# Artificial Iris on Smart Contact Lens using Twisted Nematic Cell for Photophobia Alleviation

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***Abstract*— We propose an artificial iris to tackle sensitivity caused by photophobia. This artificial iris is made with a twisted nematic cell sandwiched between two linear polarizers. The light attenuation performance of a commercial TNC was compared with TNCs made for smart contact lenses.**

***Keywords—artificial iris, light intensity modulation, twisted nematic cell***

## INTRODUCTION

Photophobia is derived from two Greek words. 'Photo' meaning light and 'phobia' meaning fear, which together mean fear of light. is an abnormal sensitivity to light. Photophobia may occur because of neurological or ophthalmological disorders. Eight decades ago, Lebensohn labelled photophobia as a condition where, "exposure of the eye to the light definitely induces or exacerbates pain [1]. About 80% of people affected by migraine suffer acute sensitivity to light. Approximately half of migraine attacks are triggered by exposure to bright light or sudden changes in light intensity [2]. Additionally, in the human eye, the iris which is indirectly responsible for allowing and maintaining healthy light levels through the pupil is either damaged or missing [3]. Hence, external light intensity controlling mechanisms are required.

The most common method used for treating photophobia is to artificially reduce the amount of light entering your eye. Some optical tints have been successful in tackling photophobia. Red tinted glasses which filter out blue light, gray tints, and the rose-colored FL-41 tints have been clinically used to treat photophobia [4]. Intraocular lenses have also been used in photophobic patients. However, they require discomforting surgery for their insertion. A non-invasive method where the amount of light entering the eye can be controlled is desirable.

Another lucrative option is the usage of smart contact lenses (SCLs). Since the turn of the millennium, smart contact lens technology has been on the rise for vision correction and biological sensing [5]–[8]. An artificial iris fit onto a smart contact lens system can be used to modulate the amount of light entering the eye. We can thus customize the light intensity modulation according to the sensitivity needs of the patient. In this paper, we have developed a new artificial iris structure with two linear polarizers on either side of a twisted nematic cell (TNC). The polarizers can be either in cross-plane or in-plane configuration and when voltage is applied, light is attenuated or not, depending on the polarizer configuration. The reduced light intensity is validated with a light meter and imaging through the artificial iris.

## WORKING PRINCIPLE AND DEVICE STRUCTURE

The TNC acts as a tunable polarization rotator which rotates the polarization of the incident rays upon application of external AC voltage and due to the birefringence property of LC materials. Without the TNC, if the polarizers are placed orthogonally, i.e. in cross-plane configuration, ideally all the incident light is blocked. However, when the TNC is sandwiched between them, the twisted nature of the liquid crystals (LC) changes the light polarization and incident light is allowed to pass. When a voltage is applied, the LC begins to align with the electric field, thus blocking the light. Thus, light attenuation can be electrically modulated as shown in Fig. 1.

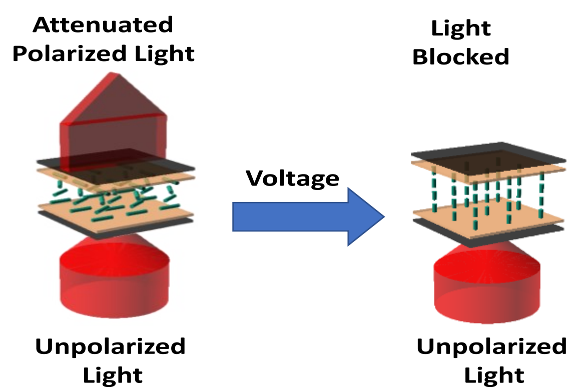


Fig. 1. Ideal working principle of the Polarizer-TNC-Polarizer, artificial iris stack for cross-polarization configuration.

For TNC fabrication we use two ITO coated glasses, and coat them with Polyamide (PI 2555). These glasses are then buffed with a rayon cloth to create anchoring sites for the liquid crystals (LC) and provide an initial tilt. The glasses are then attached in orthogonal way (cross-plane configuration) with a thin (~5 µm) tape. The TNC is filled with high performance LC like 5CB. The artificial iris assembly is then laser cut, keeping the aperture of the lens system is 4 mm. The TNC and Polarizer stack is then mounted on a flexible contact lens substrate made out of polyimide (Kapton) with integrated flexible wiring [8]. The fabrication process flow is shown in Fig. 2. (a) and the assembly on a SCL is shown in Fig. 2. (b). For cross-polarizer, the voltage is dependent on transmission, T given by,

$$T = \left(1 - \frac{\sin^2\left[\Theta\left(1+U^2\right)^{\frac{1}{2}}\right]}{\left(1+U^2\right)}\right).\left(1 - \sin^2 2\psi . \sin^2\frac{\Delta\phi}{2}\right) \qquad (1)$$

## RESULTS AND CONCLUSION

Fig. 3 shows the images of light attenuated by the artificial iris. Fig. 4. (a) shows the normalized attenuated light intensity for the commercial TNC and the TNC made with 5CB LC in cross-plane configuration. Fig. 4. (b) shows the same but for in-plane configuration. By applying ~2 $V_{RMS}$, we have achieved an attenuation of about 80% of the incident light. It can be observed that the TNC made with 5CB has a lower threshold voltage and covers the entire attenuation range under 3.3 V, making it suitable for use in low-power electronics such as smart contact lens. Cross-plane polarizer configuration can be utilized where a photophobic person spends the majority of their time in indoor conditions. Here without any voltage, maximum light is allowed to pass through. Thus, power consumption of the system can be reduced.

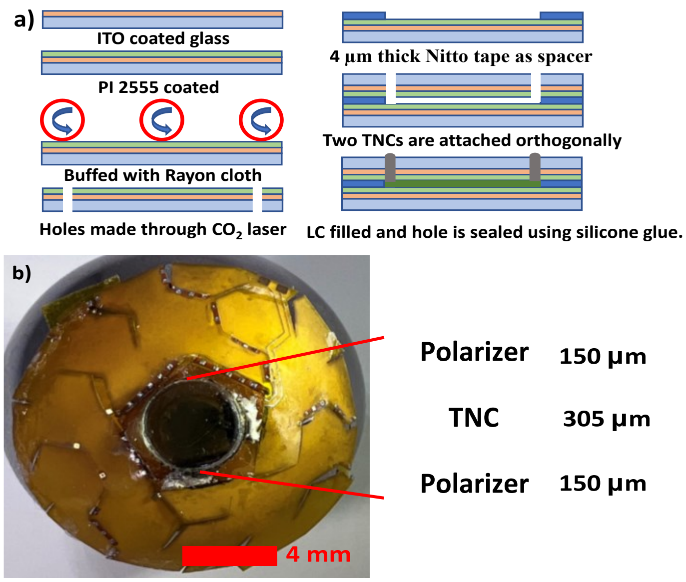


Fig. 2. (a) Fabrication process flow of TNC. (b) Artificial iris stack on flexible, smart contact lens platform.

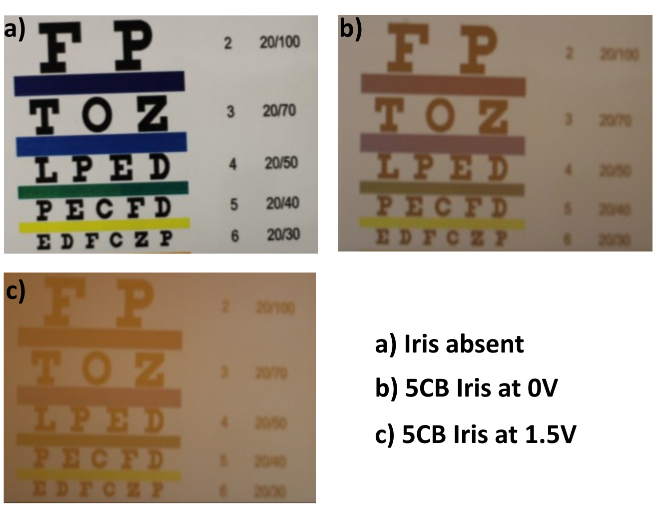


Fig. 3. Imaging for 5CB-based TNC at different voltages for cross-plane polarization.

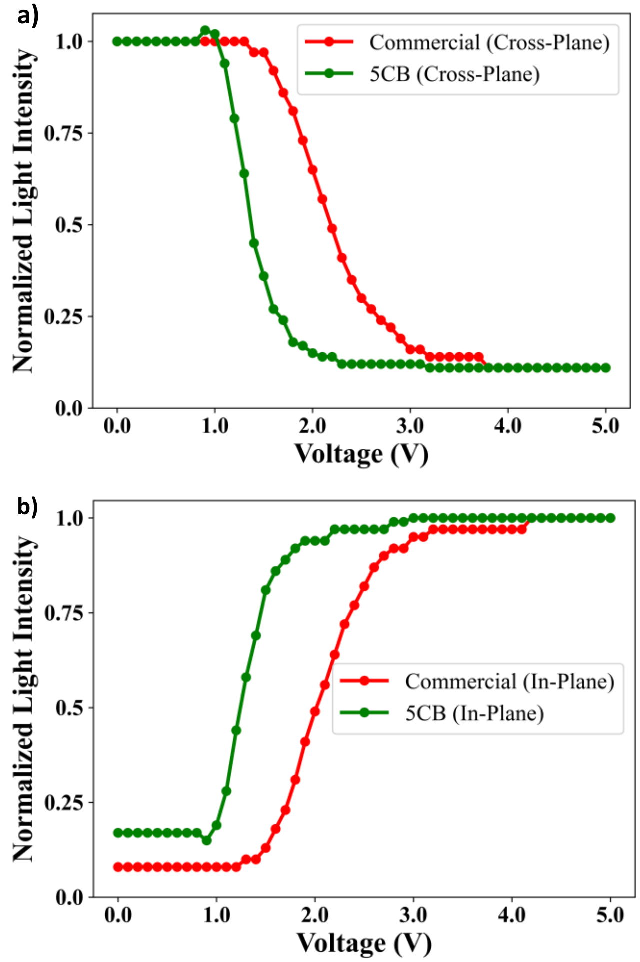


Fig. 4. Light attenuation performance of Commercial and 5CB-based TNC in (a) Cross-plane and (b) In-plane polarizer configuration.

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