Surface Characteristics Modification by Plasma Flow

A. M. Dobrovol`s`kii, A. N. Evsyukov, A. A. Goncharov, R. N. Kravchuk, I. M. Protsenko, O. V. Yaroshchuk

Institute of Physics of NASU, pr. Nauki 46, Kyiv, Ukraine, 03028

***Abstract*- In the modern technologies the various plasma treatment methods are widely used. The essential advantage of these methods are possibility to work with the dielectric and semi-conductor targets. One of possible utilization area of these technologies can be the creation of anisotropy of surface properties of materials. The using of anode layer accelerator allow easy to scale this technology on very large size substrates. We describe here the some results of experimental investigation of changes of surface characteristics of different materials after a low dose treatment by accelerated plasma. It is shown that little variations of irradiation dose can leads to essential change of surface anisotropy. In part, this can be visualized by the different type of liquid crystals alignment on substrates with different irradiation dose. The treatment in several steps allow to obtain a different alignment of liquid crystal in the one cell.**

I. INTRODUCTION

Modern plasma technologies allow obtaining the modification of surface and volume properties of materials in a very wide range [1]. Use of accelerator with anode layer as a plasma flow source solves the problem of low conductivity of the target material. Efficient treatment by the plasma flow is possible even for dielectric materials [2]. Large irradiation dose causes essential changes of chemical and physical properties of processed material. We consider the treatment dose as a number of ions targeted the surface for the time of treatment with predetermined energy of the flow. At the same time, the tasks exist which require small change only of one feature of the target surface. Particularly, for obtaining predetermined alignment of liquid crystals it is sufficient to reach just an anisotropy of surface features of the alignment layer [3, 4]. Usually such layer is represented by thin inorganic or organic film. In this work the results of experimental studies of modifications of the surface features of different layers after treatment by a small dose of ion- plasma flow, including alignment layers used for creation of liquid crystal panels, are presented.

II. EXPERIMENTAL SETUP

For treatment of samples we use a setup with possibility of static and dynamic processing. The schematic image of the setup and a process shown on Fig. 1. In the experiments we supplied the gas straight into a vacuum chamber. The substrates holder (5) allowed to change a position of the samples from one being normal to that being parallel with respect to direction of plasma flow. Thus it was possible to obtain the substrates treated with different values of α angle with respect to normal to their surface. Besides we had possibility to move the substrates for treatment in scanning regime. It enabled obtaining the samples with

1-4244-0192-5/06/$20.00 ©2006 IEEE.

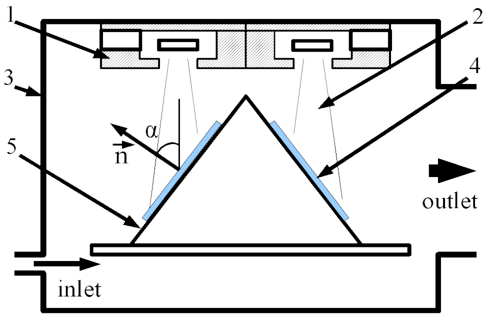
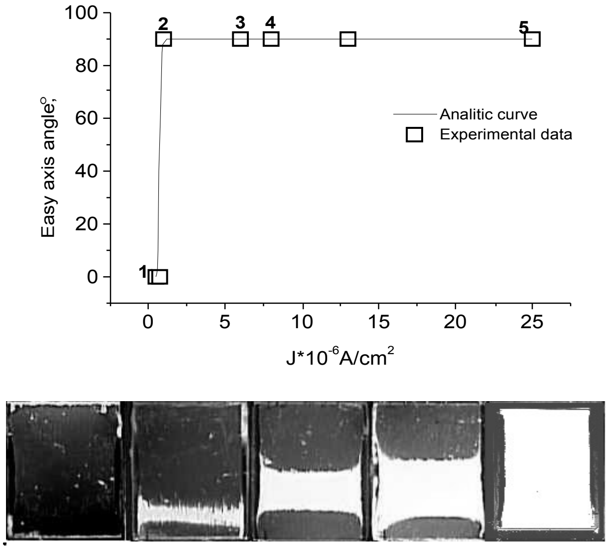


Fig. 1. The schematic image of the setup and process.
1 – plasma source; 2 – plasma flow; 3 – vacuum chamber; 4 – samples; 5 – substrates holder.



1 2 3 4 5

Fig. 2. Photos of a set of asymmetric cells viewed between two crossed polarizers and dependencies of LC easy axis angle from current density. One plate of the cells contains a rubbed PI layer and another plate contains a PVCN layer treated with plasma beam in geometry Fig. 1. The plasma irradiation parameters are $\alpha=60^0$, E=600 eV, t=10 min.

uniform treatment over the entire surface. Working gas supply straight into the chamber allows avoiding the problems dealing with uniformity of the gas supply into anode layer region under conditions of a small volume of the source. Besides, it enables easy variation of the component content of working mixture, and work at pressure level in the chamber up to 10^{-1} Pa [2]. The experiments were performed both with pure gases – Ar, H_2, N_2 and with two-component mixtures Ar+H_2, Ar+O_2, Ar+N_2.

In case when anisotropy of the features of surface layer is absent, liquid crystal usually does not possess preferred alignment. At the surface having uniform anisotropy, LC commonly forms a region with uniform mono-domain alignment [3, 4]. Thus, creation of regions with different degree and nature of anisotropy should result in appearance of regions with different LC alignment. As a consequence, change of LC alignment would serve as a test of change of the treated surface features. We also used masks during treatment of the samples. It enabled creation of the samples with different liquid crystal alignment in one cell as well as the sample with treated and non-treated surface. In such way it was possible to exhibit changes of the anisotropy nature with variations of the treatment conditions.

III. Results

Samples obtained in result of static processing are shown in Fig. 2. In all samples one side has a layer rubbed in direction of its longer dimension, another one represents a layer treated by ion-plasma flow. Direction of ion incidence corresponds to longer dimension of the sample. The photograph is taken for the samples placed between crossed polarizers. One can see that already at small treatment dose (the cell 1) the crystal is uniformly oriented at the surface along the direction of ion incidence onto the substrate. The ion current density J is 1, 2, 5, 7, and 25 μA/cm^2 for the cells 1, 2, 3, 4, and 5, respectively. The cells are 15 μm thick and filled with 5CB. Alignment occurs with small pretilt and is named as the first mode [4]. The figure shows the regions with the 1st mode and the other alignment mode (dark and bright areas, respectively) in the cells 2, 3, and 4, and the second alignment mode in the cell 5. Transition from dark to bright texture is caused by 90^0 reorientation of LC at the plasma treated substrate. One can see that this region fills all substrate with the dose growth. This mode became named as the second mode. The

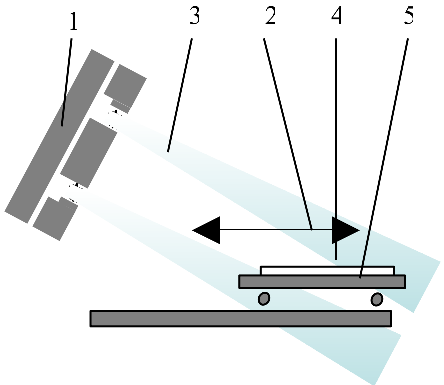
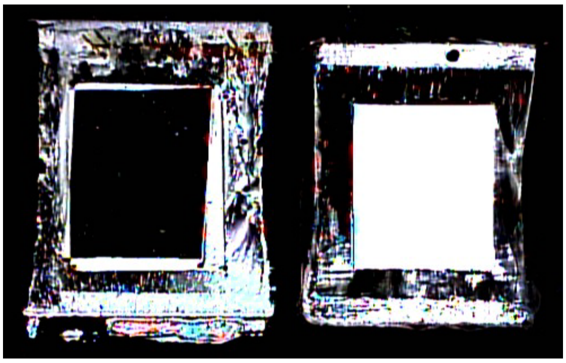


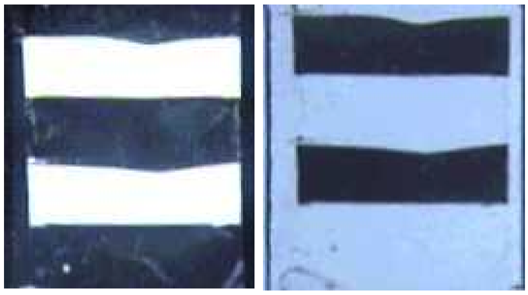
Fig. 3. The schema of the dynamic treatment process.
1 – plasma source; 2 – movement direction; 3 – plasma flow; 4 – samples; 5 – substrates holder.

experiments have shown that this effect depends on the treatment dose and is independent on the energy of incident ions. Obtaining surface layer anisotropy is possible with the use of different gases and their mixtures. Treatment of the layer in scanning regime (Fig. 3) with parameters required for the first or the second mode gives uniform LC alignment in respective mode across the entire cell (Fig. 4). Possibility of changing the alignment mode of the crystal enables easy obtaining the cells with two-domain alignment (Fig. 5). Test substrates were treated with the use of rectangular masks having open area in central part of the mask. Conditions of the treatment were chosen in accordance with selected mode. One can see that both in the first and in the second case the cell quality is high enough.



a b

Fig. 4. Photographs of two combined cells filled with LC. Cells have rubbed PI substrate as a reference substrate and plasma treated glass slide as an object substrate. The object substrates are treated with rectangular open area mask in the middle of the substrates. The cells are placed between pare of crossed polarizers.
a – mode 1; b – mode 2.



a b

Fig. 5. Photographs of a LC cell viewed between a pair of crossed (a) and parallel polarizers (b). The cell is asymmetric with one rubbed PI substrate and one plasma treated PI substrate. For obtaining the pattern, the whole area of latter substrate is first irradiated with plasma beam (E=600V, j=7 $\mu A/cm^2$, $\alpha=60^0$) for t= 2.5 min; then the portions of the substrate are covered with the mask and the remaining regions are exposed to the same plasma beam for additional t = 10 min. The dark and bright areas of the texture correspond to two different LC orientations at the plasma treated substrate: parallel and perpendicular to the alignment direction on the PI substrate, respectively.

Fig. 6. Photograph of twist nematic cell (d= 15 mkm) based on plasma treated PI substrates viewed between crossed polarizers. The cell is filled with LC. Twist angle is 90 degree. Irradiation conditions: irradiation angle is 70 degree, j=8 mkA/cm^2, E=600 V).

Absence of principal obstacles for the process scaling is demonstrated in Fig. 6 which shows the cell having 10x10 cm dimensions composed of two substrates treated in scanning regime. One can see that resulted cell possesses high enough quality.

Plasma treatment allows smooth enough variation of the surface anisotropy, as well as variation of LC pretilt angle in wide enough range. As an example, in Fig. 7

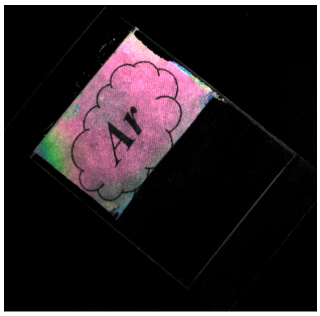


Fig. 7. Photographs of two domain LC cell between crossed polarizers. The picture with symbol is bottom of the system from LC cell and crossed polarizers. (J=1.5 mkA/cm^2, E=650 V, t=1 m, $\alpha=70^{\circ}$).

another two-domain cell is shown. Initially, the substrate aligns LC in strictly vertical manner (homeotropic alignment). Treatment by the plasma flow allows obtaining in processed area even more than 40 degrees LC pretilt with respect to normal to the surface. Both substrates are treated with the use of rectangular mask and put together with treated surfaces facing each other. Variation of color fill of patterned field is due to the cell thickness non-uniformity. Use of hydrogen as working gas mixture improves temporal stability of LC pretilt angle [5].

IV. CONCLUSIONS

Thus, one can see that the treatment even with small doses of the plasma flow enables modification of surface layer features in rather wide range. Taking into account small energy of particles and small density of the flow, it can be stated that the main mechanism of the action consists in physical sputtering of the target surface. Obtaining ideally flat surface requires the use of special expensive enough technologies. Usual flat fine-grained surface has a lot of chaotically placed unevenness of micrometer and sub-micrometer scale. It is clearly seen at the results of AFM measurements of non-radiated surface. A photograph of the sample surfaces treated in scanning regime shows formation of quasi-periodical structures with exhibited spatial anisotropy in the relief [4] having nanometer scale – from a couple of nanometers at minimum treatment up to ten and more nanometers with the dose growth. It is likely that LC responds exactly those modifications. Similar modifications in relief of dielectrics after ion-plasma treatment were observed in [1]. Use of different gases and their mixtures is possible. Use of hydrogen as working mixture reduces pretilt angle aging of liquid crystal alignment.

REFERENCES

[1] V.M. Astashynski et al., “Materials surface modification using quasi-stationary plasma accelerators,” *Surface and Coatings Technology,* 180-181 (2004), pp.392-395.

[2] A. Goncharov et al., "Plasma Devices for Ion Beam and Plasma Deposition Applications," *Problems of Atomic Science and Technology,* 2005, No 1, Series: Plasma Physics (10), pp. 169-171.

[3] P. Chaundhari et al., "Atomic-beam alignmentof inorganic materials for LC displays", Nature, 411, 56-59 (2001)

[4] O. Yaroshchuk, R. Kravchuk, A. Dobrovolskyy, P.C. Liu, C.D. Lee, O.D. Lavrentovich, “The Multimode LC Alignment on the Substrates Obliquely Treated with a Plasma Flux,” *Mol. Cryst. Liq.Cryst.,* 433, (2005), pp. 1-12 .

[5] Yaroshchuk O.V. et al., Vacuum “brusher” for the alignment treatment of the large area LCD substrates // IMID’05 Digest – 2005.-P. 768-773.

E-mail of authors: gonchar@iop.kiev.ua, dobr@iop.kiev.ua.