Variable-focal lens using electroactive polymer actuator

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abstract

We present a simple and cost-effective design and fabrication process of a liquid-filled variable-focal lens using electroactive polymer as an actuator. The lens is made of soft polymer material, its shape and curvature can be controlled by pneumatic pressure. As an actuator, we used a carbon-polymer composite (CPC); likewise it is possible to use any other ionic EAP. The device is composed of elastic membrane upon a circular lens chamber, a reservoir of liquid, and a channel between them. It is made of three layers of polydimethylsiloxane (PDMS), bonded using the technics of partial curing. The channels and reservoir are filled with incompressible liquid after curing process. A CPC actuator is mechanically attached to reservoir to compress or decompress the liquid. Squeezing the liquid between the reservoir and the lens chamber will push the membrane inward or outward resulting in the change of the shape of the lens and alteration of its focal length. Depending on the pressure the lens can be plano-convex or plano-concave or even switch between the two configurations. With only a few minor modifications it is possible to fabricate bi-convex and bi-concave lenses. We report on a 1 mm diameter lens that can be converging or diverging with the focal length from infinity to 17 mm. The 5x15mm CPC actuator with the working voltage of only up to ±2.5V was capable to alter within the full range of the focal length in 10 seconds.

**Keywords:** Liquid lens, variable-focal, electroactive polymer, PDMS, CPC actuator

1. Introduction

Variable-focal lenses have been researched for years. There are several fields including beam steering and portable imaging where usage of tunable lenses could give an extra value. Variable-focal length lenses could be constructed without using mechanical translational movement thus noiseless design of the lens system is possible.

Tunable lenses could be classified as follows: electrowetting, gel type, and liquid lenses. Electrowetting lens is based on a drop of liquid which shape is changed by applied voltage. Alteration of optical power is obtained by electrowetting behavior of the droplet and the changes of its contact angle. Although these lenses have fast response time, authors have found it hard to reach larger apertures {{1040 Jong-Moon Choi 2008}}. Moreover, relatively high voltage (~50V) is required to operate {{1056 Hendriks,B.H.W. 2005}}{{1007 Shimizu,I. 2009}}.

Gel type lens is composed of elastic material that is contracted and expanded thus changing the radius of curvature. For instance SMA actuator has been used to control contraction/expansion {{1040 Jong-Moon Choi 2008}}. Gel type lenses are relatively resistant to vibrations and shocks but have limited focal range.

Finally, the concept of liquid lens uses three key elements: transparent elastic membrane (often made of polydimethylsiloxane – PDMS), liquid, and an actuator. The membrane is deformed as a result of pneumatic pressure in the liquid. As a result of deforming the membrane, the radius of curvature of the lens is changed and optical power is altered. For pressure control, different actuators like an external pump {{1024 Lin,Wei-Cheng 2008}} or directly connected piezostack actuator {{1021 Oku,H. 2009}} have been used. Compared to electrowetting lens, liquid lenses are able to produce wider range of focal length and the design of the lens is rather simple. Considering liquid lenses, there is also an option to choose between different actuators allowing the system to be more dynamic.

Electroactive polymers (EAPs) are materials that change their shape and size in response to applied voltage. These materials have large potential in the fields of microfluidics, robotics, and biomedicine. Although ionic EAPs, like ionic polymer metal composites (IPMCs), have been developed for years, they have been rather rarely used to drive tunable lenses. However, Shimizu *et al* {{1007 Shimizu,I. 2009}} have demonstrated a promising variable-focal liquid lens system which has four IPMC strips attached to deformable lens membrane. By moving the edges of a membrane towards the liquid, the deformation occurs in the opposite direction. Therefore, a variable-focal length is achieved. IT WOULD BE NICE TO FIND SOME SERIOUS CAP IN THIS DEVICE☺. Synchronization of all the 4 IPMC strips?

Recently there has been an increasing interest in ionic EAPs based on carbon. These EAPs are called carbon-polymer composites (CPCs). CPC is a three layer actuator which electrodes are made of porous carbon material, base polymer, and ionic liquid. Unlike IPMC, the relaxation of CPC actuator is notably slower due to the low speed of desorption of ions of the ionic liquid from the porous carbon. Another advantage of CPC is. Further details about the CPC actuator used in this paper are described in {{1016 Torop,Janno 2009}}. {{1058 Torop,Janno 2009; 1057 Torop,Janno 2010}}

In current paper we propose a novel approach to construct liquid-filled variable-focal lens by using partial curing technique of PDMS and CPC actuator. In this configuration large focal range is obtained by using the voltage in the range of only 2.5 volts.

2. STRUCTURE OF THE LENS OR SOMETHING ☺

Here some equations are described and maybe something else…

2.1 This is the style of subtitles

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