The aligning properties of the sapphire with LIPSS in the twisted nematic cell

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Introduction

The one of the main factors to obtain homogeneous alignment of liquid crystals (LCs) is the creation of anisotropic properties of layers (*e.g.* creation of periodically nano-grooves [1], cross-linking of polymer owing to light [2] on the surface).

There are many different techniques for the treatment of surfaces to achieve uniform orientation of LCs, namely rubbing process [1], photoaligning [2], Lanmuir-Blodgett layers [3], and many other processes. However, the most used techniques are shown in **Figure 1**.

Rubbing technique **(a)** ***Photoalignment technique*** **(b)**

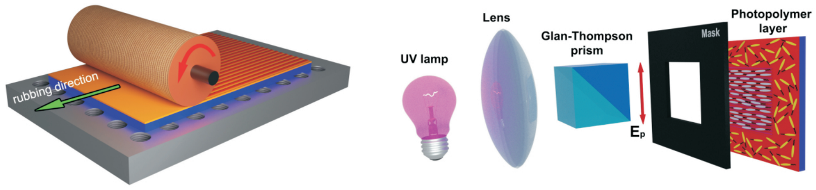

Figure 1. The schematic representation of the rubbing (a) and photoalignment (b) techniques of the LC alignment.

Recently, a new method of LC alignment by *laser-induced period surface structures* (LIPSS) on different materials was reported on metals [4,5] and transparent dielectrics [6].

The main purpose of this work is the study of main aligning properties (*i.e.* twist angle φ, azimuthal anchoring energy (AAE, W_φ) and pretilt angle θ_p) of LIPSS treated sapphire surfaces characterized by different widths *L* of unstructured gap (**Figure 2a**) and additionally coated with various polymers (**Figure 2b**). For these studies the method of combined twist LC cell was used (**Figure 2c**).

In addition, we were interested in studying the aligning properties of nanostructured surfaces covered with photosensitive polymer (*e.g.* PVCN-F) depending on the time of irradiation by the UV light and the relative orientation between the direction of polarization and the direction of nano-grooves.

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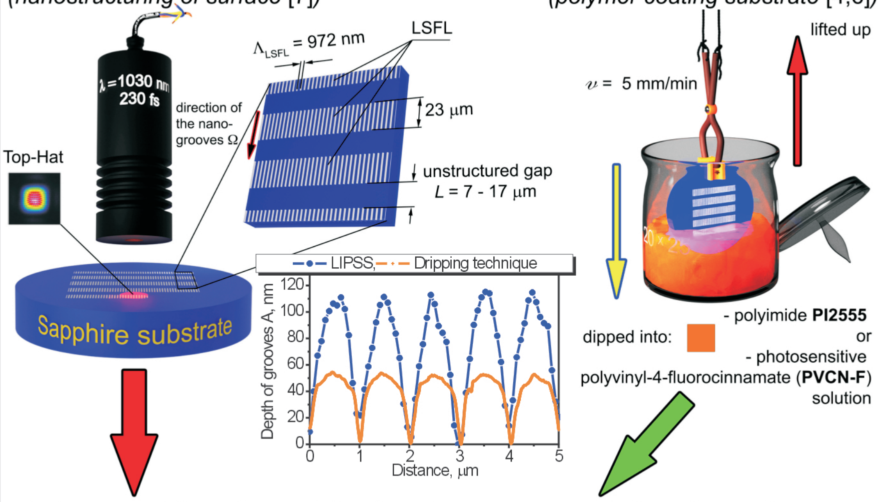
[5] A. Solodar, A. Cerkauskaite, R. Drevinskas, P.G. Kazansky, I. Abdulhalim, Appl. Phys. Lett. 113 (2018) 081603-1.
[6] I. Gvozdovskyy, Z. Kazantseva, S. Schwarz, R. Hellmann, Nanomater. 12 (2022) 508-1-15.

Methods

(a) LIPSS technique
(nanostructuring of surface [7])

(b) Dipping technique
(polymer coating substrate [4,6])

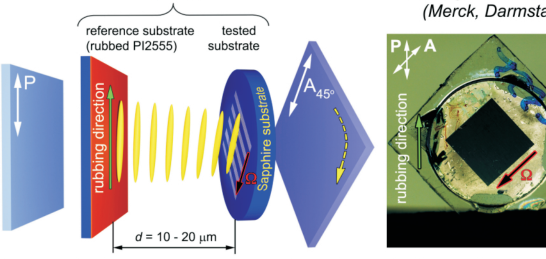


dipped into: 🟧 - polyimide **PI2555** or - photosensitive polyvinyl-4-fluorocinnamate (**PVCN-F**) solution

(c) The assembling of twist LC cell and measurement of the twist angle

Setup for the measurement of the twist angle φ [4,8]

Photo of the twist LC cell filled by the nematic E7 (Merck, Darmstadt)



The relation between twist angle φ and AAE W_φ [8]

$$W_\varphi = K_{22} \times \frac{2\times\varphi}{d\times\sin 2(\varphi_0-\varphi)}$$

K_{22} = 6.8 pN (twist elastic constant of nematic E7);
φ_0 = 45° is the angle between the easy axes of the reference and tested substrates;
φ - measured twist angle;
d - thickness of the LC cell.

Figure 2. Basic steps of preparation of the aligning surface: (a) structuring of the surface by LIPSS and (b) further polymer coating by dripping technique. (c) Assembling the combined twist LC cell.

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[7] S. Schwarz, S. Rung, R. Hellmann, J. Laser Micro/Nanoeng. 12 (2017) 67-71.
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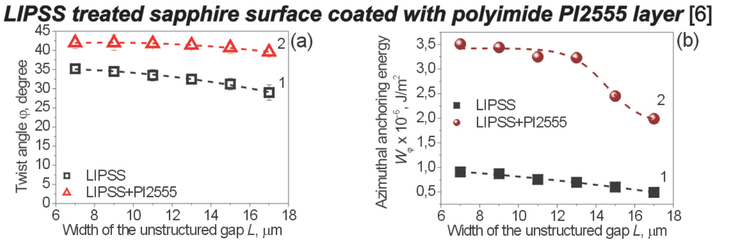
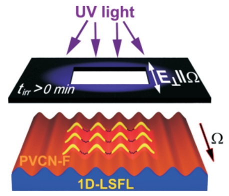
Results

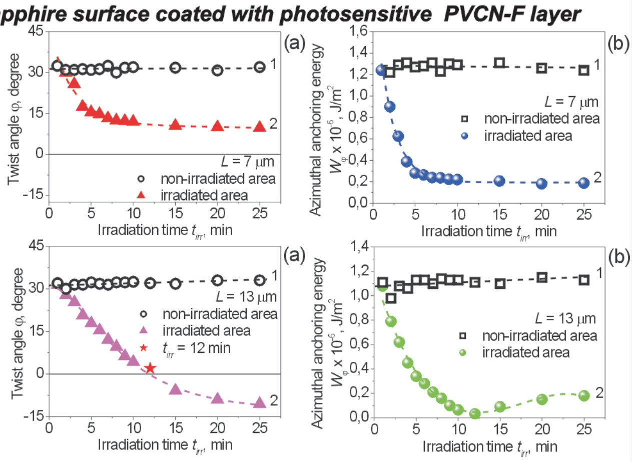
LIPSS treated sapphire surface coated with polyimide PI2555 layer [6]



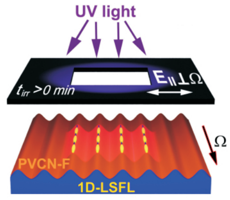
LIPSS treated sapphire surface coated with photosensitive PVCN-F layer

1) Polarization of UV light is *parallel* to the direction of nano-grooves Ω.





2) Polarization of UV light is *perpendicular* to the direction of nano-grooves Ω.



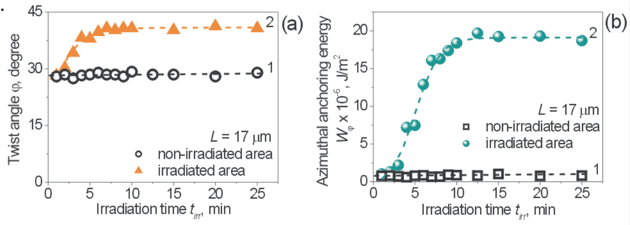


Figure 3. Dependence of the twist angle φ (a) and AAE W_φ (b) on the width *L* (or t_{irr}) for the entire sapphire surface treated by LIPSS (*curves 1*) and coated with various polymers (*curves 2*).

The increase of width *L* of the unstructured gap leads to the increase of the pretilt angle θ_p of LC molecules and contact angle β of nematic droplet, caused by the decreasing of the AAE W_φ (**Figure 3**).

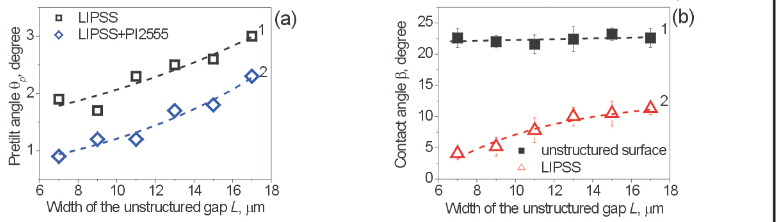


Figure 4. Dependence of the pretilt angle φ (a) and contact angle β (b) on the width *L* of the unstructured gap of sapphire substrates.

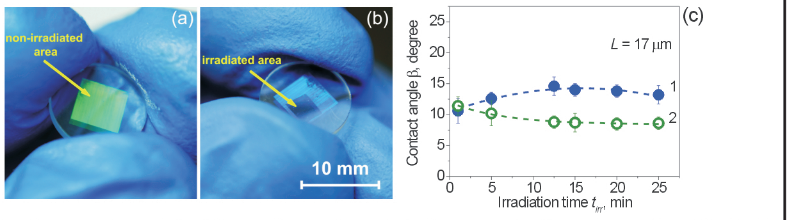


Figure 5. Photographs of LIPSS treated sapphire substrate covered with photosensitive PVCN-F: (a) before and (b) after irradiation t_{irr} = 15 min. (c) Irradiation time dependence of contact angle β of nematic E7 droplets placed on the surface, irradiated by polarized UV light with the polarization parallel (*curve 1*) and perpendicular (*curve 2*) to the direction of the nano-grooves of 1D-LSFL .

Conclusions

The value of AAE, twist and pretilt angles can be controlled in two different ways:

- by changing the width *L* of the unstructured gaps,
- by modification of the structured sapphire surface using different polymers layer.

It was experimentally shown that AAE W_φ of the substrate covered with PVCN-F film can be:

- *weakened* when, during UV irradiation, the polarization is parallel to the nano-grooves of LSFL;
- *increased* when the polarization of UV light is perpendicular to the nano-grooves of LSFL.

The value of the AAE can be controlled in the wide range from 2 ×10^{-8} to 19.7 ×10^{-6} J/m^2 by changing the polarization of UV light in relation to the direction of the nano-grooves of LSFL and exposure time.

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