Molecular Crystals and Liquid Crystals
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl16

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Version of record first published: 21 Mar 2007.

To cite this article: G. E. W. Schulze & T. Kunz (1976): Mechanical Twinning of Smectic Mosaic Textures, Molecular Crystals and Liquid Crystals, 36:3-4, 223-234

To link to this article: http://dx.doi.org/10.1080/15421407608084326

Mol. Cryst. Liq. Cryst., 1976, Vol. 36, pp. 223–234

Printed in Holland

Mechanical Twinning of Smectic Mosaic Textures

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(*Received May 10, 1976; in final form July 13, 1976*)

Smectic mosaic textures of S_B, S_G and S_E modifications and their changes after a mechanical deformation were microscopically studied. The mechanical deformation of the smectic film with a thickness of about 10 μm is caused by a translation of one slide against the other. We observe changes in the grain of the mosaic texture, which are similar to mechanical twinning or kinking in crystals. These changes were particularly investigated and interpreted in grains of S_B with optical axes lying parallel to the slides.

1 INTRODUCTION

The liquid crystals lying between slides have a thickness of about 10 μm. Observation with the polarizing microscope in an orthoscopic light path shows their texture. Observations were made using a heating stage with crossed polarizers with "White" light and a magnification of about one hundred.

Investigations on the universal stage were made without spherical segments, because these did not resist the thermal strains. The measuring error is relatively small only in the extreme positions of the optical axes, which are found in the following investigations.[1] The heating of the sample was done by an electric current (a.c.). A transparent evaporated film of SnO_2 on the slide was the electrical resistance.†

The smectic modifications S_B, S_G and S_E have the mosaic textures as their stable textures.[2–4] The uniform interference colour within a grain (or domain) proves a parallel arrangement of plane smectic layers. A grain is called pseudoisotropic if its optical axis is in the direction of the axis of the microscope. All other directions of the optical axis give colours, which depend on

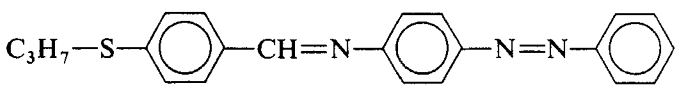
† We accepted this method of heating from our colleague Dr. S. Diele.

the thickness of the sample and on the angle between n_γ (large principal axis of the cutting ellipse of the indicatrix) and the direction of vibration of the polarizers.

Till now the investigations have centred on the undeformed textures. In this paper we observe the mosaic texture after deformation. A mechanical deformation of the grains is caused by a translation of the slides against one another or by a pressure on the slides. This paper shows that in this way regions within a grain are uniformly reoriented. We call the production of the reorientated regions by deformation into smectic grains with parallel orientation of their optical axes to the slides "mechanical twinning." This is analogous to phenomenologically similar effects in crystals.[5] The term "kinking" for this phenomenon is possible too. Further research will show which term is better for integrating the results in the field of crystallography.

2 INVESTIGATIONS ON 4-(4-*n*-PROPYLMERCAPTOBENZYLIDENEAMINO)-AZOBENZENE

2.1 Substance and its texture before deformation



has the following transition points:

$$\begin{tikzcd} \text{crystalline} \arrow[r, leftrightarrow, "111{,}1^\circ"] & \text{nematic} \arrow[r, leftrightarrow, "113{,}8^\circ"] \arrow[d] & \text{isotropic} \\ S_B \arrow[u] & \arrow[l, "104{,}6^\circ"'] & \end{tikzcd}$$

The smectic B modification is a metastable phase with a mean time of existence of about 5 minutes. S_B appears in a mosaic texture and the grains are optically positive uniaxial.

The investigations on the universal stage show that the optical axes of the grains are situated parallel or perpendicular to the plane of the sample. Fluctuations around the parallel position amount up to 4°, around the perpendicular position up to 10°. Only after heating the sample about fifty times were larger deviations, about 20° against the plane of the sample, occasionally found.

Grains in a parallel position of their optical axes to the slides are yellowish white (higher order) and in perpendicular position they are black or dark grey for all azimuthal angles. Oval melting dimples appear within a grain in parallel position by annealing between 101–104°C (Figure 1). Their long axes have the same direction as n_γ and therefore lie parallel to the normal of the plane of smectic layers.

2.2 Effects of deformation in grains with parallel position

In this case the smectic layers stand perpendicular to the slides. Figures 1, 2 and 3 demonstrate the same cutting of the object. Figure 1 shows the mosaic texture before a deformation, Figure 2 after the first and Figure 3 after a third translation of slides against one another.

In Figure 2 we see changes in the grains 1, 2 and 3: Within grain 1 an inner region and in grains 2 and 3 corner regions have changed the directions of their optical axes. In Figure 3 we see also in other grains reoriented regions. Furthermore such regions appear in areas which have changed their optical axes from a previous deformation (grain 1 and 3).

Special investigations with the polarization microscope show:

1) Reoriented regions are to be seen after small translations of the slides in grains only with parallel position of their optical axes to the slides. (Effects after extreme deformation see 2.4.)

Sequence of deformation in a mosaic texture.

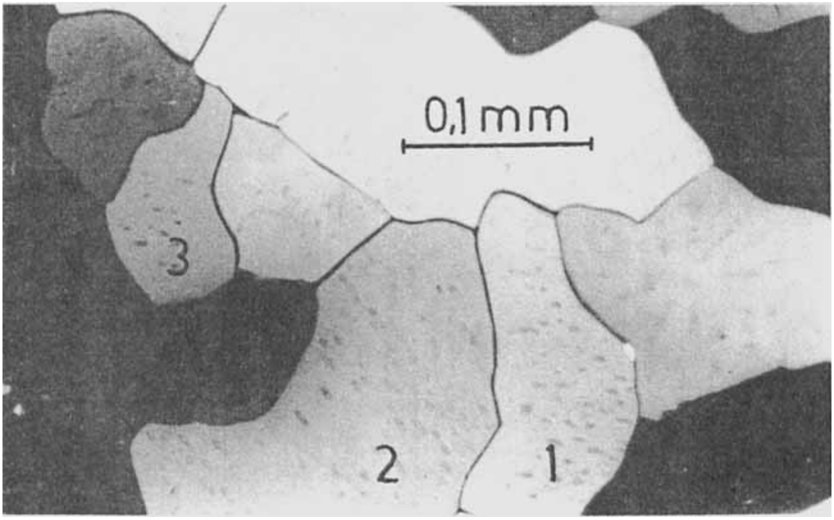


FIGURE 1 Before deformation.

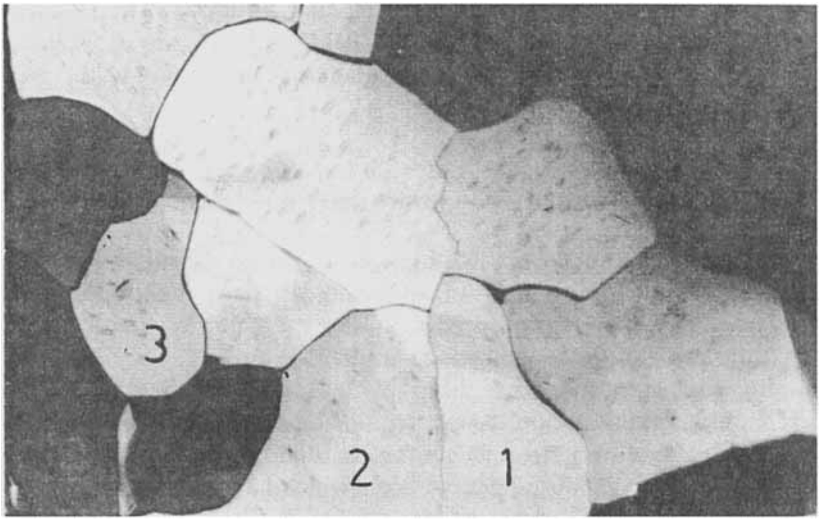


FIGURE 2 After the first deformation.

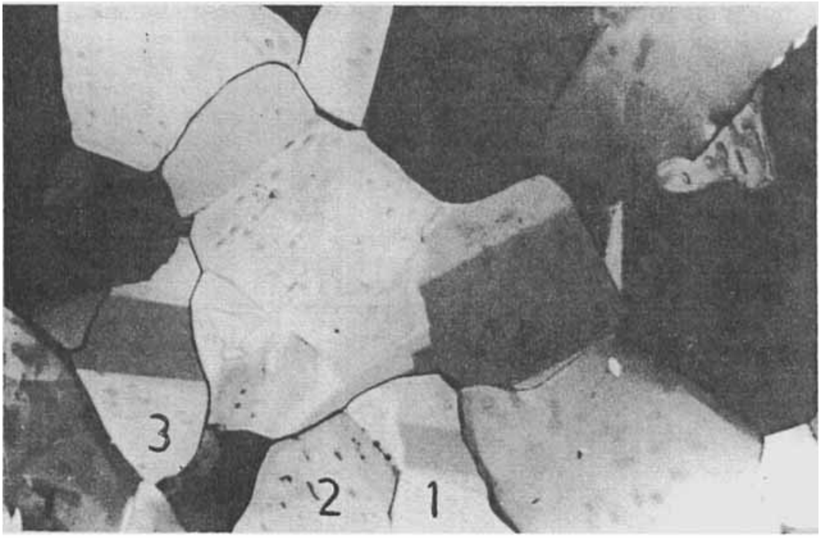


FIGURE 3 After the third deformation.

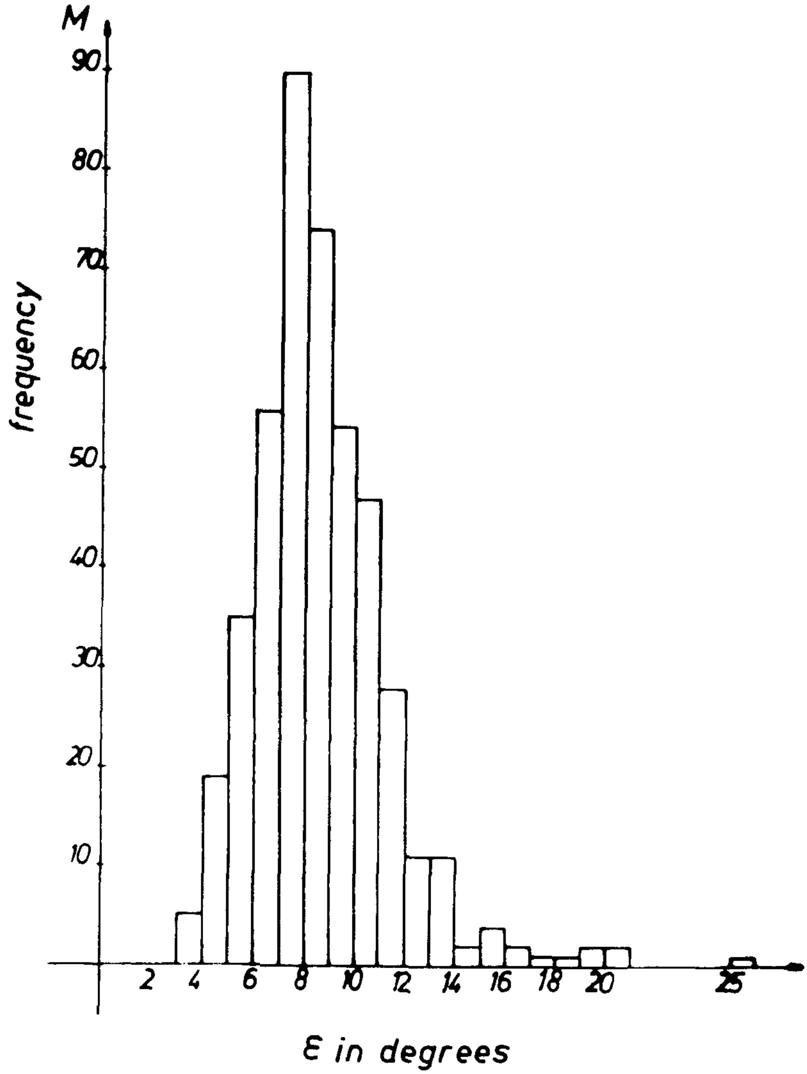


FIGURE 4 Frequency in dependence of the angle of extinction position.

2) The regions have parallel positions too.

3) Angle ε, formed by both the optical main axis of the grain and its region in the plane of the sample, was measured in 450 grains. Figure 4 shows the frequency polygon.

4) The region boundary is the trace of the symmetry plane, which stands perpendicular to the sample:

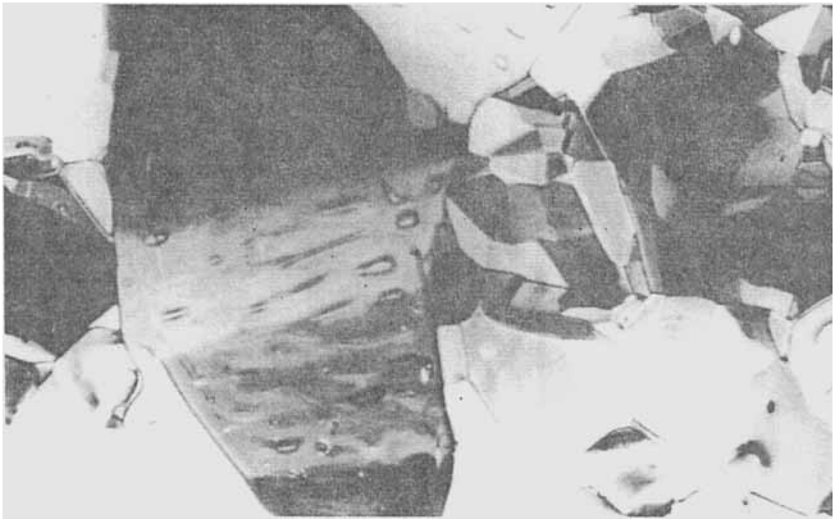


FIGURE 5 Long axes of dimples are parallel to n_γ in the three regions of a large grain.

a) If the direction of vibration of the polarizer and the region boundary lie parallel, the whole grain has the same colour and the region boundary is not to be seen.

b) Starting from this position, the angle of the extinction position for the grain and for the region amounts to $\varepsilon/2$.

5) The long axes of the oval melting dimples are also in the regions parallel to their optical axes (Figure 5). Figure 5 was made after an exceptionally large translation of the slides. With small values of ε such changes are not visible. The region boundary seems to be parallel to the long axes of the simples (see Figure 2).

6) The picture of the region boundary disappears if the polarizers are removed. In this way the region boundaries differ from the grain boundaries.

The results are summarized in a graph (Figure 6), where the plane of the graph is the plane of the sample. The smectic layers stand perpendicular to this plane.

In single cases we found that near 104°C a region ran across the grain without change of its shape. Furthermore a region in a grain grew during deformation and it shrank during the back deformation.

After a large deformation wedge-shaped regions can be seen. The results above are valid here too. Besides it seems that a polysynthetic twin system occurs within a grain and superpose on each other (Figure 7).

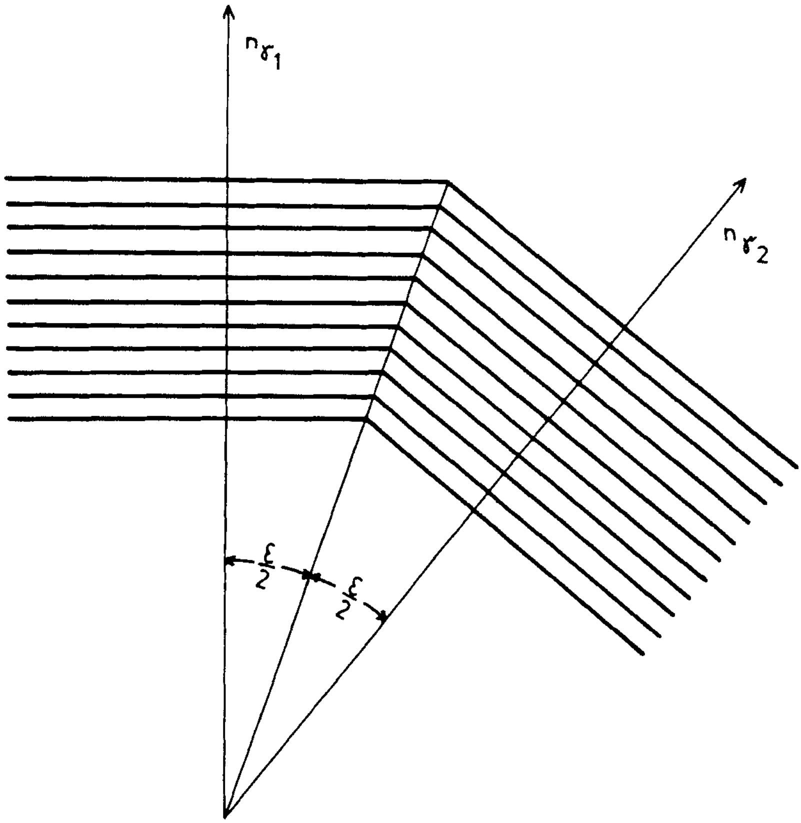


FIGURE 6 Graph of a twin, whose smectic layers are perpendicular arranged to the plane.

FIGURE 7 Superposition of multiple twinning.

The same effects appear in grains with parallel positions after a pressure on the slides.

2.3 Interpretation of mechanical twinning in a grain with a parallel position

Powers are transmitted on a grain during deformation by adhesion of the slides and by the neighbouring grains. The adhesion powers of the slides may be different not only between the grains but also between both slides of one grain. Therefore the stresses between neighbouring grains during the deformation are different in their values and directions. The grain evades these different stresses by twinning. In this way region boundaries must frequently begin on places where three grains run together (grains 1 and 3 in Figure 2). Furthermore they encroach from a region in one grain to a region in another grain (for instance grains 1 and 2 in Figure 2) i.e. along a common section of the grain boundary, on which the stresses have reached high values. Regions are formed in both the grains (mechanical twinning).

This concept enables us to understand, why the parallel position in the regions is preserved. Also the changes described at the end of 2.2 can be interpreted in this way.

FIGURE 8 A lot of subgrains, appearing in a pseudoisotropic grain after deformation.

2.4 Deformation in a grain with other than parallel position

In these cases the smectic layers do not stand perpendicular to the slides. Small translations of the slides against one another which produce reoriented regions in parallel oriented grains (2.2), do not modify the pseudoisotropic, nearly pseudoisotropic and (in samples after heating about fifty times) more inclined grains. These grains show alterations only after an extreme deformation as very large translation or intensive pressure on the slides. Figure 8 demonstrates such a grain after an extreme deformation: the grain has been split into a lot of subgrains. Every subgrain has a uniform colour, but the colour changes from subgrain to subgrain. This division of such a grain into subgrains is different from the twinning or kinking in a parallel oriented grain. Regularities between these subgrains were not investigated.

3 MECHANICAL TWINNING OF SMECTIC *B*, *G* AND *E* MODIFICATIONS

Mechanical twinning or kinking and also division in subgrains has also been found after a deformation of mosaic textures from *B*, *G* and *E* modifications listed in Table I. These mosaic textures were formed by nucleation and grain growth from the isotropic or nematic state. Their grain boundaries seem to be suitable for mechanical twinning.

In grains of some mosaic textures formed from other phases than isotropic or nematic, mechanical twinning was found only in single cases.

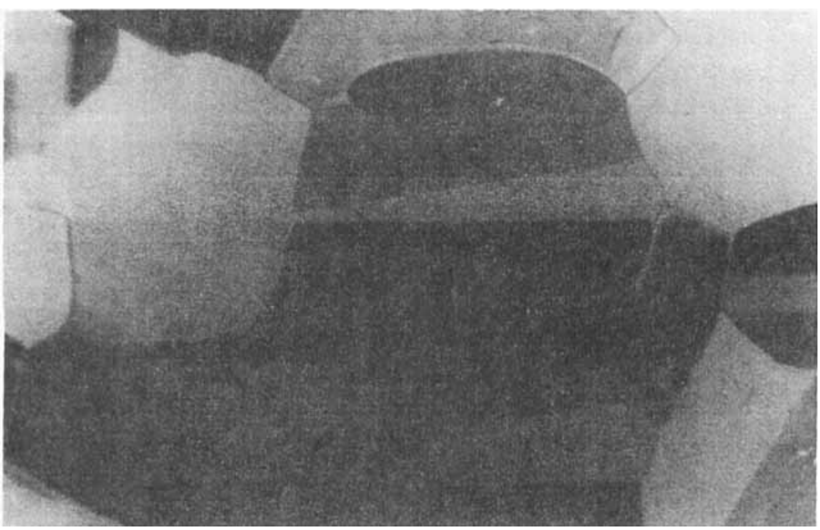
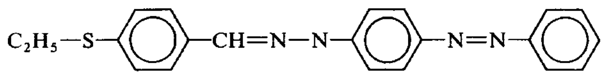
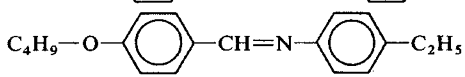
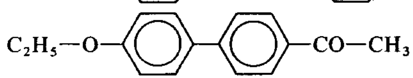


FIGURE 9 Twins in a mosaic texture of a s_B modification of another substance.

TABLE I

Substance	Modification	Figure	Transitions from	Remarks
	S_B	9	N	Homologue to substance above
	S_G	10	N	Additional polysynthetic twinning
	S_E	11	I	Some areas do not border on slides

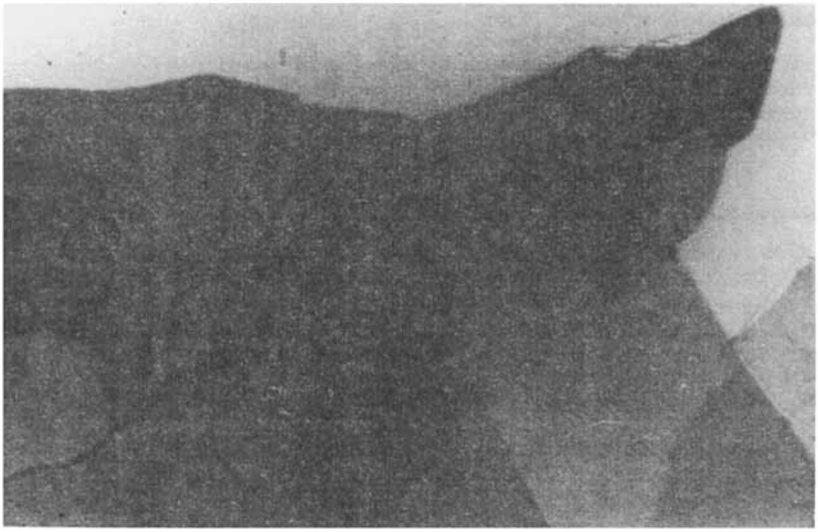


FIGURE 10 Twins in a mosaic texture of a s_G modification.

FIGURE 11 Twins in a mosaic texture of a s_E modification.

Acknowledgements

We are obliged to Prof. Dr. H. Sackmann for the suggestion to work in the field of liquid crystals and for his support. We thank Dr. D. Demus for consultation concerning substances and for discussions. For discussions in the field of crystal optics we are obliged to Dr. R. Gaedeke. The substances were taken from the collection of the Liquid Crystal Group, Halle.

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