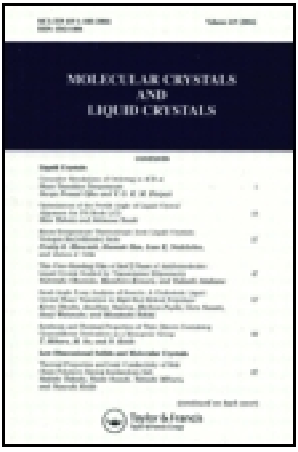

Molecular Crystals and Liquid Crystals Incorporating Nonlinear Optics
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl17

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Version of record first published: 22 Sep 2006.

Mol. Cryst. Liq. Cryst. 1990, Vol. 192, pp. 69–73
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Printed in the United States of America

ON THE ANCHORING OF NEMATICS ON SILICON SURFACES

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Abstract The study of anchoring on silicon surfaces with [001], [111] and [110] orientation shows that a nematic liquid crystal orients itself parallel to the two-fold axes of the surfaces. For [001] orientation, this leads to a bistable anchoring. For [111] orientation, the expected tristable anchoring is not observed, and only one anchoring direction is induced.

1. INTRODUCTION

The orienting action of solid surfaces on nematic liquid crystals was first pointed out by C. Mauguin[1], who had studied the behaviour of nematics on the surface of cleaved mica. Since then, the orientation –or anchoring– of nematics on the cleavage surfaces of different crystals has been studied by several authors[2-6]. Although this kind of substrate is difficult to use for applications, it is very interesting from a fundamental point of view : in contrast to most of the substrates obtained by treating glass surfaces[7], the crystalline substrates have a well-defined and known structure, which makes it easier to understand to the microscopic interactions responsible for anchoring.

We have studied the anchoring directions induced by different silicon surfaces. These surfaces were obtained by cutting monocrystalline silicon in a direction near -but not along- a cleavage plan and polishing the surface. This means that the surface is made not of one macroscopic crystalline plane, as one would obtain by cleavage, but of a succession of terraces separated by steps ; the width of those terraces is of the order of 100 Å for an angle α of the order of 1° of the cutting surface with respect to the crystalline planes of the terraces.

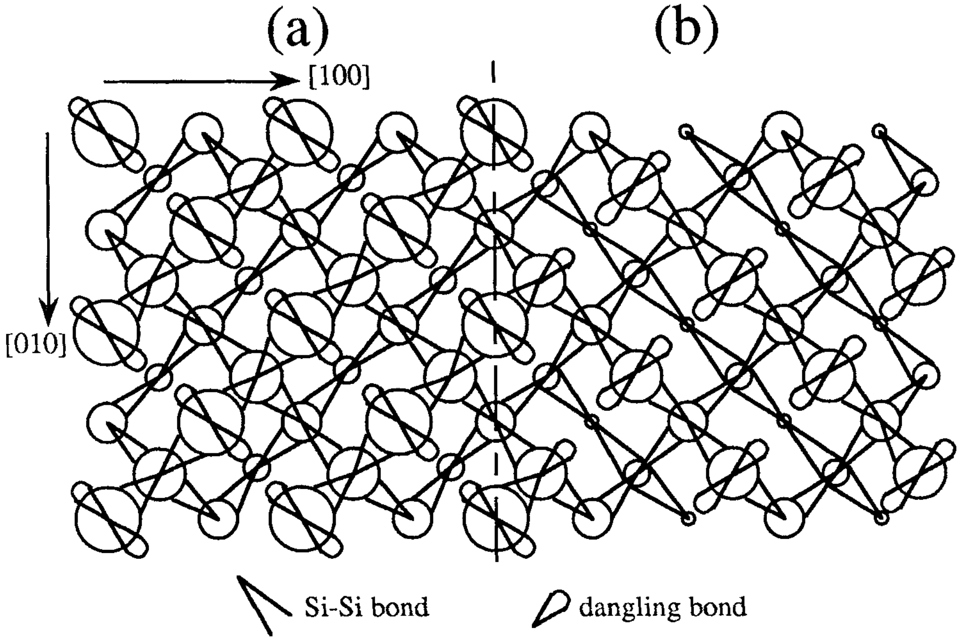

FIGURE 1 Structure of two successive terraces on a surface with [001] orientation. The different sizes of circles correspond to Si atoms belonging to different atomic planes.

2. STRUCTURE OF SILICON SURFACES

The position of silicon atoms located at the surface differs from the one they would have in the crystal bulk. The structure of this first atomic layer depends greatly on the way the surface is cleaned and the conditions under which it is stored. Our surfaces have been chemically cleaned, which leads to pure silicon surfaces whose first atomic layer lacks any coherent structure.

The surface atoms have dangling bonds ; when the surface is kept in air –as was the case with our surfaces- these atoms bond covalently with oxygen atoms to create an oxide layer. The thickness of this layer is about a tenth of a monolayer one minute after cleaning[8],approximately 10 Å after a few hours, and 30 Å after a few days[9].

The structure of the surface thus changes with time as the oxide layer grows. Figures 1 to 3 describe the structures of pure silicon surfaces oriented perpendicular to [001], [110] and [111] axes without any reconstruction of the surface. They correspond to the structures of the surfaces just after cleaning, except the first atomic layer, whose layout is undefined. These structures are altered by the formation of the oxide layer whose structure is amorphous[10].

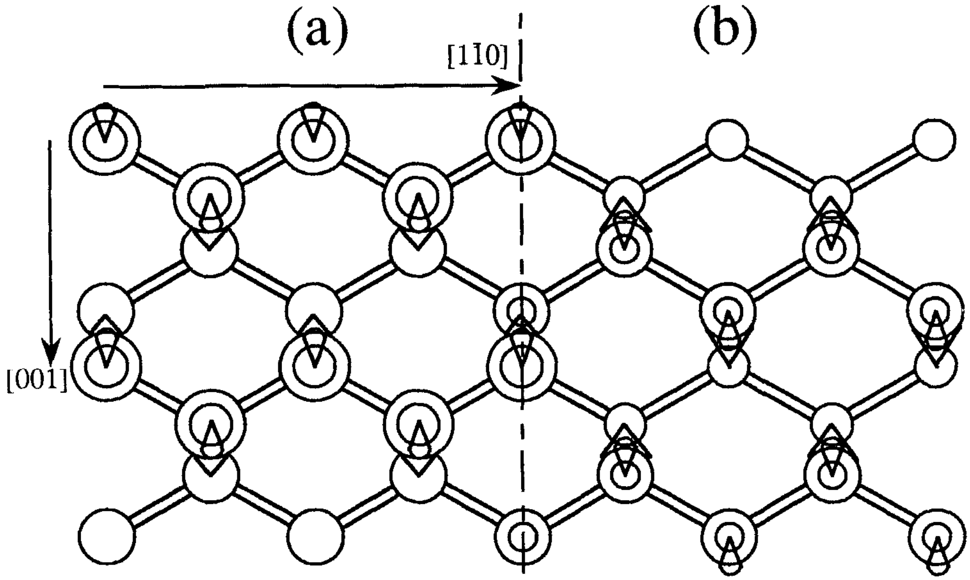

FIGURE 2 Same as Figure 1, for [110] orientation.

3. ANCHORING INDUCED BY SILICON SURFACES

By depositing nematic droplets[11], we have studied the anchoring induced by silicon surfaces perpendicular to [001], [111] or [110] axes just after cleaning. Those three kinds of surfaces induce anchoring directions in nematics which are parallel to the two-fold axes of the surface.

When the surface is perpendicular to a two-fold axis ([110] orientation), there is only one two-fold axis and we observe a monostable planar anchoring. When the surface is perpendicular to a four-fold axis ([001] orientation), there are two such two-fold axes perpendicular to each

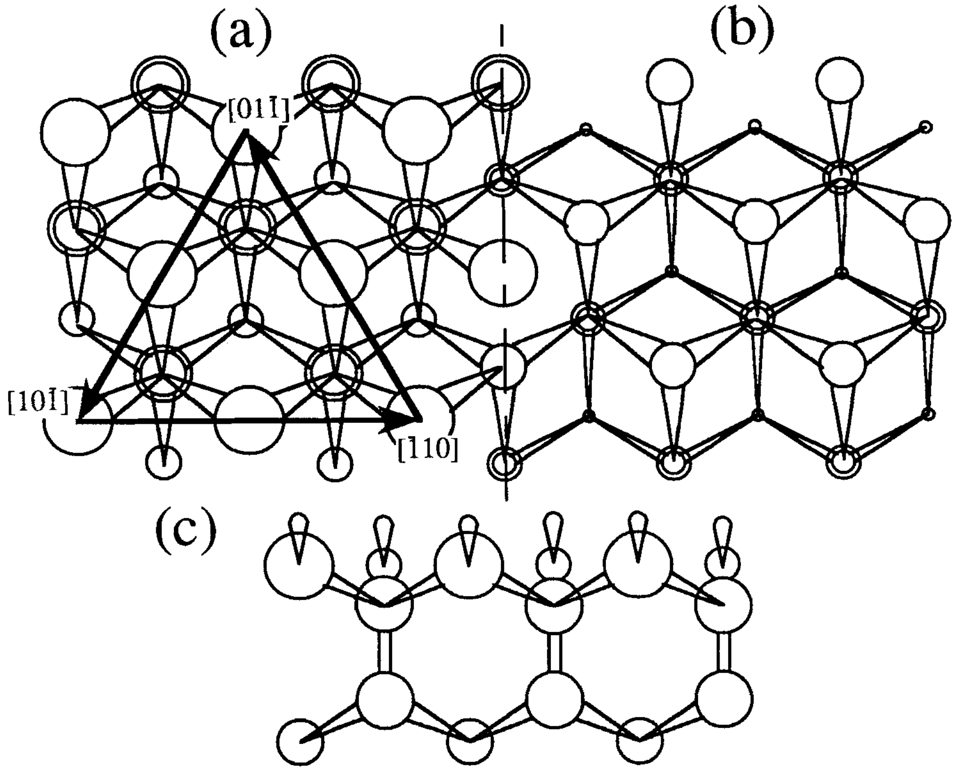

FIGURE 3 (a) and (b) : as Figure 1 for the [111] orientation ; (c) cross-section parallel to the [$\bar{1}$10] axis of the terrasse represented in (a).

other and we observe a bistable planar anchoring.

For [111] orientation, the surface has three equivalent two-fold axes, and we would expect a tristable planar anchoring. The experiment shows that only one of the three possible anchoring directions is induced by the surface. This direction is the same over the whole surface and does not change after successive cleanings which remove several atomic layers. Moreover the choice of the anchoring direction shows no correlation with the direction of the steps existing on the surface because of the misalignment with respect to the (111) plane. This symmetry breaking could be explained by a surface deformation created upon cutting the crystal. But in that case, we would also expect such a deformation to occur also on the [001] surfaces.

When we periodically deposite nematic droplets, we observe that the anchoring is altered and finally becomes degenerate planar a few days after cleaning, as we can expect from the growth of an amorphous oxide layer. This alteration of the anchoring is not observed in the droplets after they have been deposited : the anchoring conditions remain always the same as at the moment of the deposition.

4. CONCLUSIONS

We have studied the anchoring induced by silicon surfaces having three different orientations: [001], [111] and [110]. All those surfaces induce anchoring directions equivalent to the $[\bar{1}10]$ direction which is the axis around which the crystal must be rotated to change from one of these orientations to the other. It seems that nematics orient preferentially along the rows of silicon atoms parallel to the two-fold axes of the crystal, and we can expect that such an anchoring orientation will be obtained on all the surfaces parallel to a two-fold axis.

We acknowledge interesting discussions with A. Fourrier and F. Meyer (Institut d'Electronique Fondamentale, Orsay).

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