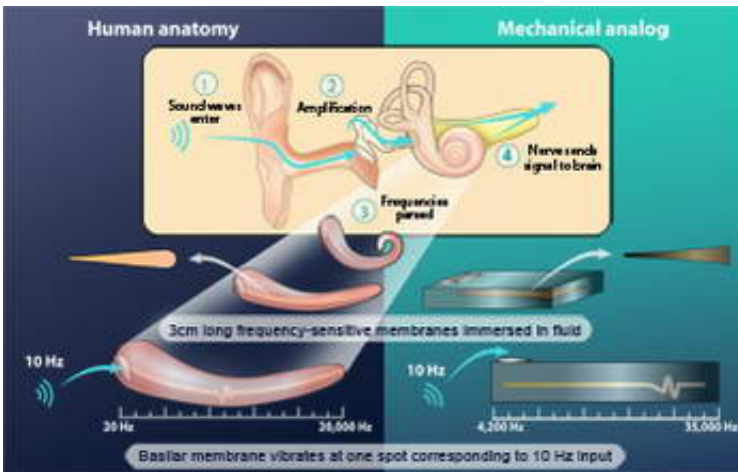


New MEMS sensor based on human organ is no tin ear

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Researchers at the University of Michigan are developing a mechanical cochlea, a device that functions much like its human counterpart in the ear. Yet, because it is composed of micromachined parts and integrated circuits, the apparatus should be inexpensive to manufacture and could potentially capture a range of frequencies well beyond those of human hearing.

This illustration compares the artificial cochlea to the mammalian organ that inspired Karl Grosh and Robert White to create their new sensor technology. Credit: Zina Deretsky, National Science Foundation

While designed primarily as a highly efficient sensor to detect sound waves underwater, the machined cochlea could one day substitute for the microphone and much of the electronics in cochlear implants at a much lower cost.

Under development by National Science Foundation student-fellow Robert White and NSF CAREER awardee Karl Grosh, the "microengineered hydromechanical cochlear model," was first reported in the Jan. 21, 2005, edition of the *Proceedings of the National Academy of Sciences*. The researchers described both a mathematical model and the device they had built--a system capable of detecting specific frequencies across a wide range.

"The machined cochlea Grosh and White developed fills a critical need for efficient acoustic sensing, as well as a need of the hearing-impaired. It could potentially offer a less-expensive substitute for some hardware in cochlear implants," says Ken Chong, interim director of NSF's Civil and Mechanical Systems (CMS) Division.

The division funded Grosh's CAREER award, which recently went to create a new program in nano-bio mechanics to promote such research.

The hydromechanical cochlea is a microelectromechanical system, or MEMS, device, meaning that it is manufactured--and functions--at a scale of a few millionths of a meter. While it does not yet generate electrical signals, it accurately collects sound data at frequencies between 4,200 hertz and 35,000 hertz, overlapping much of the range for the human ear (20 hertz to 20,000 hertz).

"This is a critical step on the way to an engineered cochlea," says Grosh. "With controlled and repeatable methods, we've created a fluid chamber and membrane that together mimic the functions of the basilar membrane and fluid-filled chambers of the human cochlea. We expect

this type of device, once perfected, to find uses in all kinds of sound-sensing applications where low power is needed."

The cochlea, located in the inner ear of all mammals, is a spiral-shaped, tubular, fluid-filled organ that receives sound waves from the bones of the middle ear and generates electrical signals for the brain to interpret.

The new device, while not the first of its kind, has three main benefits over existing artificial cochlea: the methods behind its construction are ideal for mass production; its 3-centimeter length is comparable to the unwound human cochlea, which is important for potential hearing aid applications; and because there are no moving parts, the sensor is incredibly efficient--a critical property for potential use on autonomous underwater vehicles such as unmanned military craft that rely on battery power.

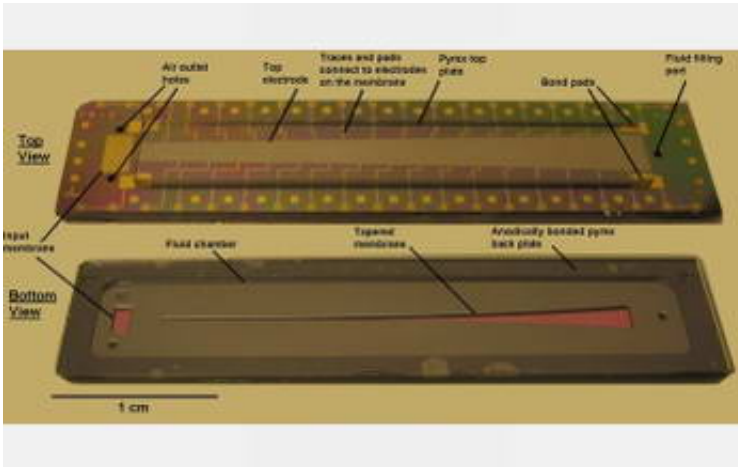
"When someone builds a microphone, they don't do it the same way the ear does," says White. "And yet, the ear is an extremely successful design. We were interested in seeing whether we could duplicate that success."

Just like optical chips based in part on the human retina, or walking robots that mimic human motion, the new design benefits from researchers' growing understanding of the human body. White and Grosh are not attempting to decipher the inner workings of the cochlea. Rather, they are trying to engineer knowledge of the cochlea into new devices. Still, through their efforts to design an analog, the researchers are learning more about how the biological cochlea works, and in some cases determining that structures in the ear, such as the outer hair cells, may have a greater influence on hearing than previously thought.

"Many researchers have attempted to emulate the function of the cochlea by using physical models," says Grosh. "Our effort is novel as it takes

advantage of the tremendous control available through micromachining techniques."

With these processes, the researchers may be able to craft large batches of inexpensive devices that each incorporates tiny, precise features.



Detailed image of an earlier artificial cochlea developed by the University of Michigan researchers. Credit: Karl Grosh, University of Michigan

In its simplest form, the new device consists of a rigid, micromachined Pyrex glass channel filled with silicone oil and topped by a thin, tapered-width membrane of silicon nitride. The membrane is sensitive to higher frequency vibrations at its skinniest end and gradually lower-frequency vibrations further along the widening structure.

A small, separate membrane of the same material, roughly 1 millimeter by 2 millimeters, provides another "window" to the fluid-filled chamber. This small piece of silicon nitride receives the initial sound waves and

transmits them into the main chamber much like the stapes in the ear transmits sounds to a human cochlea.

If one generates a sound, the device resonates in specific locations in response to the vibrations produced. Each part of the membrane resonates with a specific frequency, so when a sound wave strikes the device, the membrane vibrates most excitedly at the location that corresponds to the incoming wave. That is the site where the sound wave "crests," says White.

While the component can detect sounds, it is not yet configured to do anything with the information. The next step is to affix to the membrane sensors that can convert the vibration energy into electrical impulses a processor can recognize.

"Microelectronics and microfabrication help us complete the next step, adding many channels of electronic output and developing active control like we see in the biological cochlea," says Grosh.

Grosh and White hope to demonstrate functioning electronics and sensing materials for a 32-channel device in the near future. Adding active control to the structure will be more challenging, but they expect dramatic improvements in device performance.

Source: NSF

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