T_m - 3.1°C) is plotted in figure 3. The response time, τ_r, is defined as the time taken for the transmission of the sample between crossed polars to drop to 50% of its initial value (figure 3a). The response time decreases with increased applied voltages (curve a, figure 3b), and there is an optimum frequency (curve b) which minimises τ_r for a given applied voltage. Similar curves are obtained for polymer PG253, and higher temperatures result in a quicker response in accordance with a reduced viscosity. Response times on removal of the electric field were typically four to five times those of the optical response times τ_r.

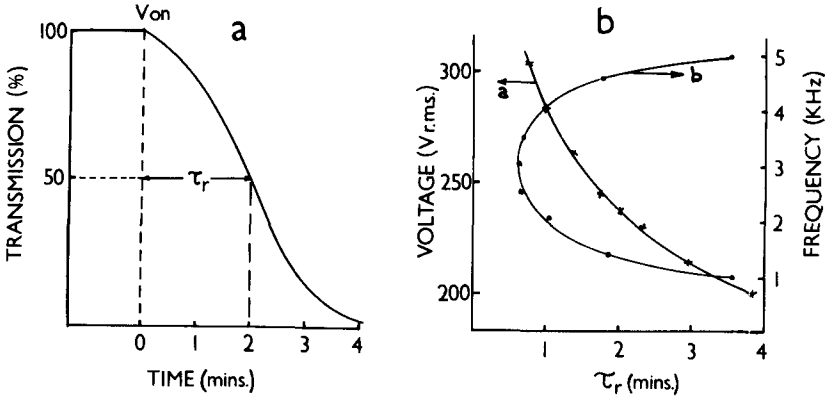


FIGURE 3 Response data for PG296 - see text.

It is apparent from figure 3b that at the optimum frequency for realignment, a favourable combination of high voltage and a temperature close to T_m will result in lower response times, indeed times as low as 500ms have been recorded in thin (≃25 microns) films of PG296.

We believe that the relatively fast response times for polymers coupled with the possibility of storage of the induced texture for long times at temperatures below T_g[3] will result in storage effect of very high contrast, and work is being carried out to investigate such effects.

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