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Liquid crystal cell with graphene electrodes

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Liquid crystal cell with graphene electrodes

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Abstract. We demonstrate a graphene-based nematic liquid crystal cells fabricated by photo alignment technique. The modulation characteristics have been measured revealing that photo alignment method shows great potential for protecting the graphene layer on glass substrate during LC device fabrication.

1. Introduction

Liquid crystal displays (LCDs) are among the most important devices in modern life, intensively used in variety of photonics and optoelectronic applications [1]. Essential components for LCDs are transparent and electrically conductive layers. Among them, a solid solution from indium (III) oxide (In_2O_3) and tin (IV) oxide (SnO_2), known as ITO, is the dominant one. Recently, the demand for ITO thin-film transparent electrodes has dramatically increased. However, a stable supply of ITO may be difficult to be achieved for the recently expanding market for optoelectronic devices because of the cost and scarcity of Indium, the principal material of ITO. Therefore, the development of alternative materials is necessary to resolve this significant problem. Furthermore, ITO deposition is sensitive to the acidic and basic environments and requires complicated technical processing. In this aspect graphene, due to its excellent electrical conductivity, low sheet resistance and very high transparency in a broad spectral range [2,3] appears to be the perfect candidate to replace the ITO contacts.

After the pioneering work of Blake et al. [4] demonstrating the first LC display with one-side graphene electrode, several attempts have been proposed for complete replacement of ITO contacts. For example, high transmittance graphene-based LC cell with performances competitive to ITO-based LC cell have been reported [5], however, the fabrication of graphene-based LC device is problematic due to the mechanical rubbing which damage the graphene layer during the alignment procedure [6].

In this paper, we demonstrate a fabrication of nematic liquid crystal cell with graphene-based electrodes using photo alignment technique. The modulation characteristics of LC cell with graphene electrodes are measured and compared with the similar cell using conventional ITO electrodes. The results reveal that the photo-alignment technique opens a great potential for protecting the graphene during LC devices fabrication.



2. Experimental details and discussion

2.1. Graphene-based LC cell fabrication

Basically the LC device consists of LC layer sandwiched by a pair of glass substrates (figure 1 shows the schematic structure). In such configuration each glass substrate is covered with conductive layer and an alignment layer.

To realize the proposed structure, first the graphene was grown on a Cu foil, using a low-pressure chemical vapor deposition (LPCVD) method [7,8]. Generally, LPCVD is widely used approach to growth high quality graphene, in large area and with controlled thickness [9]. The growth process was performed in a quartz tube using 50 sccm high purity hydrogen and 20 sccm methane flow at a temperature of 1000 °C. After completing the growth process, the graphene was transferred on the glass substrates by spin coating a poly(methyl-methacrylate) PMMA on the top of graphene/Cu sheets. After PMMA deposition on the graphene site, the PMMA/graphene/Cu foil was floated on $\text{Fe}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$ solution in order to selectively etch the Cu foil. Subsequently, the resultant film with PMMA and graphene was transferred on several glass substrates, followed by removal of the PMMA using acetone at 60 °C.

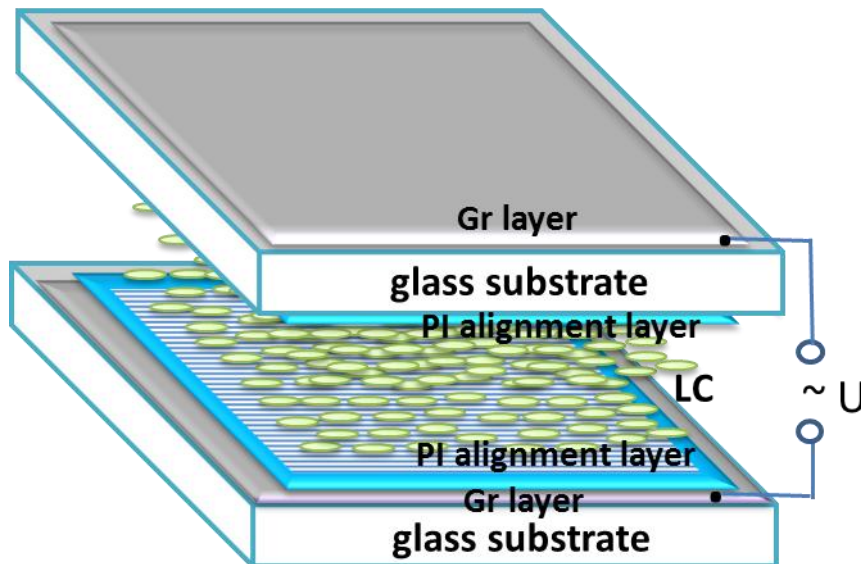


Figure 1. Schematic structure of LCD (Graphene or ITO layer stand as a conductive layer).

Before assembling the cells, the quality of graphene layer on a glass substrates were verified by Raman spectroscopy analysis. The Raman spectra were collected using a high resolution confocal Raman microscope (LabRAM HR Horiba-Jobin Yvon, HR 800) with 632.8 nm He/Ne-laser excitation under ambient conditions.

The Raman spectra of graphene transferred on a glass substrate is shown in figure 2. As it seen, the peak intensity of characteristics D-band is rather weak which indicates the fewer amounts of defects on graphene surface [10]. Furthermore, the 2D/G ratio is larger than 2 which figure out that over 90% of the area is single layer graphene.

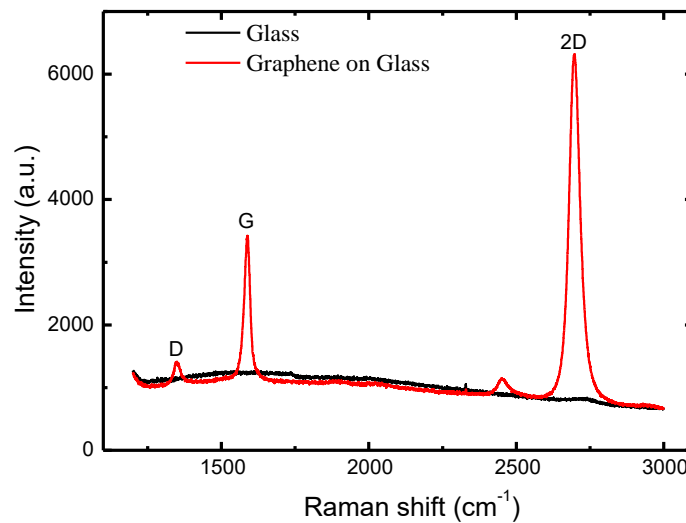


Figure 2. Raman spectra of graphene layer transferred on a glass substrate

Next, the alignment layer was prepared by spin coating a photo-curable polyimide (PI) layer (Innolux Corporation) on the above graphene-covered glass substrates and illuminated with linearly polarized UV light (wavelength of 365 nm and intensity of 1.6 mW/cm²) for 10 minutes. We note that using the photo-alignment method the direction of alignment is parallel to the polarization of the UV light [11]. Finally, the empty cells are prepared using 12 μm Mylar spacer. The LC molecules (nematic phase E7, Merck) were injected into the empty cell.

In addition, a reference LC cell using conventional ITO contacts with the same thickness was prepared for comparison using standard mechanical rubbing procedure.

2.2. Modulation characteristics

The modulation characteristics were measured by inserting the LC cell between a pair of crossed polarizers as shown at figure 3(a). AC rectangular voltage with $f=1$ kHz was applied on the device and the power of the transmitted laser beam was monitored by a power meter.

The results are shown in figure 3(b). As it is seen, the transmitted light intensity (I) through the LC cell follows the sinusoidal function of the amplitude of applied voltage due to the phase retardation (Γ) provided by the LC molecules, given by the formula [1]

$$I = I_0 \sin^2 \left(\frac{\Gamma}{2} \right) \quad (1)$$

where I_0 is the initial output light intensity.

The modulation results for graphene-based LC cell are compared with the ITO-based cell, made as reference sample. As is illustrated in figure 3(b), both LC cells have similar modulation characteristics, with quite similar values of the driving voltages for both cells. Although the LC cell with ITO electrodes demonstrates higher contrast, the oscillation behaviour of the transmitted light intensity as a function of the driving voltage values of both reference cells is very similar.

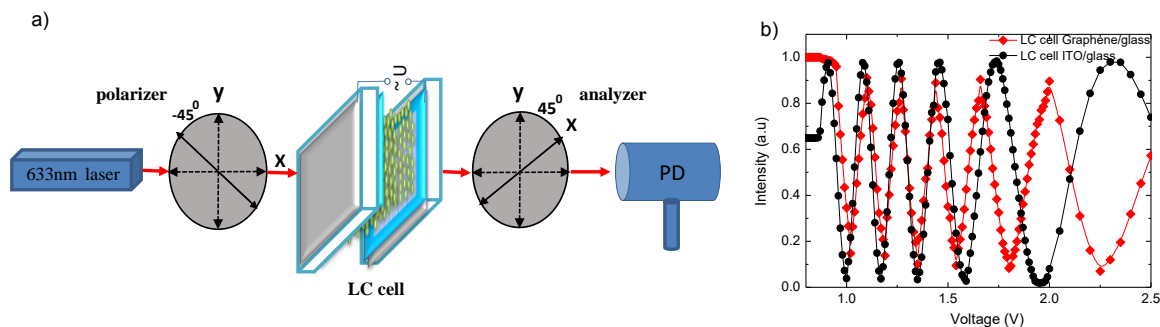


Figure 3. (a) Experimental set-up for voltage –transmittance measurements and (b) Transmitted light intensity versus applied voltage for LC cells using graphene contacts and photo-alignment method (rectangular symbols) and ITO contacts and mechanical rubbing method (circle symbols)

3. Conclusion

We demonstrated graphene contacts-based LC cells prepared by using photo-alignment method. The voltage-transmitted characteristics show similar behaviour compared to the ITO reference LC cell prepared using mechanical rubbing. The results indicate that the photo-alignment technique can prevent damage of the graphene layer during the alignment procedure.

Acknowledgements

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