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Spherical arrangement of biomimetic polymer photonic structures

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자연모사를 통한 미세 고분자 포토닉 구조의 구면배열에 관한 연구

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Abstract

Compound eyes in nature present intriguing topics in physiological optics due to their unique optical scheme for imaging. For example, a bee's eye has thousands of integrated photonic units called ommatidia spherically arranged along a curvilinear surface so that each unit points in a different direction. The omni-directionally arranged ommatidium collects incident light with a narrow range of angular acceptance and independently contributes to the capability of wide field-of-view (FOV) detection. Artificial implementation of compound eyes has attracted a great deal of research interest because the wide FOV exhibits a huge potential for medical, industrial, and military applications. So far, imaging with a FOV over 90º has been achieved only with fisheye lenses which rely on bulky and expensive multiple lenses and require stringent alignment. In this talk, we will discuss about the spherical 3D arrangement of the photonic structures of biologically inspired artificial compound eyes in a small form-factor to have and the functional and anatomical similiarity with natural compound eyes.

1. Introduction

This work presents the biomimetic efforts for artificial compound eyes by virtue of microoptics and polymer MEMS technologies. Compound eyes in nature have been one of the most intriguing subjects in physiological optics over a hundred year. The compound eye consists of a number of ommatidia which point in slightly different directions. They are optically and spatially isolated and radially arranged along the circumference of the eye. An individual ommatidium as an integrated optical unit contains a light-diffracting facet lens, a pseudocone, and a wave-guiding rhabdom enveloped by pigment cells (Fig.1a). By collecting lights impinging within a narrow range of angular acceptance, it independently contributes either to offer the capability of wide field-of-view (FOV) detection or to form an overall mosaic image [1]. Artificial compound eyes presented here are very similar to natural one in the perspective that more than eight thousands of honeycomb-packed hexagon or circular microlenses (F/1.75~2.5, 20~35 μm in diameter, $N_{Fresnel}$ < 10) and self-aligned waveguides with core diameter (3~10 μm) at diffraction limit called artificial ommatidia, i.e. individual units

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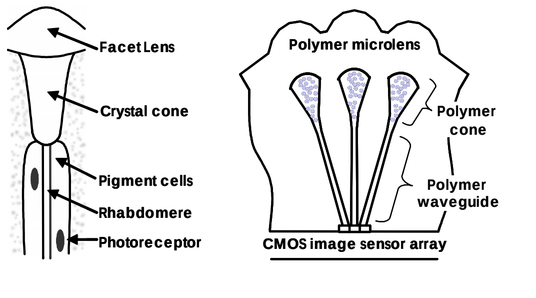

(a) Natural ommatidia (b) Artificial compound eye

Fig. 1. Anatomical comparison between ommatidia of natural and artificial compound eyes: (a) natural ommatidia and (b) artificial compound eye.

in natural compound eye, are radially arranged along the circumference of a hemispherical polymer dome (1~5mm in diameter).

2. Methods & Results

The creation of self-aligned polymer waveguides in artificial ommatidia is done by microlens induced self-written waveguides [2]. A bundle of UV light focused by microlens arrays in the resin, they induces photopolymerization that increases the refractive index relative to the surrounding. The light is optically trapped in a small region at the diffraction limit and also propagates to the absorption depth of the resin without changing the phase. The effects is simulated by a fast Fourier transformation beam propagation method in a SU-8 resin and it is also observed by a spectroscopic ellipsometer that refractive index increases with exposure energy. The spherical configuration of artificial ommatidia was achieved by incorporating the light induced self-writing process assisted by microlenses with a soft lithographic process for replicating microlens arrays onto a hemispherical dome (Fig. 2). Tthe optical characterization were done by transmission and reflection confocal microscope with additional apparatus. The angular sensitivity of individual artificial ommatidium is measured from intensity profiles at the end of waveguides in artificial compound eye where artificial ommatidia points in different directions. The angular acceptance angle (ρ_a) for a particular artificial compound eye shows ±2.2° comparable to that in a natural compound eye (ρ_n = 1.22°).

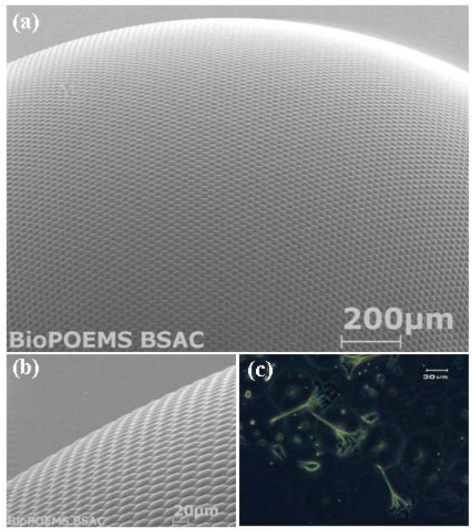

Fig. 2 SEM images of (a) artificial compound eyes with self-aligned microlenses and waveguides arranged into a hemispherical dome, (b) enlarged view of honeycomb-packed hexagonal microlenses on a curvilinear surface, and (c) Polymer waveguides revealed after the development.

3. Conclusions

With our best knowledge, this work is the first effort to integrate microlenses with waveguides along a curvilinear surface. It is believed that this completely different optical components compared to camera type single lens such as human eye may provide significant impact in miniaturizing imaging systems requiring wide FOV or fast motion detection.

Reference

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