Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

Controlling Surface Alignment on Nanoscopically Tailored Competing Domains

Jong-Hyun Kim [a], Makoto Yoneya [a], Jun Yamamoto [a] & Hiroshi Yokoyama [a b]

[a] Japan Science and Technology Corporation, Yokoyama Nano-Structured Liquid Crystal Project, TRC. 5-9-9 Tokodai, Ibaraki, 305-2635, Japan

[b] Electrotechnical Laboratory, Umezono, Tsukuba, Ibaraki, 305-8568, Japan

Version of record first published: 24 Sep 2006

To cite this article: Jong-Hyun Kim, Makoto Yoneya, Jun Yamamoto & Hiroshi Yokoyama (2001): Controlling Surface Alignment on Nanoscopically Tailored Competing Domains, Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals, 367:1, 151-158

To link to this article: http://dx.doi.org/10.1080/10587250108028633

Mol. Cryst. and Liq. Cryst., 2001, Vol. 367, pp. 151-158
Reprints available directly from the publisher
Photocopying permitted by license only

Controlling Surface Alignment on Nanoscopically Tailored Competing Domains

JONG-HYUN KIM[a], MAKOTO YONEYA[a], JUN YAMAMOTO[a] and HIROSHI YOKOYAMA[ab]

[a]*Japan Science and Technology Corporation, Yokoyama Nano-Structured Liquid Crystal Project, TRC., 5-9-9 Tokodai, Ibaraki 300-2635 Japan and* [b]*Electrotechnical Laboratory, Umezono, Tsukuba, Ibaraki 305-8568, Japan*

The alignment of the liquid crystal on the alignment layer is determined by the anchoring energy and the elastic energy. In the case of uniform alignment, the anchoring energy generally overwhelms the elastic energy to make an uniform alignment over all the area. But the behavior of the liquid crystal on artificially designed multi-domains system with competing directions of easy axis can be different. The competition between two factors is expected to force the system to stabilize in the balanced configuration that could be different from which is induced microscopically by the anchoring energy.

We used an atomic force microscopy (AFM) to create micron and nanometer size multi-domains with two alignment directions. With changing the domain size, we observed a variety of different behavior of the liquid crystal texture.

Keywords: Liquid Crystal; Alignment; AFM patterning

1. INTRODUCTION

Recently AFM (Atomic Force Microscopy) was used as an alignment tool of liquid crystal on the alignment layer. During the scanning for the topological measurement of the surface, the cantilever of the AFM practically contacts with the surface. Even its interacting force to the surface is tiny, it is enough to alter the local properties of the surface layer considering the contact area. Some verified the alignment with beautiful images of liquid crystal with the control of the AFM[1,2]. Most of all, its accurate control ability makes it possible to handle micron size in various structures. Even the size of the patterning and the speed for the patterning is limited, AFM patterning has variety of possibilities in the physics and applications

It is clear that in the structure, which is consisted of the multi-directional multi-domains system, every domain is trying to balance with the other domains to reduce the total free energy of the system by altering the direction of the liquid crystal. So the overall configuration of the liquid crystal comes out from the competing results of elastic energy and anchoring energy. Generally if individual domain size is large enough, the anchoring energy overcomes the elastic energy and each domain keeps its alignment direction at the surface and in the bulk near the surface. But in the case of small individual domain size, the elastic energy is dominant to the anchoring

energy. So the alignment of liquid crystal will result in a configuration which reduces the elastic energy. Generally in the point far enough from the alignment surface, liquid crystal tends to be uniform to reduce the elastic energy.

In this paper we created several AFM patterned multi-domains system with alternative two alignment directions. We observed the change of the configuration of the liquid crystal with several domain sizes with polarizing microscopy.

2. EXPERIMENT

We used a polyimide-coated glass as a substrate. It was rubbed uniformly before AFM patterning. To make AFM patterns we used SPA-500 from Seiko Instruments Inc. We used a standard cantilever for contact mode.(SI-AF01) We forced the cantilever to the substrate surface at around 25nN and its force was kept at that strength during the patterning. Each region has check pattern as in the Figure 1. Each domain in the patterned region has horizontal or vertical scanning direction and the patterning direction was changed alternatively domain by domain.

In this experiment we tried to keep the total size of patterned area for a given domain size at around 20um×20um. And we changed a domain size from 250nm to 8um for each patterned region. So the number of domains in a patterned region is increased in proportion to the inverse square of domain size. The speed was about 100um/sec and the density of the scanning line

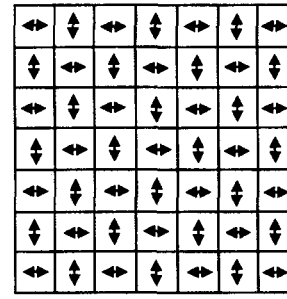

FIGURE 1. The Pattern for AFM patterning

is 100 lines/um for all the patterning.

The patterned substrate was put together with uniformly rubbed polyimide-coated substrate to be a cell. We controlled one direction of the patterning to be the same to the rubbing direction of the other substrate. The cell gap is about 15um for normal cell and about 100um for thick one. 5CB was injected into the cell. We used a polarizing microscopy to observe the texture at room temperature.

3. RESULTS AND DISCUSSION

Figure 2 shows the polarizing microscopy images with rotation of the sample in the pair of cross polarizers. We can say several aspects with this figure. The regions with large domains (8um, 4um and 2um), whose size is larger than that of wavelength of light, show obvious indication of the patterning. And as usual the image of larger domain is clearer. It appears that the alignment is uniform in the case of the smaller domain region(0.25um, 0.5um and 1um) . Probably it comes from the real uniformity of the alignment of the liquid crystal or just limited resolution of the microscopy. In the region of large domain, the black and white areas show clearly the parallel alignment and the twisted alignment respectively. Comparing (b) and (d) of Figure 2, the large domain regions keep basically the same brightness. But if we focus on the small domain regions, it seems that they are mainly consisted of two merged area. The two merged areas exchange the level of brightness with rotation. In the case of 2um domain region, all the domains reversed the level of brightness.

Next we rotated the patterning directions of the sample to be 45degree to the crossed polarizers.(Figure 3(a)). And we rotated analyzer to the same direction to the polarizer keeping the sample at the initial direction(Figure 3(b)).

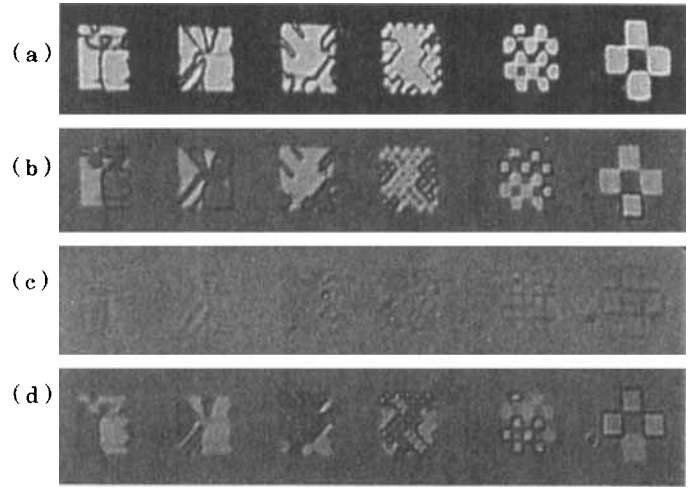

FIGURE 2 These are polarizing microscopy images with different sample direction to the crossed polarizers. The angle of the sample to the polarizer is 0, 25, 45, 65 degree from top respectively. A domain size is 8um, 4um, 2um, 1um, 0.5um, 0.25um from right side.

In the case of the large domain regions, the image is hardly changed with the rotation of analyzer. But in the case of small domain regions there are merged areas and their brightness is reversed. The relatively dark area is changed into the relatively bright area and the bright one into the dark. It means that in the large domain regions, all the domains are in parallel alignment or 90^{o} twisted alignment. So the angle of the ease axis is 45 degree to the polarizer and analyzer on the each substrate even the change of the analyzer direction. The rotation of analyzer is not effective for the change of light intensity.

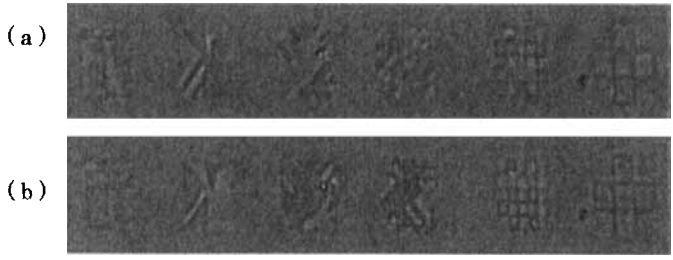

FIGURE 3. These are polarizing microscopy images. The polarizer and analyzer are crossed in (a). The ananyzer is rotated to the polarizer direction in the (b). The sample kept the same direction. A domain size is 8um, 4um, 2um, 1um, 0.5um and 0.25um from right side.

But for small domain regions, the merged area is not aligned in the same way with the large domain. Probably the director direction of the merged area rotated to the certain direction from the patterning direction as a whole.

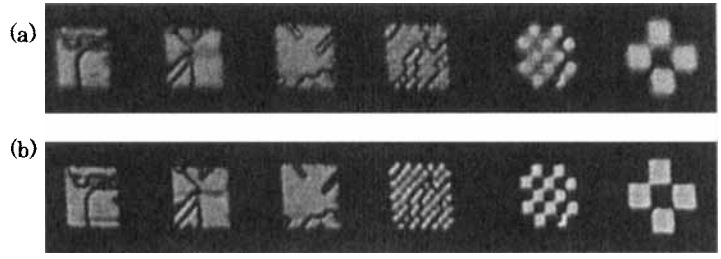

FIGURE 4. These are the images with different focusing point in the thick cell. A domain size is 8um, 4um, 2um, 1um, 0.5um and 0.25um from right side.

So we can see the exchange of the intensity with the rotation of the analyzer. We suppose that the possible directions of the uniform area are two and it is from the symmetry of the patterning structure.

In the thick cell we changed the focusing point of the microscopy(Figure 4). Figure 4(a) is an image from focusing on the rubbed substrate, and Figure 4(b) is on the AFM patterned substrate. They show a little variation in texture. In Figure 4(b), the domain structure of the pattern is clear down to 2um size. Even for 1um size domain we can get sense of the structure. When we changed the focusing to the other substrate, the domain structure became less clear. In the case of 2um domain region, part of area shows uniform color, even the boundary of possible homogeneous areas and some domains keep the same thickness and shape. This indicates that the alignment is getting uniform as the liquid crystal moves out into the bulk from the AFM patterned surface.

4. CONCLUSIONS

We did AFM patterning in check pattern with various domain sizes on the polyimide-coated substrate. We observed the texture of liquid crystal with polarizing microscopy after constructing a cell with uniformly rubbed polyimide-coated substrate.

The characteristic is changed with different domain size. The patterned regions with small domain appear to have merged alignment at least in the bulk. And the possible alignment directions are two. The regions with large domain appear to keep its alignment direction made by AFM patterning at least in the main area. In general, as the distance into bulk from the patterned surface is increased, the alignment of the liquid crystal seems to be getting uniform.

Acknowledgements

The authors wish to acknowledge his grateful thanks to Dr. Charles Rosenblatt for inspiring curiosity in this field.

References

[1] A.J. Pidduck, S.D. Haslam, G.P. Bryan-Brown, R. Bannister, and I.D. Kitely, Appl. Phys. Lett., **71**, 2907 (1997).
[2] W. Bing, M.P. Mahajan, and C. Rosenblatt, Appl. Phys. Lett., **76**, 1240 (2000).