# MEMS for Glaucoma

Thesis by

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To my family

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# ABSTRACT

# MEMS for Glaucoma

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Glaucoma is an eye disease that gradually steals vision. Open angle glaucoma is one of the most common glaucoma forms, in which eye fluid (aqueous humor) produced by the ciliary body cannot be drained away normally by patients' eyes. The accumulated eye fluid inside the anterior chamber causes high intraocular pressure (IOP), which is transmitted onto the retina in the back of the eyeball (globe), continuously suppressing and damaging the patient's optic nerves; this may lead to total blindness if not treated properly.

The current most-popular IOP monitoring technique is to use applanation tonometry, which applies applanation force onto the cornea and measures the resulting deformation in order to calculate the IOP. Even though applanation tonometry can provide quite useful information about patients' IOP, continuous monitoring of IOP is required for ophthalmologists to understand the IOP fluctuation of the patients, something which still cannot be achieved *via* current applanation approach. In addition, applanation tonometry requires skillful operation performed by well-trained professionals, such as ophthalmologists, making continuous IOP monitoring impractical.

In this work, we have developed a telemetric IOP sensor that is capable of monitoring IOP wirelessly and continuously. As the quality factor drops when a telemetric IOP sensor is implanted in the anterior chamber, due to the high loss tangent of the saline-based aqueous humor (~ 0.2) compared to air (0.0), a modified IOP sensor is developed to monitor IOP with sensing coil that is left exposed after implantation in order to avoid interruption from the eye fluid. Another approach is also proposed and tested to demonstrate that the quality factor can also be recovered by covering the sensing coil with low loss tangent materials.

Currently glaucoma is treated mostly by taking oral medications or applying eye drops. However, some glaucoma patients do not respond to those medications. Therefore, another physical approach, using a glaucoma drainage device (GDD), is necessary in order to drain out excessive eye fluid and serve as a long-term way to manage the increased IOP. Current commercially available glaucoma drainage devices do not have reliable valve systems to stop the drainage when the IOP falls into the normal range. Therefore, we have developed a dual-valved GDD to fulfill the “band-pass” flow regulation which drains out eye fluid only when IOP is higher than 20 mmHg, and stops drainage (closes the valve) when IOP is lower than 20 mmHg to prevent hypotony. The key component of GDD is a normally closed (NC) check-valve, which only opens to drain away the excess fluid when the pressure is higher than 20 mmHg. The proposed paradigm of our NC check-valve is to have a couple of parylene-C pre-stressed slanted tethers to provide the desired cracking pressure. The slanted tethers are achieved in this thesis by: 1) slanted photoresist generated by gray-scale photolithography, 2) pop-up mechanism, and 3) self-stiction bonding mechanism. The built-in residual tensile stress

can be controlled by mechanical stretching or thermal annealing. The protecting mechanism preventing the unwanted drainage when the eyes experience sudden unpredicted high IOP is achieved by utilizing a normally open (NO) check-valve. A “minimally invasive implantation” procedure is proposed in the thesis to implant the GDD subconjunctivally. The small size of the device allows its insertion using a #19-gauge needle.

To accurately design the desired cracking pressure and also predict the lifetime of the NC check-valve, parylene-C’s mechanical, thermal, and polymer properties are investigated. The results show that the properties of parylene-C are highly process-temperature-dependent and therefore can be tailored by adjusting the thermal annealing process.

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