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Abstract

Development of a Compact, Reliable, and Electrostatically Actuated Device for Microfluidic-Based Active Glasses †

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Abstract: We present the development study of a reliable and low-power actuator for microfluidics-based active glasses. The adaptive part of the lens implements two liquids of a specific refractive index separated by a thin membrane, the modification of their relative volumes allowing adaptive optical power corrections. The proposed actuator is connected to an adaptive lens by microchannels since it is intended to be installed in the temple of the glasses. The actuation is based on the electrostatic displacement of a thin film, which changes the relative volumes of two cavities filled with these liquids. The metalized film is placed slack with an "S-shape" between two electrodes biased with the actuation voltage. Very compact actuator prototypes have been developed and characterized. Power corrections ranging from +0D to +3D can be achieved via liquid volume displacement as low as 120 µL and with a power consumption of a few mW. The prototypes show good reliability without any significant change in their operation after more than 1 million actuations. For RD purposes, we have replaced some electrodes with transparent windows. With this setup, we show experimental results on the interplay between the performances and the film folding inside the actuator.

Keywords: microfluidic actuator; electrostatic micropump; active eyeglasses; ITO electrodes

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1. Introduction

About 5% of people with presbyopia are unsatisfied with traditional corrective approaches to presbyopia (progressive power, monovision, and multifocality). Laclarée proposes a novel approach based on automatic focusing with an electrically controllable lens for those people. This variable technology has been thought through to offer vision comfort without cutting on aesthetics. Laclarée provided a proof of concept with a fully functional prototype [1]. We have also conducted a pilot clinical investigation at CHU Saint Etienne (FRANCE) with 40 confirmed patients with presbyopia [2]. To achieve our purpose, we have developed and patented a novel concept of microfluidic actuators [3]. Power corrections ranging from +0D to +3D can be achieved via liquid volume displacement to adjust the focus according to the target. This microfluidic pump is based on the electrostatic actuation of ultra-thin metalized film loosely attached between two electro-grids. A wide spectrum of micropump concepts has been proposed [4]; however, for most electrostatically based actuators, the deformable membrane is clamped and stretched [5,6]. Our system combines several advantages: compact enough to be integrated into eyeglasses, low power consumption, silent, and ready to be industrialized.

2. Materials and Methods

The microfluidic actuator is based on a slack metalized film confined between two parallel PCB electrodes separated by a gap. Thus, the film separates two sealed chambers. The film is loosely attached to move freely between the two electrodes. It is pressed against one or the other electrodes under electrostatics forces actuated by electrical tension. Thus, the actuator works in a bidirectional mode: it is able to push both fluids. The actuator can be monitored either by electrical tension or capacitance (formed between the film and the electrode). Indeed, the capacitance is directly related to the surface of the film pressed against the electrode (via the surface capacitance of the electrode). Finally, we can match the film's surface with a displaced volume (via the gap between the two electrodes). The film is 1.9 µm PET with one face metalized (100 nm aluminum); thus, one electrode has to be coated with a dielectric (2 µm of perylene C). A deposit of epoxy resin and stencil printing ensures the height of the gap. The active zone is 5 mm × 45 mm. The fluids go through the slice's side and are released to the liquid lens via fluidic channels (Figure 1). The actuators (with a 300 µm gap) can move 150 µL against differential pressures of about 200 Pa with a 140 V maximum power supply at 50 Hz.

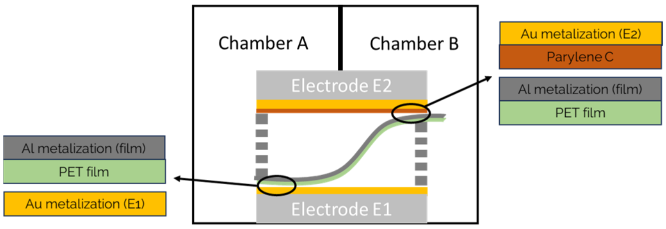

Figure 1. Sectional view of new concept actuator.

3. Results and Discussion

3.1. Benefits of the New Concept

There are several benefits to this new concept of actuators. The actuator is designed as a slice, so you can stack as many slices as you need. It depends on the volume you need. In our case, you need 120 µL to adjust optical power from 0D to 3D. The actuator is very compact, with a size of 5 mm × 9 mm × 61 mm (Figure S1). It can be more easily integrated into the frame of the eyeglasses. Finally, using PCB for the actuator's architecture is a real benefit. It is a very mature technology, and the production can be more easily industrialized.

In that way, Laclarée has started to investigate the aging and reliability of the product.

3.2. Fiability

More than a million cycles have been performed on the actuator. The idea is to lay down the film on one electrode and then on the other. Thus, Laclarée validated the sealing of the system, the electrical operation, and the total volume displaced conservation after more than a million cycles (Figures 2 and S2). This represents about two and a half years of use for the eyeglasses.

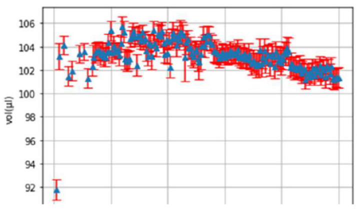

Figure 2. Evolution of the volume displaced by the actuator after 1 million cycles. A measurement is carried outapproximatively every 10,000 cycles (triangles). The total volume displaced remains stable at around 103 +/− 3 µL.

3.3. Transparent Actuator

For the transparent system model, we use ITO electrodes instead of PCB electrodes. ITO electrodes are ITO-coated glass slides cut at the right size. They are assembled using an adapted process to make a slice of a new concept of electrostatically actuated devices. We use a transparent ITO electrode to directly observe the film movements. This model system is now completely functional (Video S1). It allows us to investigate the link between displaced volume (directly related to optical power) and the capacitance of the actuator (related to the surface of the film plated on the electrode). It also makes it possible to study in detail the transition of the film on the electrode (initiation point, impact of the folds, etc.).

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/proceedings2024097022/s1, Figure S1: Photo of both face of the actuator; Figure S2: Evolution of displaced volume over capacitance or tension; Video S1: Video of ITO-actuator in operation.

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