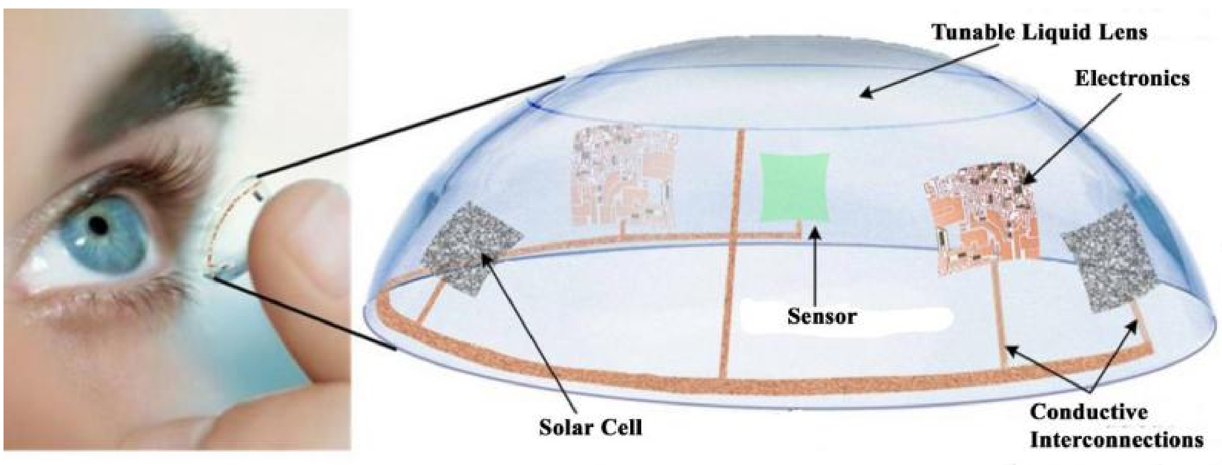
Fish and insects guide design for future contact lenses

March 14 2016



Many of the components for the contact lens -- the sensors, electronics, solar cells -- will be embedded along the edge of a flexible material. Credit: Dr. Hongrui Jiang

Making the most of the low light in the muddy rivers where it swims, the elephant nose fish survives by being able to spot predators amongst the muck with a uniquely shaped retina, the part of the eye that captures light. In a new study, researchers looked to the fish's retinal structure to inform the design of a contact lens that can adjust its focus.

Imagine a contact lens that autofocuses within milliseconds. That could be life-changing for people with presbyopia, a stiffening of the eye's lens that makes it difficult to focus on close objects. Presbyopia affects more than 1 billion people worldwide, half of whom do not have adequate correction, said the project's leader, Hongrui Jiang, Ph.D., of the University of Wisconsin, Madison. And while glasses, conventional contact lenses and surgery provide some improvement, these options all involve the loss of contrast and sensitivity, as well as difficulty with night vision. Jiang's idea is to design contacts that continuously adjust in concert with one's own cornea and lens to recapture a person's youthful vision.

The project, for which Jiang received a 2011 NIH Director's New Innovator Award (an initiative of the NIH Common Fund) funded by the National Eye Institute, requires overcoming several engineering challenges. They include designing the lens, algorithm-driven sensors, and miniature electronic circuits that adjust the shape of the lens, plus creating a power source - all embedded within a soft, flexible material that fits over the eye.

In their latest study, published in *Proceedings of the National Academy of Sciences*, Jiang and his team focused on a design for the image sensors. "The sensors must be extremely small and capable of acquiring images under low-light conditions, so they need to be exquisitely sensitive to light," Jiang said.

The team took their inspiration from the elephant nose fish's retina, which has a series of deep cup-like structures with reflective sidewalls. That design helps gather light and intensify the particular wavelengths needed for the fish to see. Borrowing from nature, the researchers created a device that contains thousands of very small light collectors. These light collectors are finger-like glass protrusions, the inside of which are deep cups coated with reflective aluminum. The incoming light hits the fingers and then is focused by the reflective sidewalls. Jiang and his team tested this device's ability to enhance images captured by a mechanical eye model designed in a lab.

In separate studies, the researchers have designed and tested a couple of different approaches for the contact lens material. For one approach, they formed a liquid lens from a droplet of silicone oil and water, which won't mix. The droplet sits in a chamber atop a flexible platform, while a pair of electrodes produces an electric field that modifies the surface tension of each liquid differently, resulting in forces that squeeze the droplet into different focal lengths. The lens is able to focus on objects as small as 20 micrometers, roughly the width of the thinnest human hair.

They developed another type of lens inspired by the compound eyes of insects and other arthropods. Insect eyes comprise thousands of individual microlenses that each point in different directions to capture a specific part of a scene. Jiang and his colleagues developed a flexible array of artificial microlenses. "Each microlense is made out of a forest of silicon nanowires," Jiang explained. Together, the microlenses provide even greater resolution than the liquid lens. The array's flexibility makes it suitable not only for contact lenses, but for other potential uses. Wrap it around a laparoscopic surgical scope and you've got a high-resolution, 360-degree view inside a patient's body. Mount it on a lamppost and you can see the surrounding intersection from all sides.

In order to change focus, the contact lens will also need to be equipped with an extremely small, thin power source.

Jiang's working solution: a solar cell that simultaneously harvests electrons from sunlight, converting them into electricity, and that also stores energy within a network of nanostructures. It works much the way a conventional solar panel does, but the addition of storage capability within a single device is novel, Jiang said. The device still needs tweaking, but the team is optimistic that it will be powerful enough to drive the lens yet small enough to fit the space available.

A prototype for clinical testing may still be five to 10 years off, Jiang said. Once it's available, however, it may not cost much more than conventional contact lenses. "There's a huge market for this and with mass production, the cost is not likely to be a barrier," he said.

More information: Artificial eye for scotopic vision with bioinspired all-optical photosensitivity enhancer, *PNAS*, www.pnas.org/cgi/doi/10.1073/pnas.1517953113

Provided by National Eye Institute