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Modification of a-C:H film surface by atmospheric pressure plasma jet for liquid crystal alignment

Alibi Baitukha *, Shinsuke Mori, Masaaki Suzuki

Tokyo Institute of Technology, Chemical Engineering Department, 2-12-1 Ookayama, Meguro, Tokyo 152-8552, Japan

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ABSTRACT

The present research work is devoted to developing methods of manufacturing liquid crystal (LC) cells. Ultrathin hydrogenated amorphous carbon (a-C:H) films are deposited on glass substrates by the plasma enhanced chemical vapor deposition method. To impart alignment properties these substrates are exposed under the atmospheric pressure plasma jet (APPJ) scanning system. Raman spectroscopy is used to describe the structural change in the a-C:H film. A polarizing optical microscope is used to describe the properties of the composed LC cells. We found that using a-C:H film as an alignment layer shows the same result as when conventional polyimide film is used. Moreover, the treatment of the a-C:H or polyimide film surfaces by the APPJ system results in good LC molecule alignment on the surface of these films.

1. Introduction

Liquid crystal display (LCD) manufacturing is a broad industry with large annual investments. Though in its routine processes there are still some areas that could be improved, like in creating alignment layers. The alignment layer is a thin layer between the substrate and the LC molecule volume. This alignment layer orients LC molecules on its surface in a particular direction. Mechanical rubbing of a polyimide surface is the conventionally used method to create an alignment layer. As a contact method of treatment mechanical rubbing introduces debris, which can cause defects that may only be detected after the LCD has been manufactured. Moreover, deposition of polyimide film as an alignment layer material consists of several steps including a baking treatment stage of up to 250 °C. To overcome these disadvantages several alternative non-contact methods were developed, like the ultraviolet alignment, Kaufman ion beam alignment, the atmospheric pressure plasma jet scanning system and other methods [1–3]. Among those alternative techniques special attention is paid to the atmospheric pressure plasma jet (APPJ) scanning system, as it can be operated simply at air conditions. Therefore, it is presented as one of the possible replacements for the conventional method. The objective of this research work is to develop a method of fabricating an alignment layer for LCD cells by the APPJ scanning system where disadvantages of the conventional method will be overcome.

2. Experimental procedure

An ultrathin a-C:H film is deposited on glass substrates by a radio frequency capacitively coupled plasma enhanced chemical vapor deposition (PE-CVD) method [4]. The area and thickness of the glass sample are 2×2 cm^2 and 1 mm respectively.

Glass samples were placed on the ground electrode and a-C:H films were deposited from a gas mixture of 1.5 sccm CH_4 and 1.5 sccm H_2 at an operation pressure of 5 Pa. Input power was equal to 100 W. Under these conditions a-C:H films were deposited uniformly over all substrates with a growth rate of 2 nm/min. The thickness of the film was measured from cross-section images obtained from an S4500 Field Emission Scanning Electron Microscope (FE SEM) operated at 8.0 kV. During the deposition procedure, the temperature of the substrate did not exceed over 50 °C compared to 250 °C in the conventional method. This factor allows us to use more temperature sensitive materials as substrates.

The next step was to impart LC alignment properties to a deposited a-C:H film by modifying this film. Glass substrates with deposited film were moved from the PE-CVD chamber and treated by the APPJ scanning system [1,5]. The schematic of the processing system is shown in Fig. 1. The APPJ scanning system is composed of a coaxial tube in which an ultrasonic (20 kHz) generator drives one power electrode and the second electrode is grounded. Argon gas was used as a working gas and fed into annular space inside of the coaxial tube. As illustrated, the plasma jet tube was angled to the surface of the substrate by 60°, and placed 10 mm above it. The ambient atmosphere is air. The input power was equal to 15 W and Ar is flown at the rate of 3 slm.

The stage on which the substrate was mounted is moved on both an X and a Y-axis by two installed motorized stages, type SgSP20-35, and controlled by a SHOT-602 two-axis stage controller. LabVIEW 8.2

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* Corresponding author.
E-mail address: baitukha.a.aa@m.titech.ac.jp (A. Baitukha).

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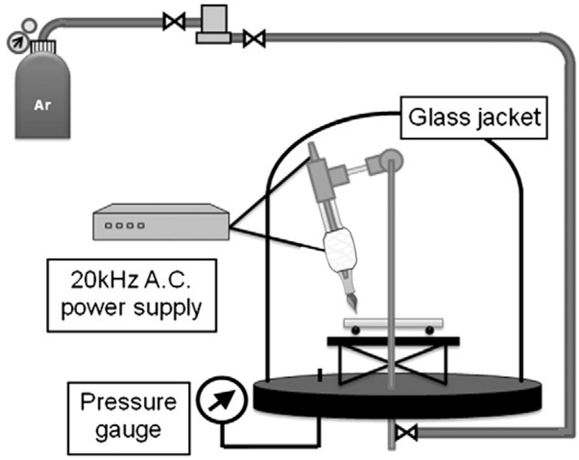

Fig. 1. Atmospheric pressure plasma jet (APPJ) scanning system.

was used to compose the controlling program, thus making possible the scanning of the substrate and providing directional treatment over all the substrate. The scanning speed in the X direction is 2 mm/s and a step in the Y direction between each scanning cycle is 0.5 mm.

In Fig. 2 a plasma jet torch electrode configuration is illustrated. In our experiments the plasma jet torch had a coaxial configuration, where the central power electrode of 1 mm and the outer grounded electrode are wrapped around the bottom part of the torch. With an electrode configuration where the field is parallel to the gas flow it was possible to reach a longer plasma jet plum. Compared to the plasma jet torch with a perpendicular to the flow field electrode configuration it was more convenient to apply and treat the surface with a-C:H film. At optimal conditions the length and width of the plasma jet are 20 mm and 2 mm respectively.

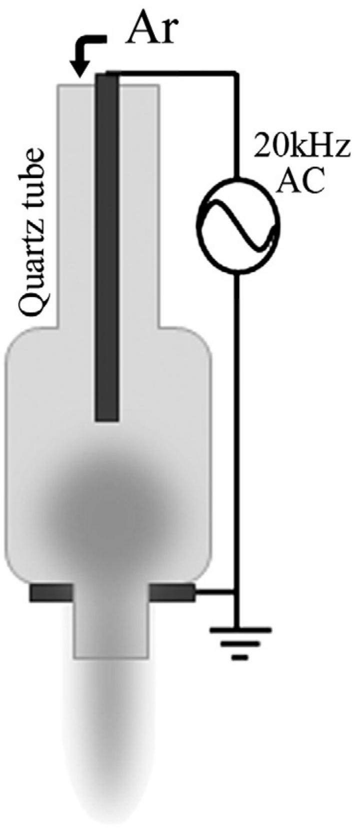

Fig. 2. Plasma torch electrode configuration with parallel to the flow field electrode configuration.

After treatment these glass substrates with a deposited a-C:H film were used to fabricate LC cells. To examine qualitatively the performance of the LC cells a polarizing optical microscope (POM) was used (Fig. 3). Cross-linked polarizing filters in an optical microscope block all penetrating light unless an optically active element, for example a cell filled with LC molecules, is installed in the light path between the filters. Therefore, we can see the distribution of LC molecules in the cell.

The gap between the two substrates was 10 μm and was filled with 5CB 4-pentyl-4′-cyanobiphenyl LC molecules. The melting point and refractive index are equal to 34 °C and 1.532 for 5CB LC molecules respectively. A Yashima optical microscope TBR-1 with installed cross-linked polarizer filters was used to analyze the completed LC cell. Transparency was measured by an Ocean Optics HR4000CG-UV-NIR spectrometer.

3. Results and discussion

As a replacement to the conventional polyimide alignment layer we considered a-C:H films. This replacement allows avoiding the heat treatment step, where the substrate is heated up to 250 °C. To measure the thickness of the deposited a-C:H film, S4500 FE SEM was used. In Fig. 4 pictures of the substrate with a deposited film and the dependence of transparency properties on thickness are illustrated. The transparency of the films in an overall manufactured cell is a crucial factor for optical devices. For practical applications an ultrathin layer of an a-C:H film, which is less than 100 nm, is enough to align LC molecules on its surface. All deposited films showed good transparent properties.

The behavior of LC molecules on the alignment layer surface is still unknown and under intense discussion. At this moment we know that the conventional method of creating an alignment layer produces grooves by mechanical rubbing on the surface of the polyimide film. These grooves could be responsible for alignment but stress from the rubbing drum on the surface and the resulting reorientation of the lateral groups in the polyimide film might also be the reason and explain how LC molecules align [3]. A treated surface increases the surface energy and hydrophilic properties, which is confirmed by contact angle measurement methods [1]. The change in surface energy indicates a change in the orientation of polar lateral groups in the film.

Since LC molecules are influenced by carbon rings through dipole–dipole interactions a beneficial condition is created for the process of aligning LC molecules vis-a-vis the APPJ system because of its preferential destruction of carbon rings. To investigate the preferential destruction of carbon rings we observed a-C:H films by Raman spectroscopy.

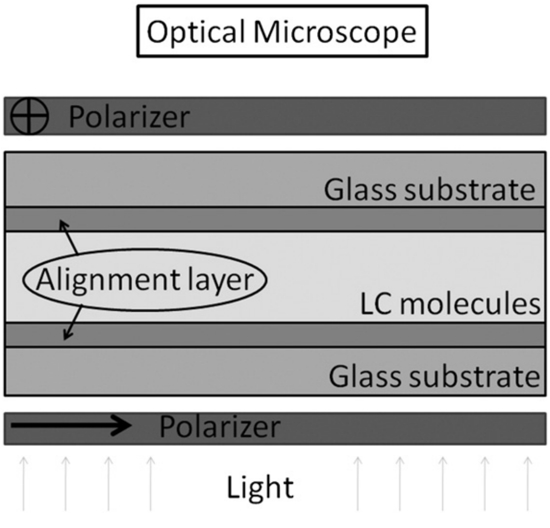

Fig. 3. Schematic diagram of the LC cell in POM.