Carbon – Containing Covering for Anchoring Breaking Nematic Microdevices

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Abstract: We demonstrate experimentally, that in residual atmosphere of scanning electron microscope the nano-scale carbon-containing (hydrocarbon) films by snuff effect can be produced. The micropattern of carbon film including axial-symmetric ones is defined by the e-beam raster. The areas of alignment of liquid crystal molecules precisely repeat the micropattern of carbon containing films with micron resolution. Liquid crystal 5CB on CH film demonstrates a breaking anchoring under simultaneous action of the ac voltage and liquid crystal material flow. AFM analysis of CH films obtained by electron beam enables to conclude that there exists the direction which defines the azimutal alignment of liquid crystal molecules on CH surface.

Key Words: Hydrocarbon covering, nematic, bistability.

1 Introduction

The majority of existing now liquid crystal devices and displays exploit a strong anchoring of director with surface. In such devices the orientation of liquid crystal molecules in surface layer equal to the field correlation length remains unchanged under control electric field. The main disadvantage of using monostable pixels with strong anchoring is a requirement of active matrix for multiplexability.

The orientational bistability in liquid crystal has attracted increasing interest because it allows to develop large passive displays with high resolution on base of passive control matrix. At now there are several types of bistable liquid crystal displays: bistable cholesteric display, ferroelectric display and bistable twisted nematic displays. Among a last type of displays there are two variations of trully bisteble ones: π-BTN [1] and the zenithal BTN devices [2]. The last devices use a microstructured substrate like a grating with short pitch and deep profile treated for homeotropic alignment.

All bistable nematic devices are based on asymmetric anchoring of liquid crystal molecules with substrates. Traditionally one substrate in cell has strong anchoring that provided by rubbed polyimide layer and other one has weak anchoring. On the substrate with weak anchoring under electric field takes place a breaking anchoring. As a result the transition between two stable textures with 0^0 and 180^0 twist takes place [1]. In first prototypes of devices [3] with breaking of anchoring the weak anchoring was achieved by using SiO evaporation [4] whereas in the next generation of devices the special polymer layers [5] are used. In the Ref.[6,7] it is reported that weak anchoring was obtained by means of photoalignment method using SDA-1 polymer. In 3 terminal bistable devices [8] the weak anchoring was obtained by traditional rubbing of ITO surface.

In present work we experimentally show that hydrocarbon films obtained by means of snuff effect [9] can be used for breaking anchoring bistable behavior of nematic liquid crystal. In contrary to BiNem device where strong flow is inside feature of the electrooptic effect used our electrooptic switching is based on the flow induced by the external action. The snuff method shows certain advantages especially for microdevices in comparison with SiO evaporation and polymer layer, namely, the pattern of requested CH films is defined by e-beam raster and can be obtained with micron resolution in any prescribed fashion.

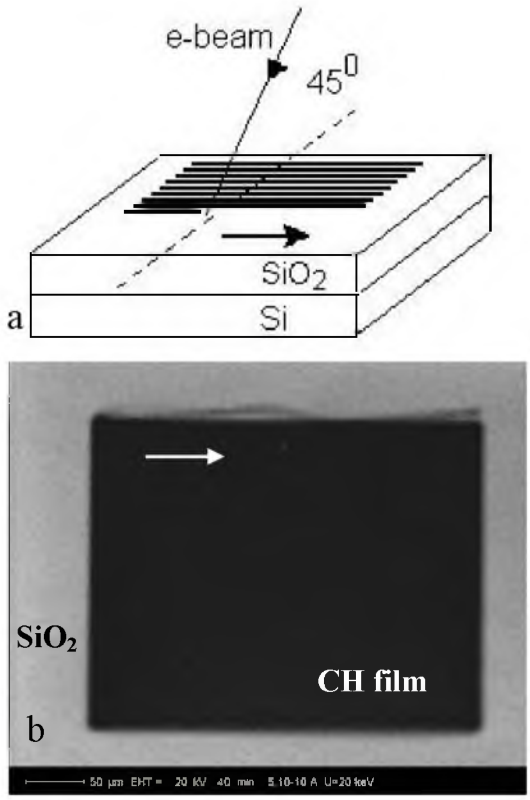

Figure1 a- Fabrication of CH film. The raster of e-beam on SiO_2 surface by oblique incidence. b- The REM image of CH film on SiO_2. The arrows in (a) and (b) point to the direction of e-beam movement.

2 Experiment and Discussion

As substrate on which CH films were produced by means of scanning microscope electron beam, we used the thermally grown amorphous silicon oxide surface (SiO_2) about 0,4 µ

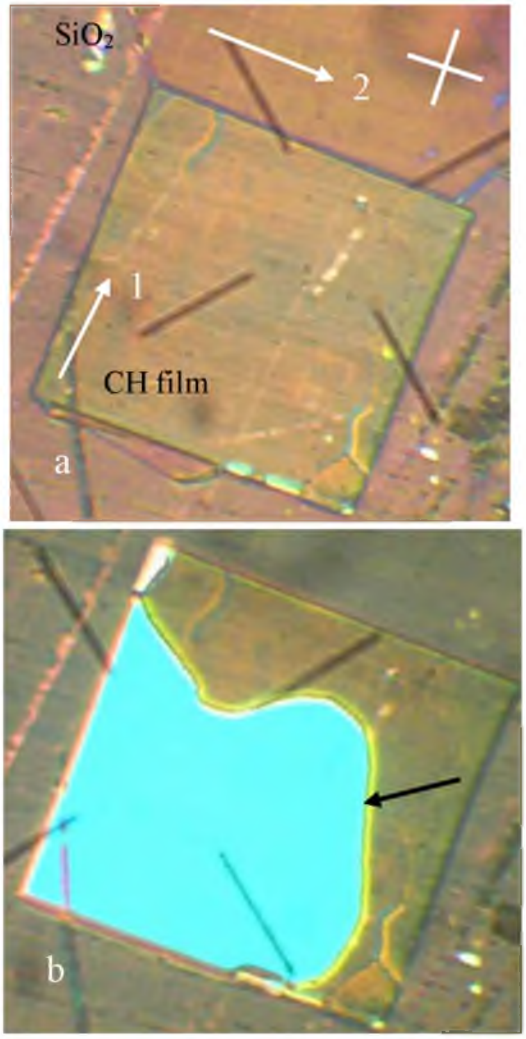

Figure 2 The polarizing micrographs of LC cell with CH film. a)- U texture. The 1 and 2 arrows correspond to the direction of e-beam movement and rubbing one respectively. b)- T texture over CH film. The arrow points to the wall between U and T textures.

thickness on monocrystalline n-type conductivity silicon (Si) with specific resistance equal to 4,5 Om×cm, Fig.1a. Before CH film producing the SiO_2 surface was etched by HF acid and then was rinsed by a distilled water.

The rectangle CH film was fabricated under oblique incidence of e-beam equal to 45^0. The e-beam current and the energy of electrons were 10^{-9} A and 20 keV respectively. Time of exposure was 40 minutes.

Figure 1b demonstrates the REM image of CH film obtained by above mentioned method. Well seen that CH film is black in comparison with the rest SiO_2 surface. The dark background of CH film is due to weak secondary electron reflection from its surface in comparison with clean SiO_2 surface.

Despite of the electron raster used for CH film preparation presents 800 single lines, Fig.1a, with the distance of 0,32 μ between neighboring ones and the diameter of electron beam spot on SiO_2 surface is approximately 0,02 μ, evidently seen in Fig. 1b that any relief on fresh made CH film surface is absent and this surface looks like amorphous.

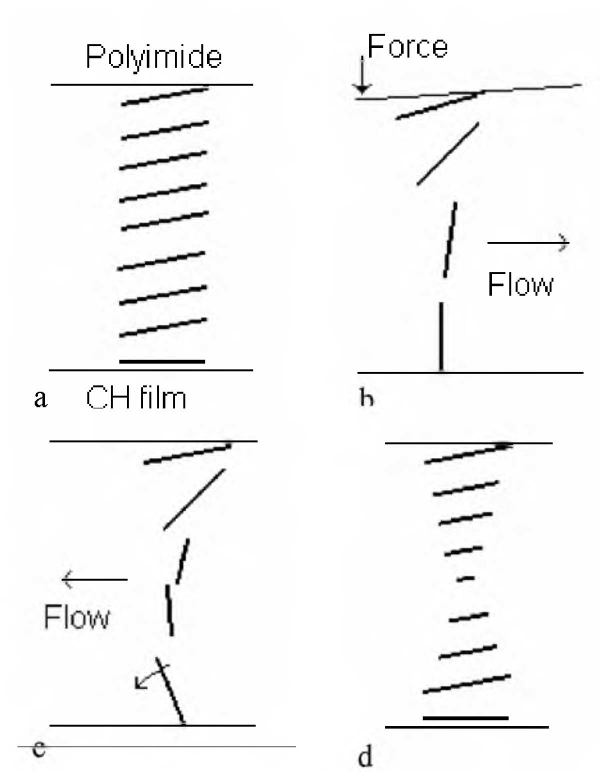

Figure 3 a) Uniform (U) texture. b) Liquid crystal flow at homeotropic state under simultaneous action of the electric field and the force. c) Back flow. d) Twisted(T) texture.

The SiO_2 substrate with CH film without any treatment was used for liquid crystal cell preparation as bottom substrate. The top glass with ITO electrode (referent surface) was coated with rubbed polyimide layer to provide strong anchoring. The uniform rubbing direction on the referent surface was set perpendicular to the direction of e-beam movement (the 1 and 2 arrows in Fig 2a).

Liquid crystal 5CB is filled into the cell in an isotropic phase. Cell thickness was 5 μ and held by teflon spacers. Because of the cell is not transparent the liquid crystal orientation was tested with a polarizing microscope in a reflection mode.

Figure 2a shows the polarizing optical micrographs of LC cell with CH film on SiO_2 surface described above. As seen over CH film and the SiO_2 surface a nematic is aligned uniformly that is due to strong influence of referent surface on balk.

Over CH film a nematic demonstrates a traditional monostable behavior, i.e. there is a Freederics transition under electric field and after switching off an electric field the orientation of nematic backs to initial state.

A bistable behavior in such hybrid cell is observed after simultaneous action of the ac voltage and the liquid crystal material flow. At first stage the liquid crystal must be aligned homeotropically under electric field (~ 10 V, 10^3 Hz) and uniformly moves in plane of cell due to small mechanical deformation of the cell under the external force, Fig.3b. At second stage, when the electric field and the force are simultaneously switched off, the back flow of liquid crystal takes place, Fig.3c. In this moment the change of liquid crystal orientation over CH film occurs. Figure 2b demonstrates the new texture over CH film which is formed after back flow of liquid crystal. This new texture is long term stable.

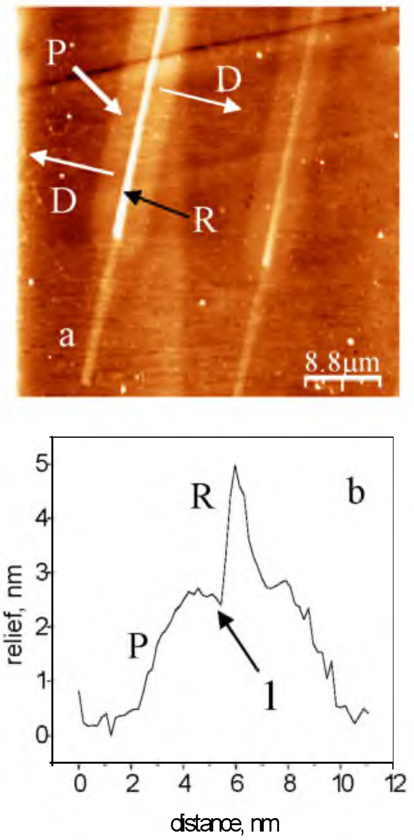

Figure 4. a - 2D AFM image of two single CH films. D-the direction of carbon particles evaporation. b – the relief of single CH film.
P-"pedestal". R- "ridge". The arrow 1 points to the recess.

The polarized analysis of boundary between U and T textures allows to conclude that director in T texture is twisted on the angle 180 ^{0}, i.e. U and T textures are topologically different. Therefore we believe that there takes place breaking anchoring on CH film at homeotropic state (Fig.3b) under electric field.

It should be noted that there exists direct interconnection between the direction of rubbing and the direction of liquid crystal flow when the T texture appears. If the position of the force (Fig.3b) is changed with respect to the direction of rubbing (or evaporation) the direction of flow also changes. In this case the new stable texture does not appear.

In order to return the twisted T texture into initial state (uniform U one) it is required to apple the electric field. In this case the wall (Fig.2b) which separates U and T areas, propagates. As result, T texture is replaced by opposite U texture. The speed of wall propagation is proportional to the ac voltage value applied to the cell.

It is well know that in breaking anchoring device a weak axis of azimutal alignment on substrate with low anchoring must be existed. In first prototypes of such devices the azimutal axis was defined by the conditions of oblique evaporation of SiO [4]. For polymer covering with low anchoring such axis is defined by traditional rubbing method[10].

Let us to consider the possible reason of existence of weak azimutal axis on CH film obtained by e-beam. Figure 4 demonstrates the 2D AFM image of two linear CH films and the relief of single CH film obtained by e-beam without any

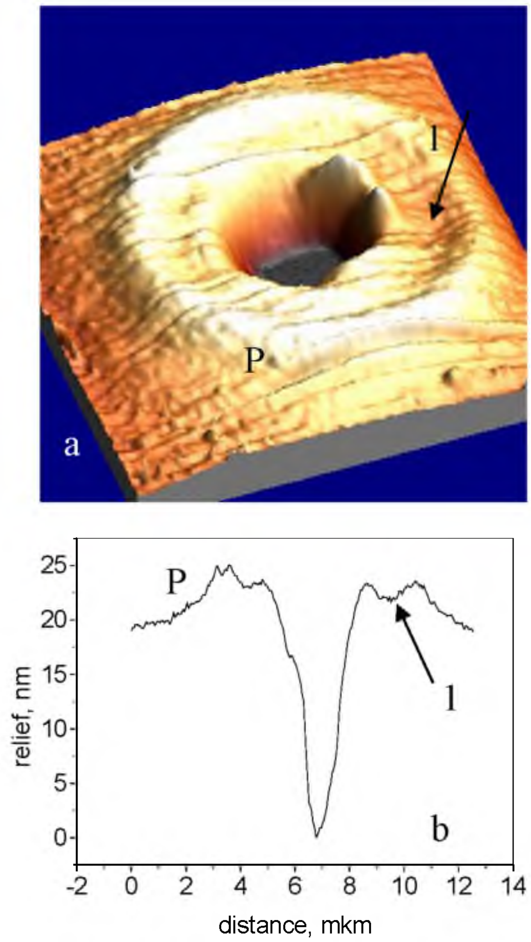

Figure 5 a, b- AFM image and relief of axial CH film obtained by no moving e-beam respectively. P-the pedestal. The arrow 1 points to the recess.

raster, i.e. the movement of e-beam was along single lines. The angle of e-beam incidence was 90^0. Well seen that each CH film contains the "pedestal" of ~ 8 μ width and the "ridge" of ~ 1,5 μ width respectively, Fig 4. The existence of the recess (the arrow 1, Fig. 4b) at the ridge foundation means that pedestal and ridge are formed thanks to the different processes. We believe that the ridge is formed due to the snuff of hydrocarbon molecules to the hot SiO_2 surface heated up by e-beam whereas the pedestal is formed due to evaporation of carbon particles which are threw away under e-beam from "ridge" area perpendicularly to trajectory of e-beam movement, i.e. must be the certain direction (D) of evaporation, Fig.4 a. In the case of no moving e-beam, i.e. without raster, the snuff effect can be excluded and the evaporation process remains only. Figure 5a,b demonstrates the AFM image and the profile of relief of the CH film obtained by no moving e-beam. The time of exposure was 3 min. The angle of e-beam incidence was 90^0. As well seen the CH-film has axial-symmetric view like a crater of ~ 8-10 μ width and hole inside of ~ 1μ width. This axial CH film contains the pedestal (P) and the recess (arrow 1) as in case of linear CH films. However the ridge (or tip) does not form. Axial-symmetric CH-film is formed only by means of evaporation of microparticles and other products of hydrocarbon oil decomposition which are threw away from crater area along axial – radial trajectories under e-beam. We believe that these carbon microparticles and other products of oil decomposition are also evaporated in axial-symmetric manner on SiO_2 surface.

Figure 6 demonstrates the microphotography of liquid crystal (5CB) layer deposited on the SiO_2 surface with single

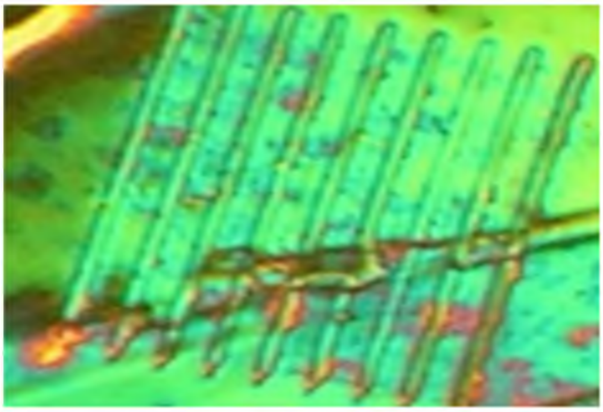

Figure 6 The polarizing micrograph of 5CB layer on SiO_2 surface with several CH films obtained by linear movement of e-beam (without raster).

CH films obtained by linear e-beam movement as described above. Well seen, that the alignment of 5CB over the pedestal and the ridge areas are different. Taking into account that in single CH film the total surface of "pedestal" is more than the total surface of "ridge" the alignment property of CH film obtained by raster movement of e-beam will be defined by the property of a "pedestal" surface. Therefore we believe that the azimutal alignment of liquid crystal on CH surface strong correlates with the direction D defined by evaporation of carbon paticles (Fig.4a).

3 Summary

In residual atmosphere of scanning electron microscope the nano-scale carbon-containing (hydrocarbon) films by snuff effect can be produced. The micropattern of carbon film including axial-symmetric ones is defined by the e-beam raster. The areas of alignment of liquid crystal molecules precisely repeat the micropattern of carbon containing films with micron resolution. Liquid crystal on CH film demonstrates a breaking anchoring under simultaneous action of the ac voltage and liquid crystal material flow induced by the external action, namely, the mechanical deformation of the cell. This enables to divide the switching process in two ways and independently to control (to optimize) them. AFM analysis of CH films obtained by electron beam and polarizing one enable to conclude that there exists the direction which defines the azimutal alignment of liquid crystal molecules on CH surface. This direction is due to specific evaporation of carbon particles appearing in the vicinity of e-beam spot on SiO_2 surface.

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