Computer Chip Contact Lenses: The Future is NOW

By: Christopher De Guzman

Google announced in July 2014 that they will be partnering with Alcon, the eye care division of pharmaceutical giant Novartis, to develop "Google Smart Contact Lenses" for a variety of ocular and medical uses. Google submitted a patent application for two smart contact lenses in September 2015, and recently obtained approval last month. The two lenses that obtained approval are the glucose-sensing contact lens and the autofocus lens for presbyopic patients. Despite announcing the glucose-sensing lens contact lens first, Novartis claims that human trials for their autofocus lens will commence in 2016.

Google's "smart lens" technology has the potential to transform eye and health care by improving the quality of life and disease management of millions of people worldwide. Specifically, the groundbreaking prototype smart contact lenses aim to help diabetic patients manage their condition by providing a continuous, minimally invasive measurement of their body's glucose levels via a "smart contact lens" that will measure tear fluid in their eye while wirelessly sending the measurements to the user's mobile device. In addition, for presbyopic patients the "autofocus smart lens" has the potential to provide accommodative vision correction to help restore the eye's natural autofocus on near objects in the form of an accommodative contact lens or intraocular lens as part of the refractive cataract management. However, these could be just the start of a clever and innovative new product category of contact lenses. Google's patent leaves the door open for external-facing sensors that could detect a range of the wearer's biological data, including internal body temperature and blood-alcohol content. The sensors could also potentially gather data about the wearer's environment. According to the patent, the device could possibly sense allergens like grass or tree pollen, pet dander, and dust mite excretions.

Glucose is not the only entity that can be measured from tears. Tears also contain a chemical called lacryglobin that serves as a biomarker for breast, lung, prostate, ovarian, and colon cancers. Monitoring lacryglobin levels could be particularly beneficial for cancer patients who are in remission. Furthermore, drug delivery may be another use for future contact lenses. If a lens could dispense medication slowly over long periods of time, it would be better for patients than the short, concentrated doses provided by eye drops. However, Google claims that this type of lens would be challenging to construct. From cancer detection and drug delivery to night vision and reality augmentation, our eyes offer unique opportunities for both health enhancement and monitoring.

How does the smart contact lens work, you ask? The contact lens is composed of a tiny wireless chip and miniaturized glucose sensor that are embedded between two layers of soft contact lens material. The electronics lie outside of both the iris and the pupil so that there is no damage to the eye. A tiny pinhole in the lens lets tear fluid seep over the glucose monitor to obtain regular readings and measurements. The lens also features a tiny antenna, controller and capacitor that gathers information from the lens and transfers it from the eye to a device (such as a mobile device or handheld monitor) where that data can be read and analyzed. It will draw its power from that device and communicate with it using a wireless technology known as RFID. Right now, Google states that it can obtain a blood glucose level reading once every second. Google described the electronics in the lenses as being "so small they look like bits of glitter" and said the antenna is thinner than human hair. The smart contact lens is designed to ease the burden of the millions of diabetics worldwide who otherwise have to painfully prick their fingers multiple times everyday to monitor their blood sugar levels.

Google has also reported that it will ensure that any data transferred from the lens cannot be manipulated, since something like this could have potentially lethal consequences if patients inject the incorrect amount of insulin. Google has also worked to develop precautions against other kinds of complications, such as a piece that is similar to a circuit breaker to prevent the lens from overheating. Furthermore, plans to add small LED lights that could warn the patient by lighting up when their glucose levels have crossed above or below certain glucose level thresholds have been mentioned to be under further consideration. Potential obstructions presented by such a technology are that the LED lights contain the toxic metal arsenic. In addition, the performance of the contact lenses in windy environments and teary eyes is still unknown and yet to be determined.

How did Google do it? Google utilized the less famous advantage of Moore's Law to intensely shrink the size of computer chips so they can be utilized in new ways. Once they decided they were going to aim for a really tiny chip that could fit into a contact lens, they had to re-think everything they knew about building wireless electronics systems. First, they got rid of all the needless components and shrunk only the most important ones onto a very tiny computer chip. To do this, they had to completely redesign them, and in some cases, build totally new tools to manufacture the components. Then, instead of mounting the components on a typical fiberglass circuit board, they mounted them on a very thin, flexible, plastic-like film.

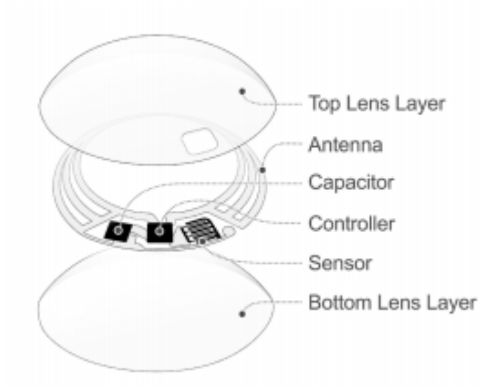

Figure 1: The Smart Contact Lens Design
Source: Google(x)

On the other hand, the autofocusing lens for presbyopic patients looks like it could be ready to be launched first. The goal of the lens is to adjust its shape depending on where the eye is looking, which would be especially helpful for the millions of presbyopic patients who need reading glasses. A current prototype of the lens utilizes photodiodes to detect light hitting the eye and determine whether the eye is pointed downward.

Experts were curious about these smart contact lenses will be powered ever since they were announced. Google claims that an external device will power the sensor, and it could be handheld or embedded into a wearable companion. Photo detector sensors and solar cells on the contact lens would harvest light to constantly power the device. Specifically, "An external reader device or 'reader' can radiate radio frequency radiation to power the sensor," the patent application states. "The reader may thereby control the operation of the sensing platform by controlling the supply of power to the sensing platform. In some examples, the reader can operate to intermittently interrogate the sensing platform to provide a reading by radiating sufficient radiation to power the sensing platform to obtain a measurement and communicate the result. The reader can also store the sensor results communicated by the sensing platform. In this way, the reader can acquire a series of analyte concentration measurements over time without continuously powering the sensing platform." The reader could also be built into "a pair of eyeglasses, jewelry (e.g., earrings, necklace), headband, head cover such as a hat or cap, earpiece, or other clothing" so that it could continually power the lens, the document explains later on. "The eye-mountable device is mounted on the pedestal such that the posterior concave side contacts the second end of the pedestal and the eye-mountable device is elevated from the base of the container," the patent application says.

Google and Novartis are far from the only compaines interested in upgrading the contact lens world with such new computer chip capabilities. In Switzerland, a company named Sensimed is working on a contact lens that measures the intraocular pressure (IOP) of glaucoma patients. Sensimed's "Triggerfish" system consists of a contact lens with embedded sensors that can sense subtle physical changes in a patient's eye, and then wirelessly transmit that data to a receiver worn around their neck. The Triggerfish lens is made of the same silicon hydrogel as many of the soft contact lenses currently on the market, but embedded within it is a microprocessor and a strain gauge that encircles its outer edge. When fluid accumulates in the eye, the diameter of the cornea changes, and that change is detected by the strain gauge. Data is processed and then transmitted via radio frequency to a receiver. In more than one-third of the 50 patients who were tested with the "Triggerfish" lens system, the results led to a direct, immediate change in treatment, Sensimed claims. For example, if a person's intraocular pressure increased at odd hours of the night, they could now detect it and change medication doses to counteract the IOP increase.

Moreover, researchers at the University of Michigan are using graphene to make infrared-sensitive contact lenses. These lenses may one day provide some form of night vision without the need of bulky headgear. Lastly, a Seattle-based company, Innovega, has developed a contact lens with a small area that filters specific bands of red, green, and blue light, giving users the ability to focus on a very small, high resolution display less than one inch away from their eyes without interfering with normal vision. This makes tiny displays attached to glasses look more like IMAX movie screens. Together, the lens and display are called iOptik.

As you can see, contact lenses have come a long way since the days of PMMA. Google and Novartis (Alcon) still have a long way to go with further development, human clinical trials and the FDA approval process, but I'm excited to see what the near future has in store. We have only thought of or seen similar devices in movies, but it is becoming quite clear that these could soon become a reality…The future is NOW!

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