

TECHNOLOGY FACT SHEET

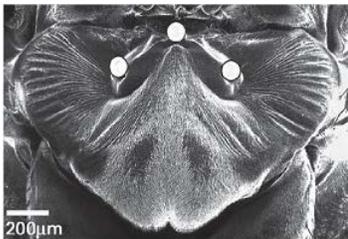
HIGHLY ACCURATE, MEMS DIRECTIONAL ACOUSTIC SENSOR

Introduction

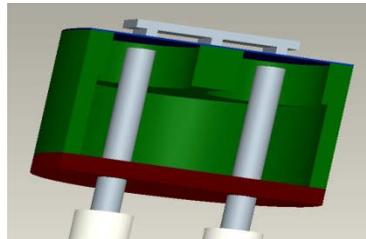
Biomimetics—that is, taking inspiration from nature to solve human problems—has yielded a profound advance in acoustic sensor technology, one that possesses unrivaled directional accuracy and capability for miniaturization. Researchers at the Sensors and Electron Devices Directorate of the U.S. Army Research Laboratory (ARL), Adelphi, Maryland, successfully created and tested a fabrication process for the sensor set, which was designed collaboratively with the University of Maryland. ARL’s fabrication methodology uses proven semiconductor device manufacturing techniques that will result in decreased production cost, while still providing flexibility for continued development of this sensor system.

Concept

Sound localization systems nominally operate with an array consisting of at least two conventional microphones. Such arrays sense differences between the arrayed mics in the time-of-arrival and intensity of sound waves. These differences provide informational cues that help pinpoint a sound source. Unfortunately, miniaturization of these conventional systems reduces the distance between the microphones, which diminishes the time and intensity differences. This erodes directional sensitivity and ultimately renders the system ineffective.



Auditory organ of *O. ochracea* (Image source: Miles, Robert, Hoy, J. Acoust. Soc., 1995)



Conceptual Drawing of Fiber Optic Acoustic Localization device inspired by *O. Ochracea* (Image source: ARL)

In an effort to solve the problem of size versus sensitivity, engineers and scientists have turned to biomimetics, where *Ormia ochracea*, a small parasitic fly, has become the subject of widespread study. This insect has garnered a lot of attention recently due to its ability to determine the direction of a sound source with exceptional accuracy (i.e., within 2°). This ability comes from its unique hearing organ, a tiny but complex structure within the fly positioned near the base of its front legs. The hearing organ has tympani-like membranes that are interconnected, a key characteristic that actually amplifies time-of-arrival differences. This results in microsecond-level resolution and provides the fly with highly sensitive directional hearing. ARL has fabricated the joint ARL-Univ. of Maryland design, which closely mimics the interaural mechanics of *O. ochracea*. Tests demonstrate the system nearly replicates the fly’s capability, producing a sound localization accuracy of 2 °.

Invention Overview

- ❖ Compact size with directional capabilities of much larger acoustic sensor arrays
- ❖ Constructed with commonly available materials using MEMS fabrication techniques
- ❖ Size and sensitivity opens an assortment of opportunities in different commercial and government product markets
- ❖ TRL 4 – Two-membrane sensor prototype built, bench-tested, and field-tested on robotic platform
- ❖ Final patent application filed
- ❖ “Microscale implementation of a bio-inspired acoustic localization device” SPIE 2009 available on the web

Doing Business with ARL

- ❖ ARL is a leader in partnering with domestic firms
- ❖ Successfully developed and implemented innovative tools to ease the technology transfer process
- ❖ Tools include Patent License Agreements (PLAs); Cooperative Research and Development Agreements (CRADAs); Test Services Agreement (TSA); and others
- ❖ Visit www.arl.army.mil for more information

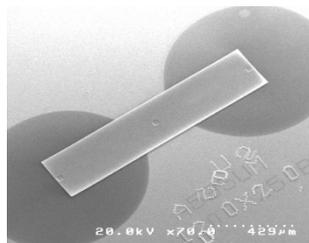
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Features/Capabilities/Intellectual Property

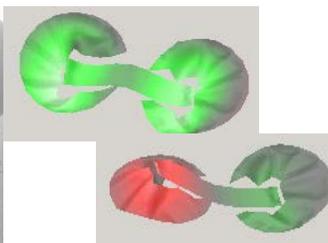
O. ochracea has an interaural distance between tympanic membranes (eardrums) of only 500µm, making it an ideal model for creating miniature acoustic sensors. However, conventional machining processes are not adequate to produce sensors on this size-scale with precision and in commercial quantities. This ARL invention uses micro-electro-mechanical systems (MEMS) machining techniques specifically tailored to fabricate thin film membranes and stiff coupling beams necessary to mimic the architecture of *O. ochracea*. This results in a device an order-of-magnitude smaller than a comparable conventional array (1.25 mm vs. 12 mm) and much more sensitive, with a demonstrated interaural time delay amplification up to 20x (compared to 4x for a conventionally machined device and 30x for *O. ochracea*).

Other features/capabilities/intellectual property offered by this invention include the following:

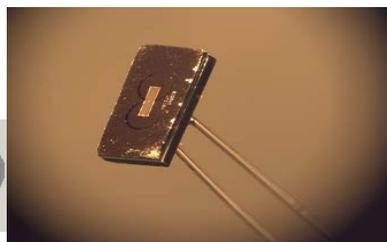
- Multiple membrane devices possible, increasing locational capability
- Extremely small assembled devices (less than 5 mm)
- SEDD IP includes novel materials selection and fabrication process



SEM image of fabricated MEMS device (Image source: ARL)



Measured Bending/Rocking modeshapes of MEMS device mimic *O. Ochracea* (Image source: ARL)



Integrated device utilizing optical fiber detection (Image source: Univ of Maryland)

Potential Markets/Applications

MEMS microphone and acoustic sensor technology has grown from less than 12 million units sold worldwide in 2003 to more than 340 million sold in 2009. The total available market for MEMS acoustic devices for cell phone, consumer electronics, headsets, hearing aids, and sensor products is anticipated to be 535 million units in 2013. Applications for the ARL invention include the following:

Commercial Applications:

- Non-intrusive sound localization for law enforcement, security
- Acoustic receiver for navigation of autonomous robots/vehicles
- Enhancement of hearing aids
- Medical acoustic imaging

Military Applications:

- Sensors to pinpoint sniper, mortar fire
- Soldier worn device to localize threats
- Navigation of small robotic platforms

Key Advantages & Benefits

- ❖ Coupled three- and four-membrane devices being fabricated to investigate multi-dimensional azimuth and elevation angles
- ❖ Size and frequency range scalable to meet application needs
- ❖ Anticipated production cost not expected to be significantly different from other MEMS devices
- ❖ Inventor team available to work with commercialization partner

Contact Information

This technology was developed by ARL. It is now available for licensing and CRADA opportunities.

For further information please contact:

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