Liquid Crystal Alignment on Competing Domains

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ABSTRACT

Fine structures for liquid crystal alignment were formed on the alignment layer by an atomic force microscopy. A structure is check pattern, which is consisted of multi-domains with two writing directions. As the distance from the surface increases, the direction of director in the bulk seems to be merged into a direction. The merging distance is supposed to be proportional to the domain size. The same phenomenon occurs with the circular pattern. Merging of the aligning direction in the bulk is due to the tendency to reduce the elastic energy.

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

In a structure, which is consisted of the multi-directional multi-domains, the liquid crystal alignment of each domain is adjusted to reduce the total free energy of the system. So the overall configuration of the liquid crystal is the result of competition between elastic energy and anchoring energy. In general if individual domain size is larger than extrapolation length, the anchoring energy overcomes the elastic energy. Most of area in each domain keeps its alignment direction at the surface and in the bulk near the surface. But in the reverse case, the elastic energy is dominant to the anchoring energy. So the alignment of liquid crystal will result in a configuration, which satisfies reduced elastic energy. So there is overall change of alignment on the surface too. As the elastic energy is the only factor which affects to the alignment in the bulk away enough from the surface, liquid crystal tends to be uniform to reduce the elastic energy.

In this paper we created several AFM written multi-domains with alternative two writing directions. The change of liquid crystal texture was observed in different domain sizes with optical polarizing microscopy. We made a circular pattern and also observed the texture of liquid crystal with the microscopy.

Substrate was polyimide-coated glasses. It was rubbed uniformly before AFM writing. To make AFM writing, we used SPA-500 from Seiko Instruments Inc. We used a standard cantilever for contact mode(SI-AF01). The force between the cantilever and the substrate was at around 25nN.

![Figure 1. Optical polarizing microscopy images of different inner domain sizes with the rotation of cell.](image-url)
The pattern is check with several sizes of inner domains as in Figure 1. The writing direction was changed alternatively domain by domain. The total size of written region for a given domain size is around 20um × 20um. The speed was about 100um/sec and the density of the writing line is 100lines/um for all the writing. The AFM written substrate was assembled with a uniformly rubbed polyimide-coated substrate to be a cell. We controlled one direction of the writing to be the same to the rubbing direction of the other substrate. The cell gap is about 15um. 5CB was injected into the cell. Figure 1 is polarizing microscopy images with rotation of the cell in a pair of crossed polarizers. The regions with large domains (8um, 4um and 2um), whose size is larger than that of wavelength of light, show obvious indication of the writing. As usual the image of larger domain is clearer. The alignment seems to be uniform in the case of the smaller domain regions(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 dark and bright areas show the parallel state and the twisted state respectively. If we compare (b) and (d) of Figure 1, the large domain regions keeps basically the same brightness. But it seems that small domain regions are mainly consisted of two merged regions. Two merged regions exchange the level of brightness with rotation. Both regions supposed to have rotated alignment as a whole to the writing. In the case of 2um domain region, all the domains reversed the level of brightness.

Figure 2 shows circular pattern, in which the writing direction is along tangent. The outer radius is 20um and inner radius is 10um. Liquid crystal(5CB) was sprayed over the substrate to cover the written region as thin layer. We got the dark state on rubbed region with adjusting the rubbing and polarizer into the same direction as Figure 2(a). The writing direction of two parts in the written region is the same to the rubbing. Other two parts have the perpendicular writing direction to the rubbing. Above four regions assumed to be dark. But actually the regions with perpendicular writing direction to the rubbing is not dark, but bright(Figure 2(a)). The dark and bright regions follow the sample rotation as Figure 2(b)(c). The dark regions supposed to be in the parallel state and the bright regions supposed to be in the twisted state. So the liquid crystal on the top layer is supposed to be aligned more or less uniformly, even the bottom substrate has various alignment directions.

We did AFM writing in check pattern with various domain sizes and in circular pattern on the polyimide-coated substrate. We observed the texture of liquid crystal with polarizing microscopy. In check pattern the character of liquid crystal is dependent on domain size. The written regions with small domain size appear to have merged alignment. And the possible alignment directions are two. The regions with large domain appear to keep its alignment direction, which is stipulated by AFM writing. The circular pattern also indicates that the alignment in the bulk is merged into a direction. In general, as the distance into bulk from the patterned surface is increased, the alignment of the liquid crystal seems to be getting uniform.

References