



HAL
open science

Defects and textures of hexagonal discotics

Y. Bouligand

► **To cite this version:**

Y. Bouligand. Defects and textures of hexagonal discotics. *Journal de Physique*, 1980, 41 (11), pp.1307-1315. 10.1051/jphys:0198000410110130700 . jpa-00208958

HAL Id: jpa-00208958

<https://hal.science/jpa-00208958v1>

Submitted on 4 Feb 2008

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Classification
 Physics Abstracts
 61.30 — 61.70

Defects and textures of hexagonal discotics

Y. Bouligand

E.P.H.E., Laboratoire d'Histophysique et de Cytophysique, C.N.R.S., 67, rue M.-Günsbourg, 94200 Ivry-sur-Seine, France

(Reçu le 22 avril 1980, accepté le 18 juillet 1980)

Résumé. — Les défauts et les textures ont été étudiés dans les mésophases discotiques formées par un hexa-alcoxy-triphénylène (le dérivé pentyl). Deux textures principales peuvent être distinguées, suivant que les piles moléculaires sont orientées, surtout verticalement ou surtout horizontalement. La texture verticale est plus fréquente entre lame et lamelle, la seconde étant favorisée par un interface avec l'air (gouttes avec la surface supérieure libre). Les deux textures sont construites autour de disinclinaisons $+\pi$ ou $+2\pi$ d'orientation horizontale dans les textures verticales et réciproquement. Il y a deux sortes de parois correspondant soit à une discontinuité des axes cristallographiques, soit à une discontinuité de courbure. Les germes de la texture verticale soulignent l'ordre hexagonal des colonnes moléculaires. L'origine des disinclinaisons $+\pi$ est analysée dans les textures horizontales. Un modèle est proposé pour les textures soumises à un cisaillement.

Abstract. — Defects and textures were studied in the discotic mesophases formed by an hexa-alcoxy-triphenylene (the pentyl derivative). Two main textures are distinguished, with molecular stacks lying mainly vertical or horizontal. The vertical texture is more frequent between slide and coverslip; the second one is favoured by the air-interface (drop with a free upper surface). Both textures are built around $+\pi$ or $+2\pi$ disclinations lying either horizontally in vertical textures or conversely. There are two different kinds of walls, corresponding either to a discontinuity of crystallographic axes or to a discontinuity of curvature. Germs of vertical textures present an outline with the symmetries of the hexagonal order of the molecular columns. The origin of the $+\pi$ disclinations has been analysed in horizontal textures. A model is proposed for the textures submitted to a shear.

1. Introduction : planar molecules and uniaxial negative mesophases. — Microscopic studies of graphitization in carbonaceous materials (aromatic hydrocarbons, coal-tars, petroleum pitches) have shown the formation of a liquid crystalline phase, at temperatures between 350 and 450 °C [1-6]. The isotropic pitch or tar can transform into a negatively uniaxial mesophase. The anisotropic spheres coalesce and form textures similar to those of classical nematic liquid crystals (which are positively uniaxial). The carbonaceous mesophases are made of stacked planar molecules (Fig. 1A) and are extremely complex mixtures. The transitions are not reversible, since such materials present a rapid chemical evolution, involving reticulation at this high temperature.

Several groups have synthesized new pure components forming uniaxial negative mesophases in temperature domains where they are stable. A review of their symmetry groups and their main physical properties has been recently published [7]. In most liquid crystals, the molecules are rod-shaped and made of a rigid median part with benzene rings and two flexible extremities, which are paraffinic chains.

In order to obtain a liquid crystalline phase with aligned flat molecules, chemists have synthesized molecules formed by an aggregate of benzene rings, which is planar and rigid, and a set of lateral flexible paraffinic chains. This structure is thus a two-dimensional counterpart of the unidimensional molecular structure in classical liquid crystals. A very elegant synthesis has been made with a unique benzene ring in the core [8]. These molecules are benzene-hexa-*n*-alkanoates (Fig. 1B). Another group of molecules is built around a triphenylene core (Fig. 1C) [9, 10]. In contrast with the carbonaceous mesophases, these newly synthesized liquid crystals are hexagonal and not nematic. From the first X-ray diffraction patterns [8, 11, 12], a general model has been derived. The discoidal molecules form a system of parallel piles, with hexagonal packing as indicated in figure 1D. The distance between molecules in a pile shows strong thermal variations.

The parallel molecule piles are flexible and allow the formation of defects and regular textures, which can be observed in microscopy. The mesophases are easily sheared and the liquid character is evident.

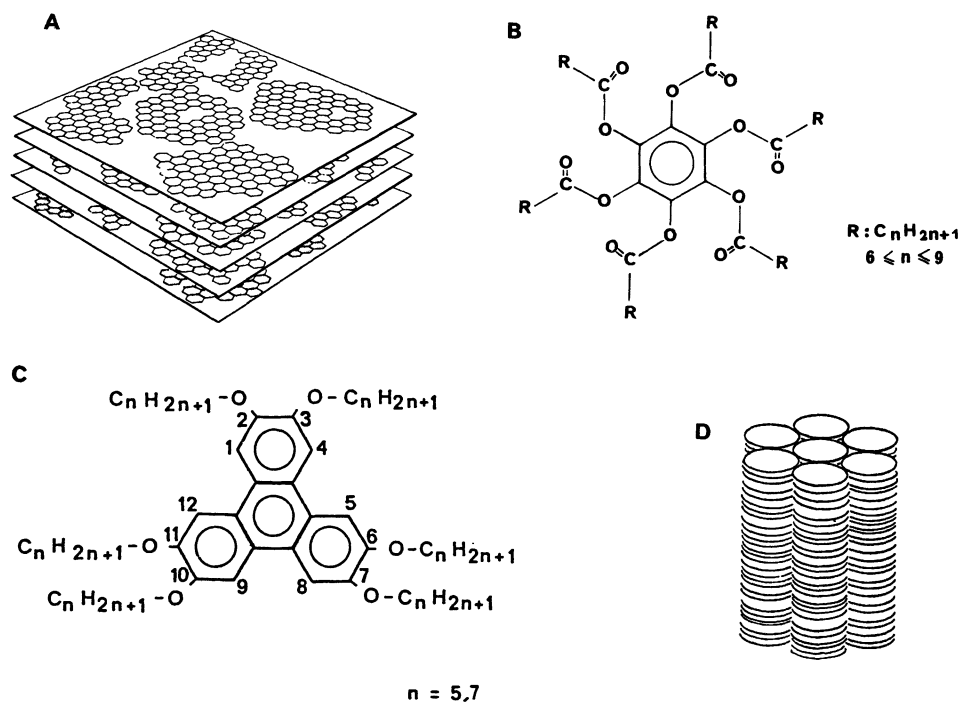
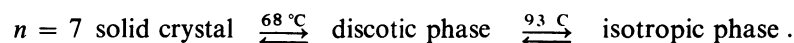
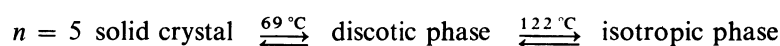


Fig. 1. — Chemistry and structure of carbonaceous and discotic compounds. A : Structure of a carbonaceous mesophase, after Zimmer and White [4]. The planar molecules formed by aromatic polymerization lie almost parallel. The successive planes have been represented to facilitate the drawing, but do not actually exist. Such phases have the symmetries of a negatively uniaxial nematic liquid. B : Benzene-hexa-*n*-alkanoate [8, 12]. C : Hexa-alkoxy-triphenylene [9, 10, 13]. D : Schematic representation of a hexagonal discotic phase, after Chandrasekhar *et al.* [8]. The discs are spaced irregularly in each column.

2. **Material and methods.** — The compounds studied are triphenylene esters synthesized in the Thomson-C.S.F. laboratories by the group of J.-C. Dubois [9]. We have observed the two meso-

genic derivatives corresponding to $n = 5$ and $n = 7$ (Fig. 1C). All micrographs presented in this article correspond to the compound $n = 5$. At normal pressure, the following transitions [13] occur :



Discotic germs form in isotropic liquid with a slight retardation of one to two degrees. There is considerable supercooling of the discotic phase below the melting point of the solid crystal (about 20 °C in the case of the compound in C_5).

Mesophase drops between slide and coverslip and free surface drops have been observed in a polarizing microscope Orthoplan-Pol-Leitz. The preparations were heated in a hot stage Mettler FP5.

A movies on the subject was made with the help of the « Institut de Cinématographie Scientifique », directed by J. Painlevé, and the « Service Audiovisuel de la Thomson-C.S.F. » [14].

3. Discotic liquids between slide and coverslip. —

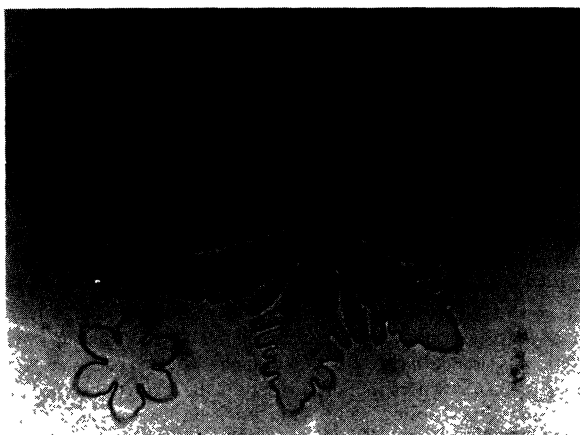
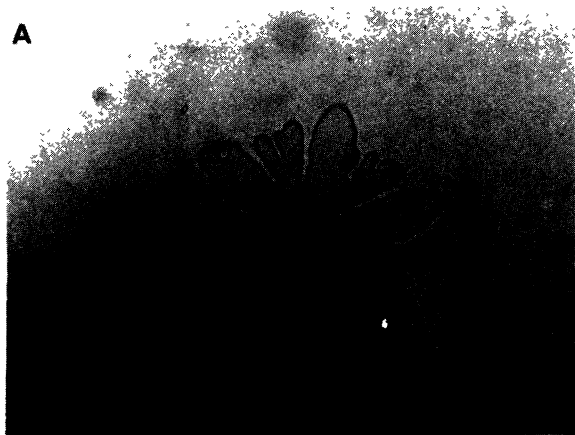
3.1 HOMEOTROPIC GERMS. — When the isotropic phase is cooled, one sees growing germs resembling flowers. They coalesce and form a mosaic of domains. Most of these domains do not show any polarization

colours, and this means that the flat molecules are horizontal, the negative optical axis being vertical (parallel to the microscope axis). Certain germs and domains however, show brilliant colours and are not homeotropic. They will be considered below.

Very slow cooling allows a detailed observation of the isotropic-discotic transition. The most convenient examinations of the growing germs are made between parallel analyser and polarizer. The homeotropic germ is first circular, and its shape becomes regularly hexagonal (Fig. 2). Growth is greater at the six vertices of the hexagon and the germ transforms into a star. Each branch forms new edges parallel to the edges or bisectors of the primitive hexagon. Finally, each branch of order one forms lateral branches of order two, which in turn may generate branches of order three (Fig. 3AB). The star-shaped nuclei resemble snow-flakes [15]. They differ only in their rounded angles.



Fig. 2. — Homeotropic germs isolated in isotropic liquid. One finds discoidal, hexagonal and star-shaped germs. Certain shapes are irregular. Crossed polars and first order retardation plate ($\times 120$).



It appears evident that the hexagonal arrangement of molecule piles is reflected in the shape of the nucleation germs of the discotic phase.

The growth of the discotic phase is exothermic. When two discotic nuclei are about to coalesce, growth stops, and this seems to be due to release of heat (Fig. 3C).

Some germs show concentric dense rings (Fig. 3C). We suspect the presence of a greater density of defects and such as screw-dislocations of the hexagonal array in such zonations. The geometry of the growing hexagonal germs is studied in figure 4A-E.

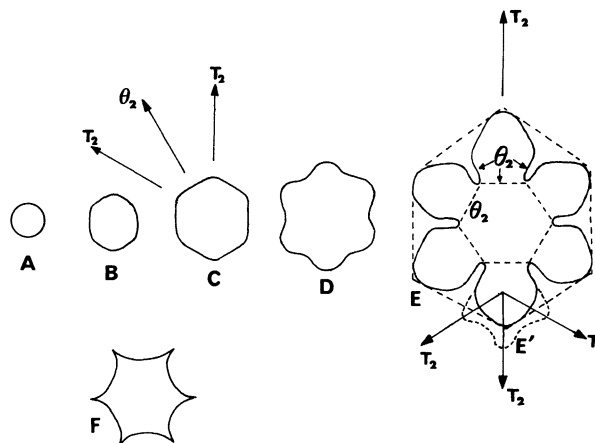


Fig. 4. — Growth and melting of homeotropic germs in the isotropic phase. A-E : Successive contours of an ideal germ and relative orientations of T_2 and θ_2 axes [17]. E' : is the profile of one branch some instants later ; two second order branches form in the directions T_2 . F : Profile of a melting discotic hexagon at the isotropic transition.

3.2 NON HOMEOTROPIC GERMS. — Certain germs are not immediately homeotropic, but show polarization colours for a half second or more and then become homeotropic. Other germs keep their non homeotropic orientation, form small rectangles resembling the germs we describe below in drops with a free upper surface.

3.3 MELTING OF GERMS. — When germs are reheated between slide and coverslip, the shape evolution is different from that observed during growth. The melting of hexagonal germs leads to the formation of concave edges and sharp vertices, as indicated in figure 4F. Melting of non homeotropic germs leads to the formation of extremely thin needles before they disappear.

Fig. 3. — Star-shaped germs. A : Two star-shaped homeotropic germs. The small one is a six-pointed star. The germs occupy the whole thickness separating the slide from the coverslip, with the exception of the tips of the branches, where the isotropic-discotic interface is oblique. The outline of the germs is less sharply defined at the extremities of the branches. Parallel polars. B : Several seconds later, the small germ has formed six branches. Parallel polars. C : Growth inhibition between neighbouring star-shaped germs. One observes concentric rings (r) in certain germs (arrows). Crossed polars and first order retardation plate ($\times 120$).

3.4 DOMAINS. — When cooling is relatively rapid (3° to 10°C per minute), numerous germs appear and coalesce. Most domains are uniformly homeotropic. However, many are divided into two homeotropic regions separated by an elongated, non homeotropic zone (Fig. 5A), with brilliant polarization colours. Between crossed polars, there is generally complete extinction, at the rotatory stage position which makes the elongation axis parallel to one of the polars.

One easily verifies with a compensator that the slow axis lies parallel to the elongation axis. This means that the parallel piles of molecules are in planes normal to the elongated zone. It also happens that the coloured stripes present a more or less fan-shaped aspect (Fig. 5B) and, in that case, there is no

position of complete extinction. The maximum angle separating the stripes in a domain is about 25° . The slow axis always lies parallel to the radiating coloured stripes observed between crossed or parallel nicols.

3.5 GEOMETRY OF NON HOMEOTROPIC ZONES. — Median coloured zones observed in homeotropic domains often present an axial core. This line, observed between parallel polars, is invisible when parallel to the electric vector of the incident beam. It shows its maximum contrast when the axis is normal to the electric vector of the polarized incident wave. This is illustrated in [13] and a complete interpretation is found in a work by Grandjean [16] concerning a similar geometry.

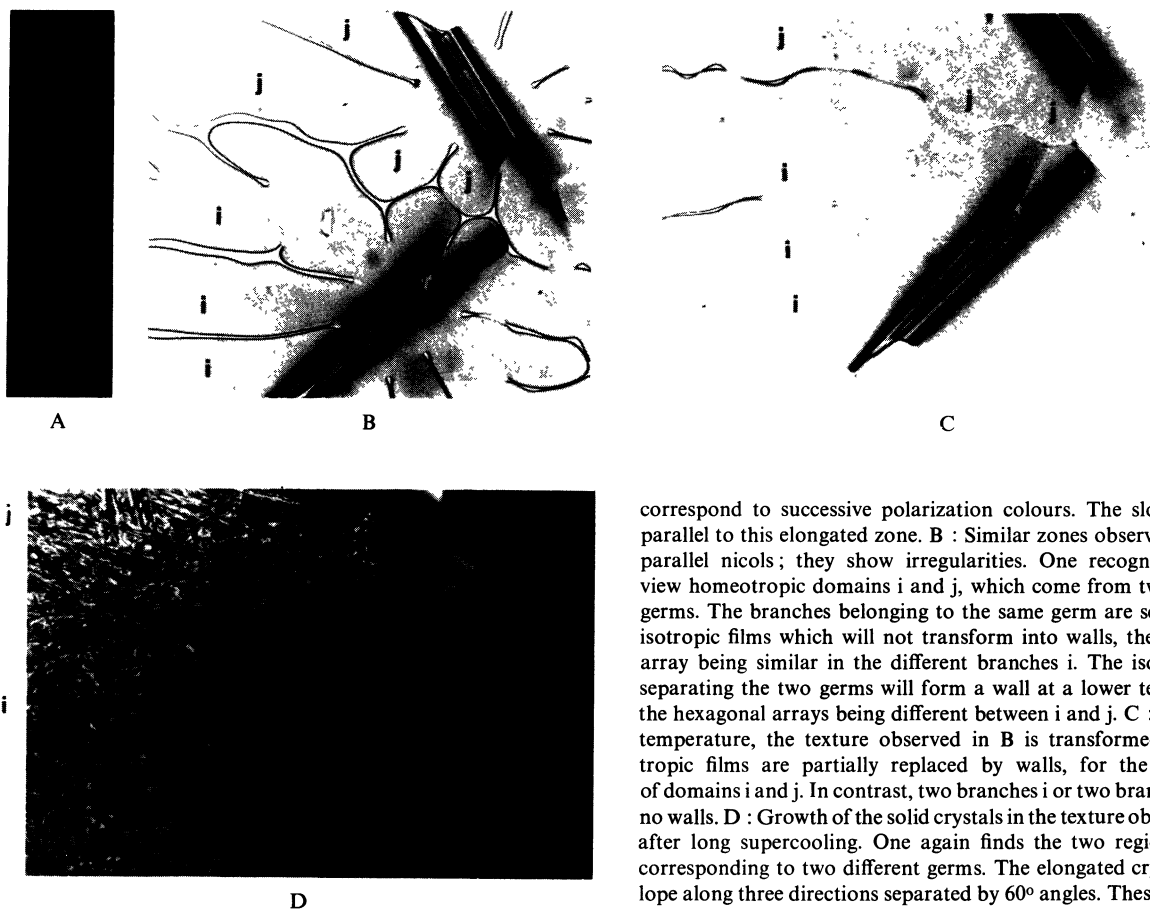


Fig. 5. — Domains in a discotic phase observed between slide and coverslip. A : Birefringent elongated zone in a homeotropic domain observed between crossed polars. The parallel bands

correspond to successive polarization colours. The slow axis lies parallel to this elongated zone. B : Similar zones observed between parallel nicols; they show irregularities. One recognizes in this view homeotropic domains i and j, which come from two different germs. The branches belonging to the same germ are separated by isotropic films which will not transform into walls, the hexagonal array being similar in the different branches i. The isotropic film separating the two germs will form a wall at a lower temperature, the hexagonal arrays being different between i and j. C : At a lower temperature, the texture observed in B is transformed. The isotropic films are partially replaced by walls, for the separation of domains i and j. In contrast, two branches i or two branches j form no walls. D : Growth of the solid crystals in the texture observed in C, after long supercooling. One again finds the two regions i and j corresponding to two different germs. The elongated crystals develop along three directions separated by 60° angles. These directions are different between i and j. In the right part of the micrograph, one observes the supercooled discotic phase, with birefringent distortions, appearing in the vicinity of walls. Parallel polars and crossed polars respectively in C and D ($\times 120$).

The theoretical study of the geometry of hexagonal non smectic mesophases suggests that the axial cores are straight lines δ [17]. Certain fan-shaped zones also present an axis δ . Other zones have two δ axes (or more). These axes can be attached to the slide or to the coverslip. Some axes are oblique. The elongated brilliant zones are often devoid of axes. We suppose then that the axes are virtual, lying outside

of the mesomorphic slab. Possible models of these textures are indicated in figure 6.

3.6 SHEARED HOMEOTROPIC DOMAINS. — A shear generated by a horizontal translation of the coverslip introduces many parallel and equidistant stripes lying normally to the shear direction. An excellent picture is published in [13]. These stripes probably

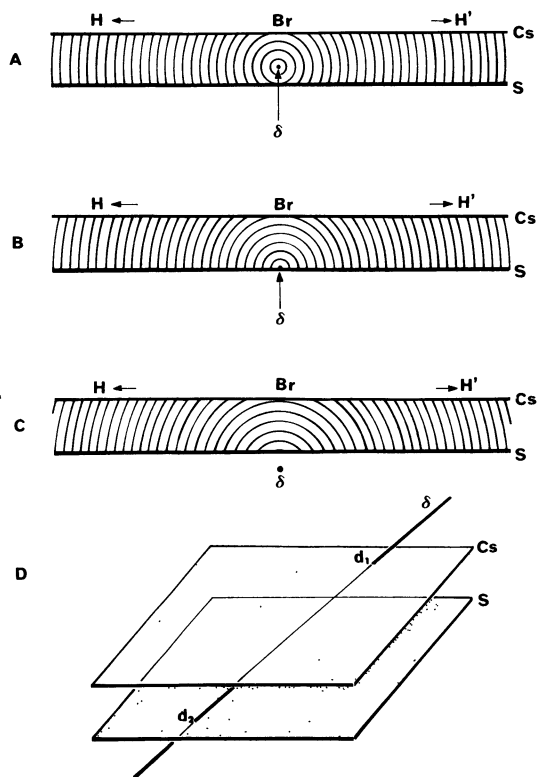


Fig. 6. — Model of a slightly oblique δ line. A, B, C : Three vertical sections of the texture. D : Perspective of the position of the δ line with respect to the limiting planes of the slide S and the coverslip Cs. The segment $d_1 d_2$ is real, the outer half lines are virtual. A corresponds to a section across $d_1 d_2$; in B, the section plane contains d_2 . In C, δ is virtual. In polarizing microscopy, the zone surrounding δ shows brilliant polarization colours (Br). The indication $\rightarrow H$ means « towards the homeotropic zones ».

correspond to the geometry indicated in figure 7. The association of successive pairs of δ lines allows a general tilt along the shear direction. The evolution of the discotic phase has been filmed during the shear.

3.7 WALLS. — Before the germs coalesce, they are separated by thin isotropic films (Fig. 6B) which disappear at a temperature of about ten degrees centigrade below the isotropic transition. It should be noted that the examined samples were not extremely pure, with about 5% of impurities. This probably explains why the two phases, discotic and isotropic, can coexist over such a large temperature range. At a lower temperature (Fig. 5C), walls replace these isotropic films and have very weak contrast, when they separate only homeotropic domains. These walls are well underlined when they separate homeotropic domains from non homeotropic regions of neighbouring domains. The existence of walls between homeotropic domains indicates a difference in orientation of the hexagonal array. It has been verified that the thin isotropic films separating the branches of a given germ disappear and do not form walls (Fig. 5C), due to the fact that the different branches have identical orientations, since they originate from a unique germ.

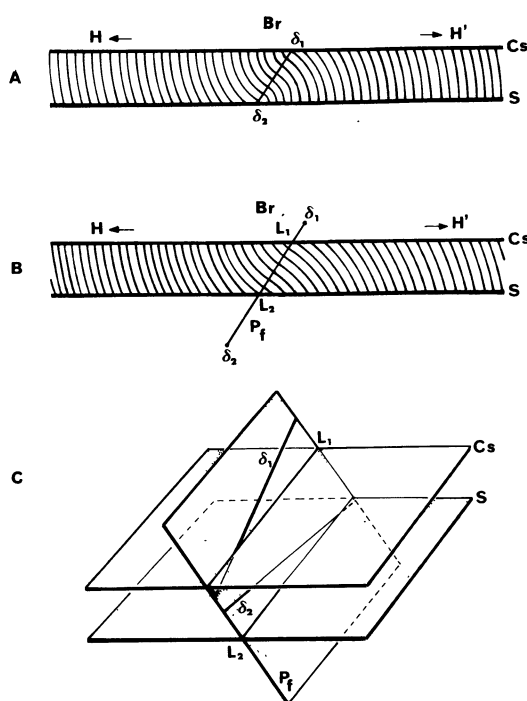


Fig. 7. — Tilted texture in a sheared homeotropic preparation. Legends as in figure 6. A and B : two vertical sections of the general situation represented in C. Two domains are separated by a plane P_f containing two lines δ_1 and δ_2 with virtual parts. The plane P_f cuts the planes Cs and S along two parallel lines L_1 and L_2 .

3.8 SOLID CRYSTALS. — The walls separating homeotropic domains are invisible between crossed polars. They become visible when the discotic liquid is strongly supercooled and is very near crystallization. Distortions appear in the homeotropic domains, mainly in the vicinity of the walls (Fig. 5D). Solid crystalline needles form in the homeotropic domains. These very elongated crystals adopt three main orientations separated by an angle of $+\pi/3$. These orientations probably correspond to the main crystallographic axes of the hexagonal structure of the discotic liquid. It can be verified that crystals which grow in a given homeotropic domain are parallel to the edges of the hexagonal germ from which this domain has been formed.

4. Drops with a free upper surface. — 4.1 GENERAL ORIENTATION OF MOLECULES. — Some crystals of the discotic compound can be deposited onto a glass slide which is placed in a hot stage. Once isotropic transition is reached, mesomorphic germs are obtained by a progressive cooling. These germs present brilliant polarization colours between crossed nicols, meaning that the piles of molecules are not vertical. As will be shown from the study of disclinations, the piles are mainly horizontal. However, certain germs are homeotropic and show a growth very similar to that described above, between slide and coverslip.

Germs showing polarization colours are first spheri-

cal and rapidly present a rectangular outline. The rectangular edges are parallel to the slow and fast axes of the ellipsoid of indices. The shape transforms as indicated in figure 8. Molecules are either

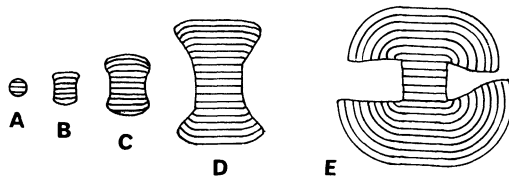


Fig. 8. — Successive shapes of a growing germ in a drop with a free upper surface. The lateral fans observed in E are at the origin of the $+\pi$ disclinations. The step D corresponds to the brief presence of an outline evoking the profiles of evolutes.

normal or parallel to the surface. In certain regions however they are oblique, namely, along the rounded angles of the germs. It seems that there are two minimizations of the surface energy, the absolute minimum corresponding to molecules parallel to the discotic-isotropic interface. Along the air interface, we again find the two preferential orientations, normal and parallel, but the situation is inverse and the molecules lying normal to the surface are favoured. As at both interfaces, normal and parallel orientations are possible, homeotropic germs and domains appear in both situations : drops between slide and coverslip and drops with a free upper surface. However, in the second case, horizontal textures (parallel piles lying parallel to the air interface) are much more frequent.

4.2 GROWING GERMS. — The rectangular germs transform rapidly and can form elongated shapes (Fig. 9). The edges parallel to the piles are favoured



Fig. 9. — Growing germs in a drop with a free upper surface. The lateral fans have formed a $+\pi$ disclination on the left side of the elongated germ. Crossed polars and first order retardation plate ($\times 120$).

and curve (Figs. 9, 10A). Fans often form along the sides of germs where molecules lie parallel to the interface with the isotropic liquid. One often observes series of parallel fans in certain elongated germs (Fig. 9). The growth of isolated fans or the fusion of opposite fans lead to the formation of $+\pi$ disclinations, which are probably dispirations [18]. The core of these disclinations is initially isotropic [19]. The molecular piles being mainly horizontal, the disclination lines are vertical. In the bulk of the discotic liquid, one finds numerous vertical disclinations, which are generally of the $+\pi$ type (Fig. 10AB). There are also some 2π disclinations (Fig. 10C). As already indicated [19], the $-\pi$ and -2π disclinations are excluded.

4.3 WALLS. — Before germs enter into contact, with each other, they are separated by thin isotropic films. Walls replace these films when the temperature decreases. The contrast in walls reaches a maximum when the two facing domains present piles lying at right angles. The walls are generally vertical, but there are numerous examples of obliquity. In some rare cases, the wall presents a hyperbolic contour, whose foci are two $+\pi$ disclinations. It also appears that certain walls follow approximately the circular arrangement of molecular piles of one of the two adjacent domains (Fig. 10). In many cases, there is no clear relationship between the structure and the wall orientation. Many walls have a continuous orientation, whereas other walls show a zig-zag shape formed by a series of segments which often join at right angles. Walls can also join at triple points (which are actually vertical lines). These junctions often play the role of $-\pi$ disclinations. Numerous radiating walls appear when the temperature is lowered. These walls clearly visible around disclinations, are found mainly in supercooled phases (Fig. 10BC).

4.4 ASSOCIATION OF DOMAINS. — One easily verifies, with the help of a rotating stage between crossed polars, that the molecular stacks form concentric arcs of circle in the non homeotropic domains. This is very clear around the $+\pi$ disclinations, but this property is general. We find the common axis of the parallel arcs for each domain. This axis corresponds to a vertical line δ and the arcs are thus horizontal. Each domain of concentric arcs is limited by two planes P cutting along δ . The orientation of the molecular stacks is constant along P and varies continuously, when crossing P, but the curvature of arcs changes abruptly. Each domain has one δ axis, but this latter belongs generally to many different domains. Walls corresponding to an orientation discontinuity form certain limits to these domains. We must also consider different interfaces such as those due to phase transitions and those due to the presence of glass or air.

The arcs present parallel or opposite concavities



A



B



C

Fig. 10. — Vertical disclinations observed in drops with a free upper surface. A : Growing germs, with singularities (s) appearing at the isotropic interface; c : a profile which corresponds to an evolute; o : a similar profile with a different orientation of molecules and which is not an evolute. Some homeotropic germs have appeared in the upper part of the micrograph. Crossed polars, with a first order retardation plate. B : Texture in a supercooled discotic phase. Some solid crystals (e) are growing and curve parallel to the concentric columns of the discotic liquid. This texture is characterized by numerous walls and $+\pi$ disclinations. The arrows indicate walls following approximately the concentric alignment of molecules; r is a rectangle formed by two opposite domains (see Fig. 11A). C : Legends as in B. This texture however presents several 2π disclinations. The core is simple or complex, with the formation of walls. Crossed polars in B and C ($\times 120$).

in neighbouring domains (Fig. 11). Such opposite domains are often associated and form rectangles in the liquid. Both types of associations (parallel

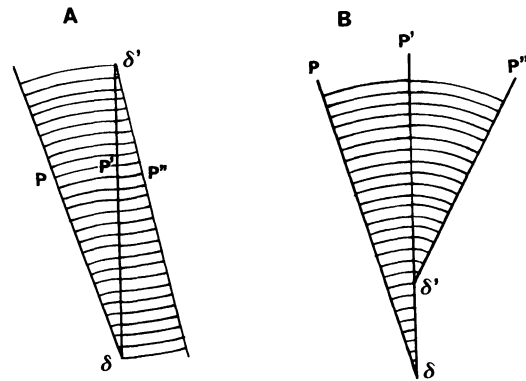


Fig. 11. — Parallel and antiparallel associations of domains. A : opposite concavities of the concentric arcs in the two adjacent domains. B : the concavities are oriented in the same sense.

or opposite concavities) are found in textures which show a global splay of the molecular stacks. Such zones correspond to a high density of transversal edge dislocations [17]. These translation defects must be concentrated in the walls which are also found in these textures. In the preparations, the rectangles resulting from the association of opposite domains and walls resemble series of organ pipes. Such arrangements are frequent in very thin drops.

4.5 RODLETS. — When non homeotropic domains or germs are reheated, they pass through a series of shapes which differ strongly from those observed during the isotropic-discotic transition. They give rise to rodlets which transform into very thin needles at the extreme end of the transition. The use of a first order retardation plate indicates that the molecular stacks lie normal to the long axis of rodlets. The slow axis of the ellipsoid of indices is parallel to the elongation axis, as in smectic rodlets. The rodlike smectic molecules are approximately parallel to the « bâtonnet » and form layers normal to it. In the discotic « bâtonnet », the molecular piles are normal to the long axis, but do not form coaxial circles. The stacks are probably parallel and horizontal. The δ lines are very rare.

In water-lipid hexagonal mesophases, different sorts of « bâtonnets » have been observed, formed by slow evaporation of isotropic solutions. These rodlets are figures of revolution about a central axis. The curved rods of the hexagonal lattice encircle the axis. The « bâtonnets » are grown in very thick preparations ($200\ \mu$) and differ from the discotic rodlets at the end of the isotropic melting. Homeotropic platelets also exist in water-lipid preparations, but their shape is not hexagonal as in discotics.

4.6 SOLID CRYSTALLIZATION. — After very long supercooling, crystals form and underline the concentric geometry of the molecular columns. The elongated crystals thus have a curved shape and must contain very high densities of dislocations. Such crystals begin to appear in figure 10C. A beautiful

micrograph of these concentric alignments is published in [13].

5. Discussion. — **5.1 MODELS.** — We have compared two main situations in which the molecular columns were either vertical or horizontal. The examination of horizontal textures facilitates the conception of models interpreting the elongated brilliant zones in homeotropic domains. One observes $+\pi$ or $+2\pi$ disclinations or groups of two $+\pi$ disclinations (Fig. 10BC). It is quite clear that such defects also exist in vertical textures and form brilliant zones. Our models of figure 6 are plausible, but must be completed with all the possible associations of δ lines. Such associations are involved in the modified textures, due to a shear (Fig. 7).

The geometry of hexagonal (non smectic) mesophases leads to the formation of caustic surfaces which can be developable [17]. The curvature energy is infinite along such surfaces, which degenerate into singular generators δ . The existence of these lines is quite obvious in the textures described above. However, it seems that certain caustics might have a very brief existence. For instance, germs observed in figures 9 and 10A present vertical δ lines at their periphery (points s). Before such singularities appear, certain parts of the germ outline recall an evolute, but a rapid increase in curvature at this point leads to the formation of a δ line. It is likely that the evolute itself (during its brief existence) is virtual and that a slightly different contour avoids an infinite curvature of the molecular stacks. In growing rodlets, the elongation axis is normal to the molecular piles and, thus, is parallel to the screw dislocations. Since the interfaces normal to molecules are favoured, lateral fans appear.

5.2 FIRST AND SECOND ORDER WALLS. — The texture is divided into a set of closed domains. One must distinguish two sorts of walls : *First order walls* correspond to an abrupt variation in the orientation of vector \mathbf{n} or vector \mathbf{a} , or both [17]. These walls, in many cases, are probably grain boundaries or dislocation walls. Their contrast shows continuous variations in space. In horizontal textures, for instance, two facing sets of concentric stacks form an angle which decreases progressively towards zero in a zone where they become tangent. *Second order walls* correspond to limiting planes P [17] linking δ lines. There are no discontinuities in the molecular orientations, but a discontinuity in the curvature radius of the molecular piles. First and second order walls allow a complete separation of domains. However, the curvature discontinuities can be very weak and, in numerous cases, the texture analysis is difficult. In smectics A, the confocal domains are limited only by second order walls, first order walls are absent.

As indicated above, radiating walls appear around δ lines, when the temperature is lowered. A simple

explanation may be that the stacks forming concentric arcs become sinuous. This means that the cooling transforms a sphere of mesophase into an elongated revolution ellipsoid whose axis is parallel to the director \mathbf{n} . There is, therefore, a *dilation tensor*, which can be represented by a flattened revolution ellipsoid around \mathbf{n} .

5.3 OTHER EXAMPLES OF DISCOTIC MESOPHASES. — The textures observed by the Chandrasekhar group [12] in benzene-hexa-*n*-alkanoates seem to be different from those observed with triphenylenes. Certain mesophases are observed in lyotropic conditions only, in benzene solution. The component $n = 6$ gives a lyotropic discotic phase with a spiralized growth of spherulites. Certain micrographs show star-shaped textures with polarization colours. There are, accordingly, very strong differences from the textures observed in triphenylenes.

There are many new discotic compounds which are not hexagonal and they have been reviewed by Billard [13]. We have not had the opportunity to look at their textures, but their comparative study would be of a very high interest.

A recent work by Dubochet and Noll [20] deals with nucleosomes aggregates. Nucleosomes are one of the most fundamental subunit in the organization of chromatin, the genetic material enclosed in the cell nucleus. Each nucleosome is made of two copies of four different types of proteins, called histones, and a DNA double helix of about 140 base pairs. All these nucleosomes have approximately the shape of a flattened revolution ellipsoid and the dense packing of this material indicates the presence of hexagonal discotic symmetries. One also finds in this study a three-dimensional reconstruction, where the nucleosome stacks form a system of right-handed helices (instead of coaxial circles as in discotics). The coaxial layers of helices present a left-handed twist, which implies, for a discotic system, a very high density of screw-dislocations. This complements the fact that double helicoidal DNA forms spontaneous cholesteric mesophases [21-23] and that the sense of this twist has been shown to be left-handed [23-25]. The sense of this twist is conserved in the discotic phase of the nucleosomes and this must be due to the external position of DNA in nucleosomes. The helical character of DNA is probably responsible for the twist interactions between neighbouring piles of nucleosomes.

Another interesting comparison can be made between discotic mesophases and concentrated solutions of double helicoidal DNA. The study of X-ray diffraction patterns shows hexagonal packing of DNA molecules [26]. The stacked base pairs are not in register between neighbouring DNA molecules. The only difference from a discotic phase is that the base pairs are linked by phosphates and riboses. A remarkable point is that a helicoidal arrangement is revealed by the X-ray diffraction patterns of the

triphenylene discotic mesophases [11]. Both senses must exist in equal proportions since the triphenylene compounds are not active. The helicoidal arrangement of DNA is well known and is right-handed. This gives a very similar aspect to the diffraction patterns of concentrated solutions of DNA and those of discotic triphenylene derivatives. It thus appears that mesomorphic media with discotic symmetries might have favoured the first syntheses of double helical nucleic acids during the prebiotic phase on earth.

Acknowledgments. — Discotic products were supplied by Dr. J.-C. Dubois from Thomson-C.S.F. Research Laboratories (Domaine de Corbeville, Orsay, France). Thanks are due to Dr. J.-C. Dubois and Professor J. Billard for their interest and discussions. I am indebted to Mr. J. Painlevé and Mr. O. Rechou who filmed the evolutions of discotic mesophases. I also wish to thank Dr. J.-P. Gourret, who pointed out to me the work of Dubochet and Noll showing discotic symmetries in concentrated nucleosome preparations.

References

- [1] TAYLOR, G. H., *Fuel* **40** (1961) 465.
 [2] BROOKS, J. D. and TAYLOR, G. H., *Carbon* **3** (1965) 185.
 [3] BROOKS, J. D. and TAYLOR, G. H., *Chemistry and Physics of Carbon*, P. L. Walker ed. (Marcel Dekker Inc. N. Y.) **4** (1968) 243.
 [4] ZIMMER, J. E. and WHITE, J. L., *Mol. Cryst. Liq. Cryst.* **38** (1977) 177.
 [5] DIDCHENKO, R., *Polymer preprints, A.C.S.* **18** (2) (1977) 81.
 [6] GOUNDER, R. J., *A.C.S. Symposium Series* **74** (1978) 108.
 [7] BILLARD, J., *Pramāna*, to appear.
 [8] CHANDRASEKHAR, S., SADASHIVA, B. K. and SURESH, K. A., *Pramāna* **9** (1977) 471.
 [9] NGUYEN, H. T., DUBOIS, J.-C., MALTHETE, J., DESTRADE, C., *C. R. Hebd. Séan. Acad. Sci.*, Paris **286C** (1978) 463.
 [10] DESTRADE, C., MONDON, M.-C., MALTHETE, J., *J. Physique Colloq.* **40** (1979) C3-17.
 [11] LEVELUT, A.-M., *J. Physique Lett.* **40** (1979) L-81.
 [12] CHANDRASEKHAR, S., SADASHIVA, B. K., SURESH, K. A., MADHUSAN, N. V., KUMAR, S., SHASHIDHAR, R., VENKATESH, O., *J. Physique Colloq.* **40** (1979) C3-120.
 [13] BILLARD, J., DUBOIS, J.-C., NGUYEN, H. T. and ZANN, A., *Nouveau J. Chim.* **2** (1978) 535.
 [14] BOULIGAND, Y. and RECHOU, O., *Discotic Liquid Crystals*, Institut de Cinématographie Scientifique, Paris (1980).
 [15] BENTLEY, W. A. and HUMPHREYS, W. J., *Snow Crystals* (MacGraw Hill) 1931 (Dover Publ., N. Y.) 1961.
 [16] GRANDJEAN, F., *Bull. Soc. Fr. Minéral.* **42** (1919) 42.
 [17] BOULIGAND, Y., *J. Physique* **41** (1980) 93-102.
 [18] HARRIS, W. F., *S. Afr. J. Sci.* **74** (1978) 332.
 [19] KLÉMAN, M., *J. Physique*, to appear.
 [20] DUBOCHET, J. and NOLL, M., *Science* **202** (1978) 280.
 [21] ROBINSON, C., *Tetrahedron* **13** (1961) 219.
 [22] LERMAN, L. S., *Symp. Quant. Biol.* **38** (1973) 59.
 [23] BOULIGAND, Y., SOYER, M.-O. and PUISEUX-DAO, S., *Chromosoma* **24** (1978) 251.
 [24] LIVOLANT, F., GIRAUD, M.-M. and BOULIGAND, Y., *Biologie Cellulaire* **31** (1978) 159.
 [25] LIVOLANT, F. and BOULIGAND, Y., *Chromosoma* **68** (1978) 21.
 [26] LUZZATI, V., *Prog. Nuclei. Acid Res.* **1** (1963) 347.