A new triboelectric auditory sensor for social robotics and hearing aids

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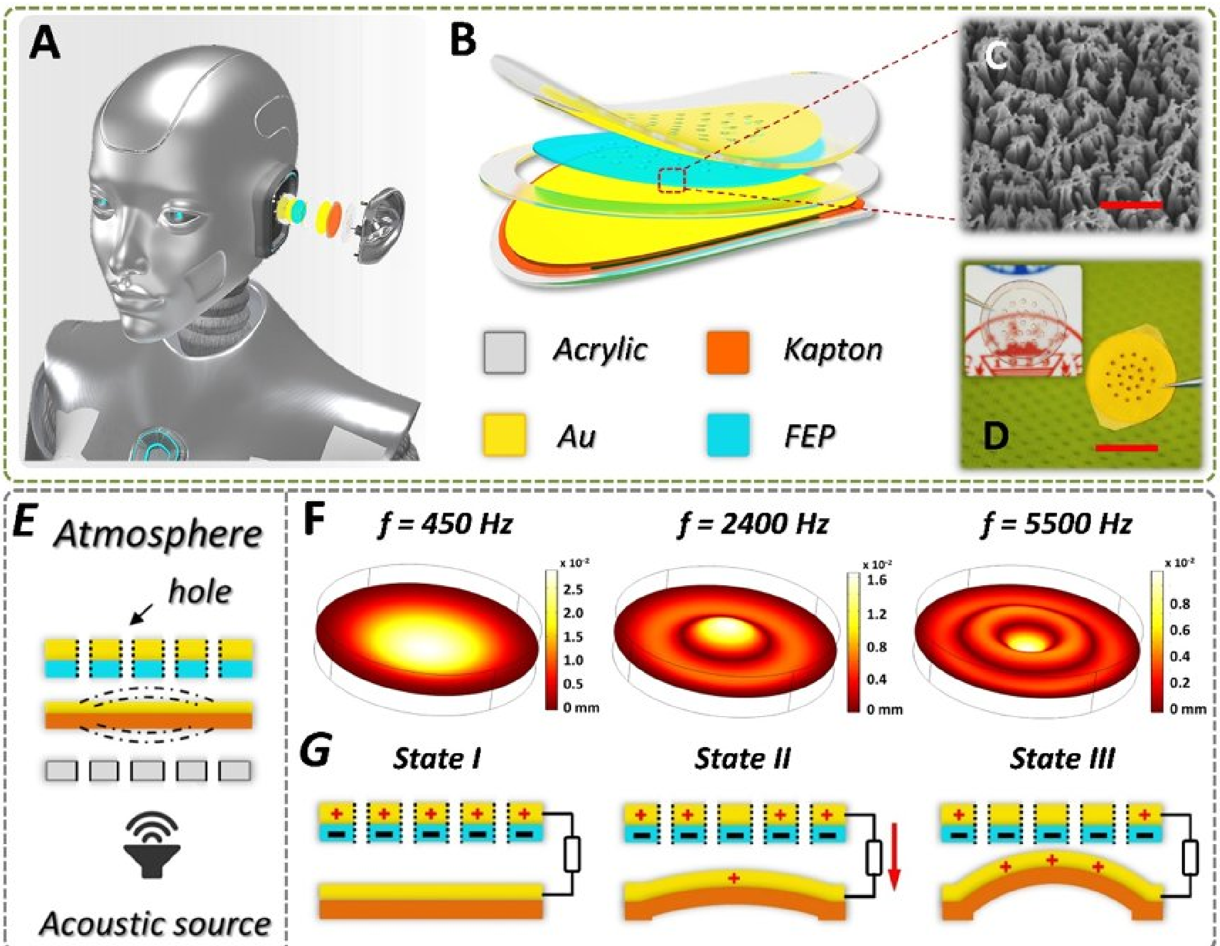


Structure and mechanism of the TAS. Credit: Hu et al.

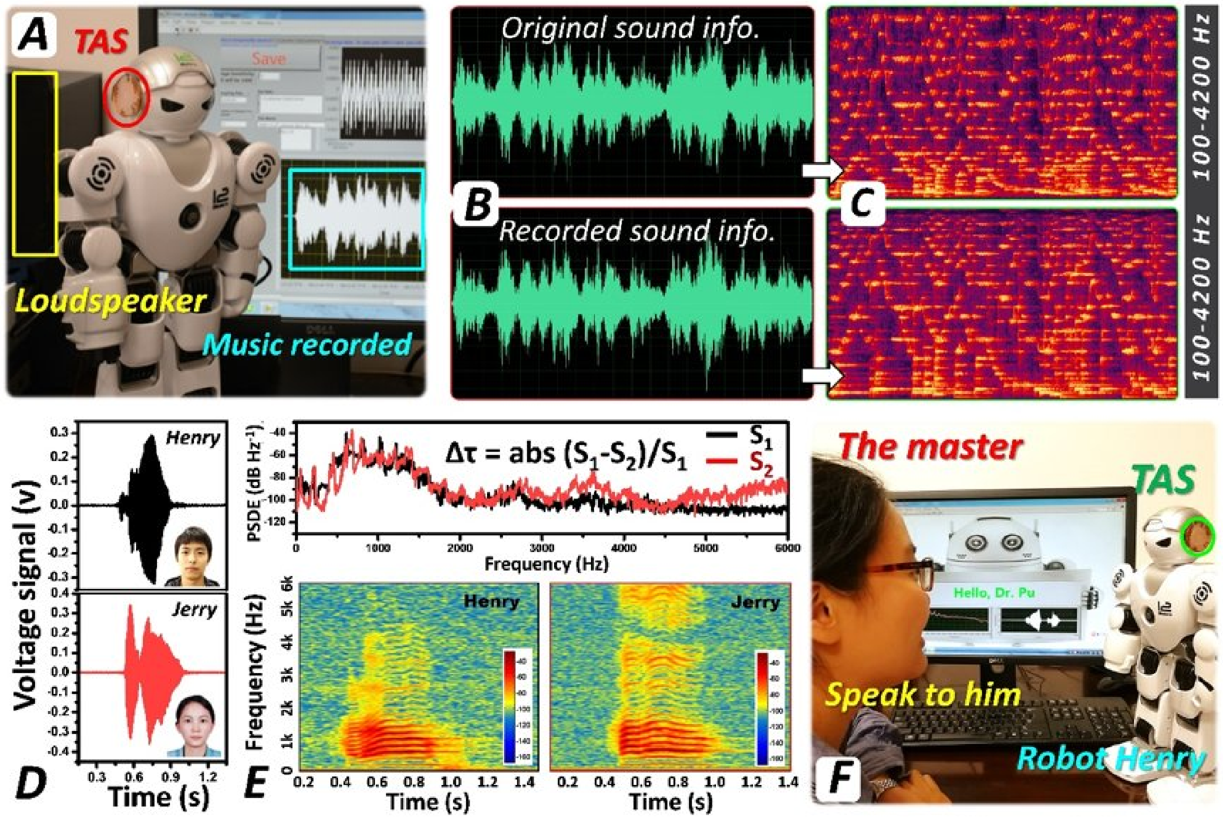
Researchers from Chongqing University, in China, have recently developed a self-powered triboelectric auditory sensor (TAS) that could be used to build electronic auditory systems for external hearing aids in intelligent robotics applications. Their recent study, published in *Science Robotics*, could inform the creation of a new generation of auditory systems, addressing some of the key challenges in the field of social robotics.

The auditory system is the most straightforward and effective means of communication between human beings and robots. Ideally, robotic auditory systems should allow robots to listen to human instructions while also perceiving their vocal intonations, in order to respond accordingly.

One of the key aims of social robotics is hence to design auditory sensors that are powerful and sensitive in a wide frequency range. These applications could also benefit the 10 percent of the global population that have hearing impairments.

"Commonly, people with impaired hearing always lose one or several specific frequency regions," the researchers who carried out the study told Tech Xplore. "The purpose of external hearing aids is to amplify the specific impaired sound regions to the audible level for those people. Therefore, the use of auditory sensors with frequency selectivity as hearing aid devices for recovering impaired hearing would enhance human-robot social interactions."

An additional challenge within the field of robotics is related to power and energy. To successfully design auditory sensors with broadband frequency response and frequency selectivity, researchers should use traditional acoustic sensors with precise signal processing circuits, which raise the power consumption and reduce the working period.



Application of the TAS for imitating an auditory system. Credit: Hu et al.

"The conventional way of building self-powered acoustic sensors is based on the piezoelectric effect and trapezoid device architecture," the researchers explained. "However, piezoelectric sensors have a fairly low output signal and a relatively high frequency response region in comparison with the frequency range of the human voice. In addition, the multi signal channels, complicated fabrication process and piezoelectric materials substantially improve their costs."

To address these problems, the researchers designed a circular-type, single-channel, and self-powered auditory sensor (TAS) that is easy to fabricate, based on triboelectric nanogenerator technology.

Nanogenerators are a type of technology that converts mechanical and thermal energy into electricity.

There are three main types of nanogenerators: piezoelectric, triboelectric and pyroelectric. Both piezoelectric and triboelectric generators harvest mechanical energy to create electricity, but while the former do this through a nano-structured piezoelectric material, triboelectric ones achieve it via a conjunction of the triboelectrification and electrostatic induction effects.

Credit: Hu et al.

"The highlights of our TAS device are the self-powered sensing and tailorable spectrum properties," explained the researchers. "TAS has a vibration membrane covered with a conductive layer and a bottom conductive layer covered with a tribo-material layer. When under acoustic wave, the membrane vibration causes contact between the membrane and tribo-material, creating charge distribution. Due to the electrostatic induction effect, the vibration would generate signal output through two conductive layers. For each fixed membrane, there would be a specific vibration character. Because of the simple structure of TAS, we can design the boundary condition of the membrane to realize the customizable spectrum that we need."

When tested, the sensor developed by the researchers produced a high output signal, board band frequency response, and frequency selectivity property in the human voice range. Their sensor is also relatively easy to build and provides a customizable spectrum in a single channel device. "The high output signal and single channel may largely reduce the signal processing, thus reducing power consumption," the researchers said. "The materials used and its easy fabrication improve the feasibility of designing transparent auditory systems and a broad range of other devices. We think this technique could provide a cost-economic and energy-efficient auditory system for both robotic and hearing aid applications."

The work of this team of researchers highlights the sizeable potential of triboelectric nanogenerator technology to meet challenges in the field of social robotics and to build more effective hearing aids. They are now planning the development of new sensors for a variety of human-robot interactions, while pushing their recently developed technology towards industrialization.

More information: Hengyu Guo et al. A highly sensitive, self-powered triboelectric auditory sensor for social robotics and hearing aids, *Science Robotics* (2018). DOI: 10.1126/scirobotics.aat2516

Abstract
The auditory system is the most efficient and straightforward communication strategy for connecting human beings and robots. Here, we designed a self-powered triboelectric auditory sensor (TAS) for constructing an electronic auditory system and an architecture for an

external hearing aid in intelligent robotic applications. Based on newly developed triboelectric nanogenerator (TENG) technology, the TAS showed ultrahigh sensitivity (110 millivolts/decibel). A TAS with the broadband response from 100 to 5000 hertz was achieved by designing the annular or sectorial inner boundary architecture with systematic optimization. When incorporated with intelligent robotic devices, TAS demonstrated high-quality music recording and accurate voice recognition for realizing intelligent human-robot interaction. Furthermore, the tunable resonant frequency of TAS was achieved by adjusting the geometric design of inner boundary architecture, which could be used to amplify a specific sound wave naturally. On the basis of this unique property, we propose a hearing aid with the TENG technique, which can simplify the signal processing circuit and reduce the power consuming. This work expresses notable advantages of using TENG technology to build a new generation of auditory systems for meeting the challenges in social robotics.

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