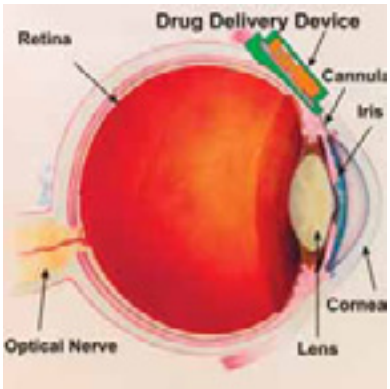
Out of Sight Implants for the Eye

A new microfluidic device, designed by bioengineer Ellis Meng and an interdisciplinary team of researchers, could be a gift to the vision-impaired.

Out with the old and in with the new. In a few short years, microfluidic devices may replace eye drops, gooey ointments and intraocular injections for those suffering from glaucoma and other vision-threatening diseases.

Assistant Professor Ellis Meng is a microelectromechanical systems (MEMS) fabrication specialist in the Viterbi School's Department of Biomedical Engineering and the winner of a National Science Foundation Faculty Early Career Development Award. With a team of interdisciplinary scientists from the Keck School of Medicine at USC and Caltech, she has developed a new generation of intraocular devices that promise to alleviate some of the more invasive and often painful interventions associated with the management of glaucoma and age-related macular degeneration , two of the leading causes of blindness in the world.



Schematic of the human eye shows where an intraocular device is placed.

Glaucoma is an incurable disease characterized by gradual loss of peripheral vision. An estimated 3 million to 6 million people in the United States, including 4 percent to 7 percent of the population over age 40, have elevated eye pressure. The disease occurs when the optic nerve is damaged by increased pressure inside the eye. As it worsens, the field of vision gradually narrows and eventually leads to blindness.

Age-related macular degeneration (AMD) is the leading cause of blindness in people 55 and older, and primarily affects the macular photoreceptors that serve the central vision of the eye. The condition impacts a person's ability to read, recognize faces and drive, making them legally blind. Estimates indicate that there are about 1.75 million Americans with AMD; by 2020, that number is expected to climb to nearly 3 million, and at the same time, an additional 8 million people will have clinical signs of AMD and be at high risk of progression to late-stage vision loss.

"There are physiologic barriers to treatment, because the medication has to be delivered to the interior and usually the back wall of the eye, where the macula is located, and that's a difficult place to reach," Meng says. "It requires monthly injections into the eye with a needle. That introduces the possibility of side effects, such as infection and bleeding, not to mention the associated pain and discomfort of the injections."

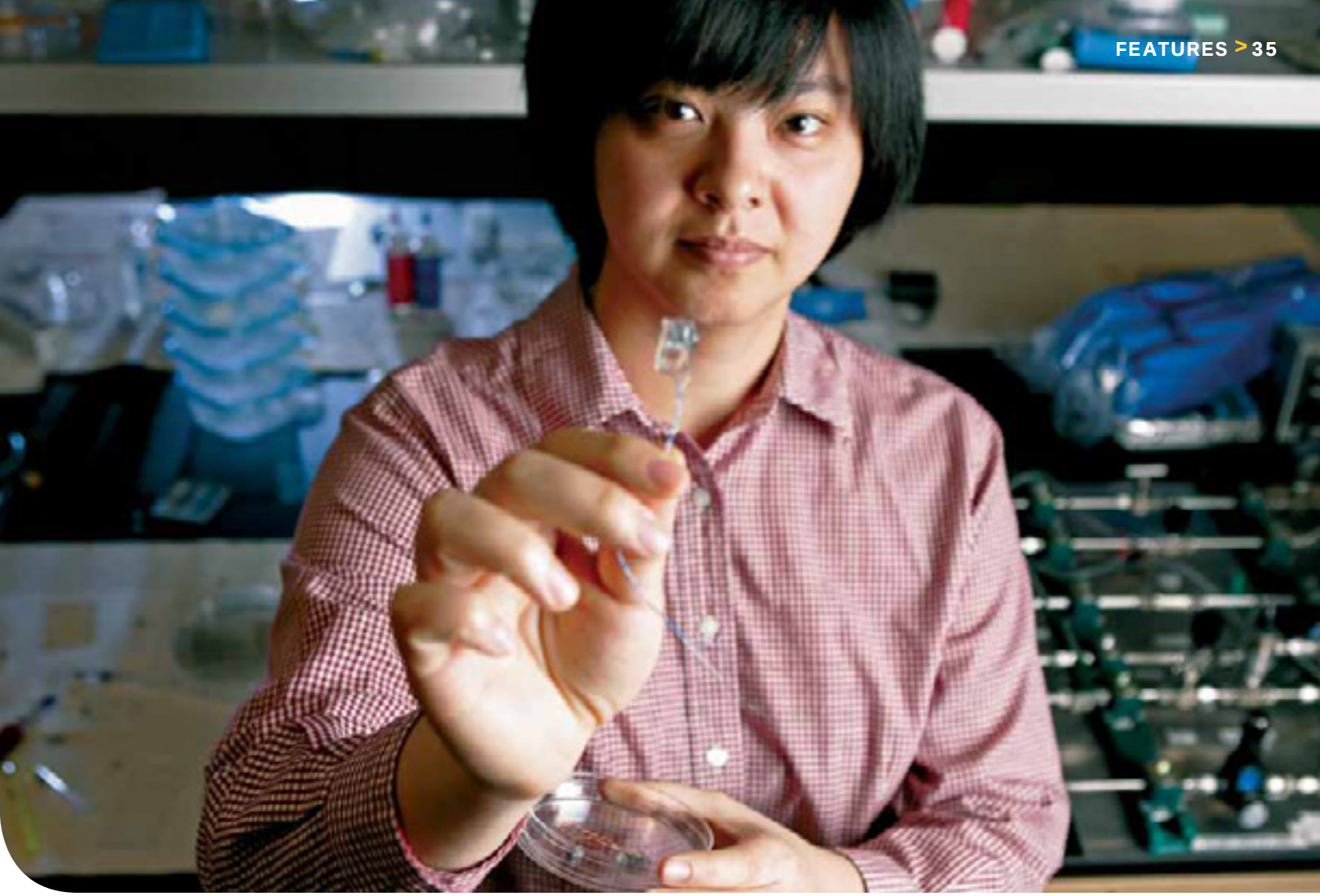
Microfluidic devices, which are based on MEMS technology, offer several advantages over traditional approaches to glaucoma therapy: They can be implanted permanently in the eye and can be refilled.

"We are about two years away from commercializing the first implantable intraocular delivery system for AMD, as well as glaucoma management, and for the treatment of other eye diseases," says Meng, holding up an implant about the size of a wristwatch battery. "I think this is really going to improve our ability to slow the progression of chronic, degenerative conditions."

Meng has spent several years experimenting with microfluidic devices. Her current devices measure about 5 to 7 millimeters in diameter and act like a tiny chemistry lab to deliver minuscule volumes of medication to the eye. The device is more like a tiny reservoir of fluid attached to an even tinier tube—called a "cannula"—which is threaded through the interior of the eye and fastened to its anterior wall.

Unlike current intraocular devices, Meng's is refillable. Operated either manually or electrically, it only has to be implanted once, which is an appealing feature for anyone who has repeatedly undergone more invasive procedures. Of course, the more bells and whistles that are added, the more bioengineering smarts it takes to design these microdevices. But that isn't a problem.

Meng is developing her implant with help from one of the nation's leaders in retinal prosthetics, Mark S. Humayun, a physician and biomedical engineer who is associate director of ophthalmology research at Doheny Eye Institute, Keck



Ellis Meng holds up one of her new eye implants, which is about the size of a wristwatch battery.

School of Medicine at USC. Humayun is on the faculty for both the Keck and the Viterbi Schools and directs the Biomimetic Microelectronic Systems (BMES) Engineering Research Center, a collaboration between the Viterbi and Keck Schools that is developing novel implants to treat disabilities such as blindness, paralysis and memory loss.

Humayun is a surgeon with a Ph.D. in biomedical engineering. He has spent the last 20 years developing an implantable artificial retina that can stimulate the remaining photoreceptor cells in the retinas of people who are suffering from retinitis pigmentosa. This degenerative disease causes blindness as the rods and cones in the eye lose their ability to function.

Humayun sees intraocular implants as a promising technology for treating and slowing down the progression of degenerative eye diseases. The microfluidic device that Meng's group has fabricated shows potential: It has done well in early pre-clinical implantation studies and, in early tests, appears to be working as expected.

The device is made of micro-machined silicon and biocompatible polymers. The drug reservoir is attached to a tiny electrolysis-actuated pump that will turn the mechanism on like a faucet.

The implant is surgically embedded in the eye wall just behind the cornea, the transparent, dome-shaped window covering the front of the eye. Meng says the tiny tube is inserted through the eye wall and can be threaded to the front or back part of the eye. Each time the electrolysis pump is activated, a controlled dosage of medication will be injected.

In preliminary experiments, Meng and her co-investigators used dye to visualize initial delivery in porcine (pig) eyes, then later used phenylephrine, a drug used to dilate the pupil, in rabbit eyes to obtain physiological evidence of the drug's effect in vivo. The reservoirs were repeatedly dispensed and refilled, and the researchers recorded notable effects on pupil dilation after dispensation of the drug.

"We didn't have any functional damage from repeated refilling of the device," Meng reports. "We observed pupil dilation with repeated dispensation, which means the medication reached its destination."

Her results were presented in various professional meetings and were well- received, signaling a successful conclusion to Phase 1 testing. Now it's time to take the next step. //