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Review of the feasibility of a new touch-sensitive digital display enabled by block copolymer materials

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Abstract. Nowadays, electronic devices are widely used, and as an important part of many electronic devices, human-computer interaction displays have a lot of room for development. At present, traditional touch displays typically incorporate materials such as indium tin oxide (ITO) or graphene, which have limitations such as inflexibility, average accuracy and needing external power supplies. This article describes a motion sensor without additional power supply, which is based on one-dimensional photonic crystals of interpenetrating hydrogel network block copolymer (IHN-BCP), composed of photonic crystals alternating between different layers. The article concentrates on the viability of addressing these difficulties. The result shows that Block copolymers are unique polymers consisting of two or more distinct polymer chains, with the potential to exhibit self-assembling behaviour. Due to the special properties of block copolymer, this display could have flexible substrates and detect various contact and non-contact human motions. This device can be applied to interactive screens for cell phone screens, factory equipment, and other electronic products, and can also provide a reference for the future development of flexible screens.

Keywords: Touch-Sensitive Digital Display, Block Copolymer, Self-Assembly, Self-Powered Operation.

1. Introduction

Due to its potential in developing interface technologies, user-interactive screens that allow the visualization of human information, like movement, temperature, and humidity, have drawn a lot of interest [1]. In order to create human-motion interactive displays, sensors and displays are often physically combined with a microprocessor. Alternatively, sensors and displays can be combined onto a single platform without the need for a microprocessor to translate data. Use light-emitting diodes or electroluminescent components to observe various movements including touch, sliding, and tapping, and the brightness changes with the intensity of the stimulus. These results have been confirmed by many previous studies. However, these devices are constrained by the need for external power sources and their rigidity, which make the systems heavy and inefficient in terms of energy use.

To solve the aforementioned issues, a new interaction display that combines energy-absorbing technology with a sensitive display module that works throughout the whole visible spectrum is required [2]. Taebin Kim et al. conducted a study about a triboelectric nanogenerator (TENG) uses electrostatic induction and contact electrification in conjunction with a variety of contact and non-contact human

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motions [3, 4]. H.S. Kang et al. found that due to the simple and reversible modification of both the microstructures and dielectric constants of the BCP domains under varied stimuli, structural color (SC) resulting from self-assembled block copolymer (BCP) photonic crystals is of interest [5]. Based on previous relevant studies, a TENG is appropriate for the motion-sensing display's self-powered sensing component. Additionally, when the structural color (SC) of a photonic crystal (PC), which is composed of two distinct components, is responsive to motions in the visible range in a reversible manner, it might be possible to visualize motions [6]. Combining the above principles, a team prepared the raw materials by living anionic polymerization and assembled an experimental device for testing.

This research has reference value for the development of flexible screens. Screens based on this technology can be used in a large number of instruments and devices that require human-computer interaction, suggesting a possible direction for the development of digital display.

2. Block Copolymers

Block copolymers are a class of polymers composed of two or more distinct polymer chains, referred to as blocks, that are covalently linked together. These copolymers possess remarkable properties resulting from the immiscibility of their constituent blocks. Block copolymers can undergo self-assembly, a process in which the blocks organize themselves into periodic microdomains, driven by the thermodynamic incompatibility between the blocks. This self-assembling behavior can be harnessed to create complex nanostructured materials with precise control over feature size and shape.

The advantages of utilizing block copolymers in making a touch-sensitive digital display are noteworthy. Firstly, block copolymers offer flexibility and stretchability, enabling the fabrication of touch-sensitive displays that can conform to curved surfaces or flexible substrates. This flexibility expands the potential applications of touch-sensitive displays, such as in wearable devices or flexible displays. Secondly, block copolymers provide improved transparency compared to traditional touch-sensitive display materials like indium tin oxide (ITO). This translates to better visual quality, brighter displays, and enhanced viewing experiences. Lastly, the self-assembly behavior of block copolymers allows for the creation of nanostructured films with uniform and controlled patterns for touch sensing. This precise patterning enhances the sensitivity and accuracy of touch detection on the display.

3. Material preparation and Equipment production

The team first prepared the materials needed for the experiment and assembled the Equipment. Via live anionic polymerization, a polystyrene-block-poly(2-vinylpyridine) (PS-b-P2VP) was created. Then, by spin coating a BCP solution in propylene glycol monomethyl acetate onto a silicon substrate, a 1μm-thick PS-b-P2VP film was created. Then The film was chloroform vapor solvent annealed at 60 °C for 24 hours to provide clearly defined in-plane alternating PS and P2VP lamellae. The BCP film was then submerged in a 1-bromoethane solution for 24 hours to quaternize the P2VP blocks. PEGDA, 2-HEA, Li+TFSI, 2-hydroxy-2-methylpropiophenone, and deionized water were combined to form an ionic gel. Polyvinyl alcohol was additionally added for stretchability. Spreading the ionic gel solution over the BCP film surface allowed the solution to preferentially diffuse into and expand the quaternized poly (2-vinyl pyridine) (QP2VP) domains [2]. In the end, heat evaporation through a mask was used to deposit a electrode on a polyethylene terephthalate substrate. The Cr/Au electrode was covered with a IHN-BCP/ionic gel layer atop a conductive carbon sheet [2].

4. Equipment Testing and Principles

Li^+TFSI^-, a hygroscopic ionic liquid, quickly absorbed moisture in the QP2VP layers, changing the size of the IHN-QP2VP domains according to RH. In reaction to humidity, the SC of the 1-D BCP PC film that results from the photonic bandgap changes. As schematically depicted in Figure.1, IHN-BCP PC film's electrification makes it possible to simultaneously sense and display a variety of finger motions with ambient humidity.

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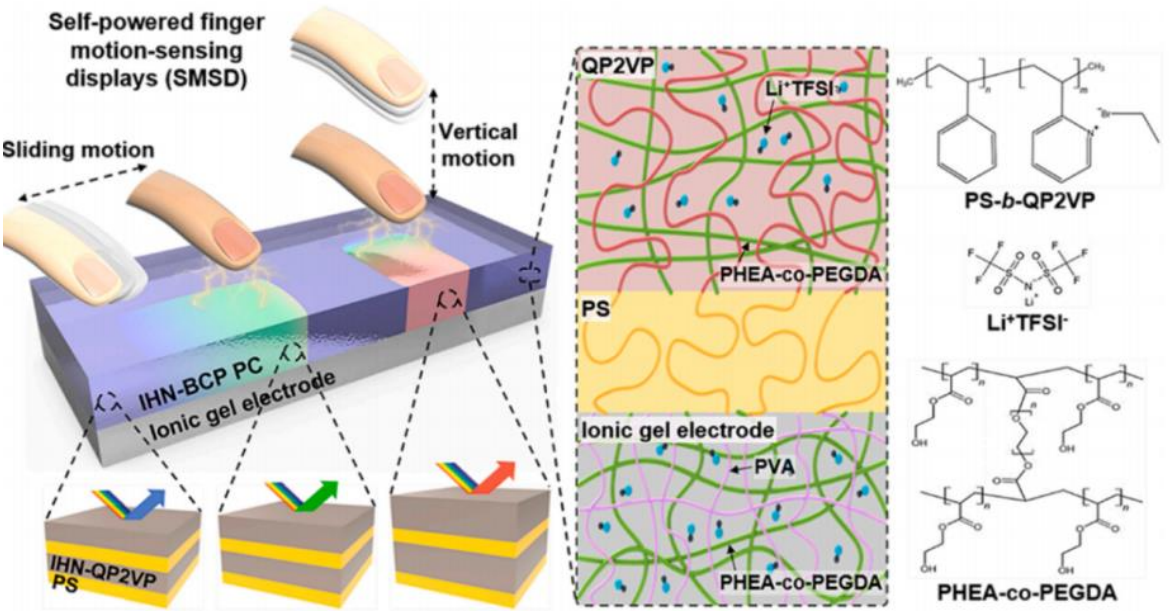

Figure 1. Making an SMSD with a humidity-sensitive controller [2].

An IHN-BCP was successfully made by IHN-QP2VP and PS lamellae stacked vertically on the ionic gel layer and alternately arranged. Interestingly, as a function of RH, the wavelength at the highest reflection was redshifted. The humidity made it possible to regulate an IHN-BCP PC's SC over a wide wavelength range throughout the whole visible spectrum. It is important to note that the SC of an IHN-BCP PC varied depending on the starting concentration of Li+TFSI- at a specific RH [2].

In a handmade humidity-controlled chamber, the IHN-BCP TENG's performance was assessed. PFA's hydrophobic properties were favorable for the dependable performance of an IHN-BCP TENG. According to the findings, in addition to serving as a humidity sensor, IHN-BCP TENG with humidity-responsive SC can also be employed as an energy harvester for the device's self-powered operation [2].

By dispersing electrified surface charges, water molecules frequently reduce electrification in a TENG, lowering the TENG's performance with humidity [7, 8]. The TENGs with layers of p++ Si and BCP/p++ Si were clearly degrading in performance in a humidity-dependent manner. The IHN-BCP TENG in contact mode demonstrated improved performance with humidity despite the contribution of water molecules to the degradation of TENG performance [9]. This was mostly because the capacitance of the IHN-BCP will increase with humidity.

The capacitance of the device will increase by 3.44 times at a frequency of 10kHz. The condition is for RH to change from 30% to 90%. At various frequencies between 50 kHz and 300 kHz, a comparable increase in capacitance with humidity was seen. This is mainly because unpaired electrons associated with the oxygen atoms in a water molecule can easily migrate from the bottom plate to the top plate during friction, the IHN-BCP TENG has better output performance [10].

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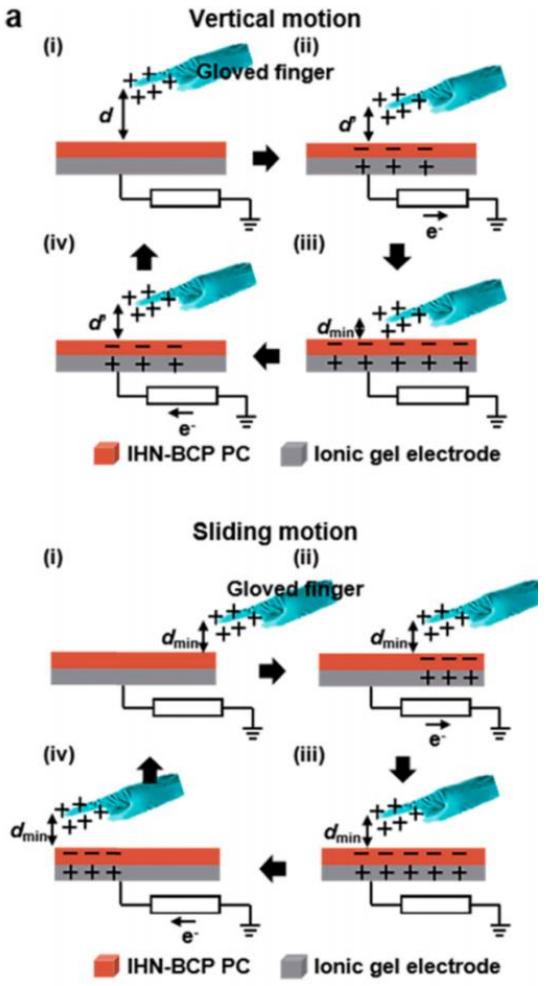

Figure 2. IHN-BCP TENG's humidity-dependent non-contact triboelectric performance [2].

Figure 2 displays the outcomes of an investigation into the IHN-BCP TENG's non-contact triboelectrification's humidity-responsive triboelectric performance. A commercial nitrile glove was used to seal the finger in order to ignore the performance-affecting impact of finger humidity. When the gap between the finger and the dielectric surface is close to the minimum gap distance (dmin), the voltage rises vertically until it reaches its maximum value. The finger moves in a sliding motion above the surface while dmin remains fixed. The output voltage of the device grew as the distance between the gloved finger and the IHN-BCP film shrank during the repeated vertical motions, and a value of about 1.92 mV was noted with a dmin of 0.5 cm [3]. However, the device's output voltage at a certain gap falls when the humidity level rises. As an illustration, the output voltage was roughly 0.88 mV with a dmin of 0.5 cm at 60% RH and 2.32 mV at 30% RH. Additionally, dampness had an impact on how well the TENG performed during the sliding motion. For instance, the device's output voltage, which was 1.26 mV at a 0.5 cm gap at 30% relative humidity, was reduced to 0.72 mV at 60% relative humidity [2]. The output performance of IHN-BCP-TENG in non-contact vertical and sliding motion deteriorates with increasing RH. This is the opposite of the legal result in the contact mode. When a charged object approached another one, electrostatic induction was increased [11, 12]. In this case, it is unlikely that water molecules coupled with Li+ ions in an IHN-BCP film will result in improved electrification. However, it is conceivable that as humidity rises, water molecules easily disperse the triboelectric charges on the surface of the nitrile glove, lowering electrostatic induction. This causes the output performance of TENGs operating in non-contact mode to degrade with dampness.

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5. Discussion

This research has reference value for the development of flexible screens. Screens based on this technology can be used in a large number of instruments and devices that require human-computer interaction, suggesting a possible direction for the development of digital display. However, for this research, the following points can be improved. For humidity control reliability, we should try to improve the product's anti-interference performance, such as by maintaining the basic control of the product when there are water beads on the surface. Improve the product's response speed. The product's response speed is slow in comparison with traditional products, affecting control efficiency and the user experience. It should be considered how to combine with other mature technologies to further enhance the practicality of the product. For example, fingerprint unlocking technology is a major hotspot on the smartphone screen. How to apply fingerprint unlocking technology and other practical technology to this new structure of the electronic screen will be a major problem in the future.

6. Conclusion

This study illustrated a revolutionary display platform that concurrently recognized and visualized several finger motions. The SMSD used SC of an IHN-BCP PC that was self-assembled and humidity-dependent triboelectrification. According to the study, the preferential swelling of IHN-QP2VP layers with water caused the SC of the PC to be red-shifted with humidity, enabling the observation of the humidity in the whole visible range. In contact mode triboelectrification, humidity also improved an IHN-BCP PC's TENG performance, while in non-contact mode it suffered. The team employed the water screening effect and increased capacitance of the IHN-BCP PC, respectively, to explain the varied humidity-dependent TENG behaviors in contact and noncontact modes. However, this article also has some limitations in the study of this new type of screen, with incomplete references to relevant literature and a relatively single source of experimental data. In this regard, more relevant literature should be consulted and enhance the dialectical and objective nature of the article through comparison between different literatures.

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