Design and Implementation of Multichannel Piezoelectric Acoustic Sensor

R. S. Hallikar[1], S. Munshi[1], M. U. Kumari[1], K. Padmaraju[2]

[1]R. V. College of Engineering, Bengaluru, Karnataka, India
[2]JNTU Kakinada, Kakinada, Andhra Pradesh, India

Abstract

An ear being the most essential sense organ of human body plays a vital role in communication. There is estimated 5.3% of the world's population suffering from hearing loss according to WHO out of which 7% of India's population require hearing aid. Patient suffering from hearing loss is mainly due to the damage of inner ear snail-shell like structure cochlea containing hair cells and generally coined as sensorineural hearing loss. The hearing aid available in the market just amplifies the incoming acoustic signals, which require an external power supply along with a speech processor. The cochlear implants (CI) on the other hand try to regain hearing closer to that of natural hearing. The research is based on simulation studies of a multichannel piezoelectric acoustic sensor that mimics the functionality of the natural basilar membrane (NBM) without an external energy source and signal processing unit.

Mimicking the inner ear membrane, that plays the main role in frequency separation of incoming sound waves. The inner ear hair cell generates the electrical impulse because of potential difference between the hair cells, which stimulate the brain cells there by regaining hearing. The design for an artificial basilar membrane (ABM) was chosen to be trapezoidal in shape, so that with varying width different positions of ABM resonate at specific frequency. The length was chosen to be 28mm with varying width from 1mm to 8mm.

The entire mechanical behavior of piezoelectric material was carried out in COMSOL Multiphysics as the simulation tool. FEA analysis of the McPAS model was carried out with COMSOL Multiphysics. Simulations were carried out up to 10 KHz of audible frequency range. Each specific location of a membrane vibrates with relatively large amplitude at its local resonant frequency, thus generates larger electrical signal output on the resonating position than those on non-resonating positions. The colors and deformation indicate relative displacement of each point on the membrane at local resonance frequencies. At resonant position maximum displacement (red color) exists. This maximum displacement changes gradually from apex area (wide width) to base (narrow width) area as frequency increases.

The simulation in COMSOL Multiphysics proved that the McPAS could separate the acoustic signals based on their frequency.

Higher frequency signals resonated at a location closer to the base and the lower frequencies near apex. The frequency range applied to the McPAS was 1 kHz-10 kHz and observed maximum displacement was 2.85um.

Reference

1] H. R. Cooper, L. C. Craddock, Cochlear Implants – A Practical guide, Whurr Publishers London and Philadelphia, pp. 1, 2006.
[2] N. S. Lawand*1, Joost van Driel*1, and P. J. French*1, Electric Field Density Distribution for Cochlear Implant Electrodes, Delft University of Technology, January 2012.
[3] V. Békésy, G. Some biophysical experiments from fifty years ago. Annu. Rev. Physiol. 1974, 36, 116.
[4] Shintaku, H.; et.al Development of piezoelectric acoustic sensor with frequency selectivity for artificial cochlea. Sens. Actuators A Phys. 158, 183192,2010.
[5] Y. Jung, et.al, Development of a Multi-Channel Piezoelectric Acoustic Sensor Based on an Artificial Basilar Membrane, Department of Nature-Inspired Nanoconvergence Systems, Korea Institute of Machinery and Materials,2014.
[6] D. J. Anderson ,et.al, “Batch-Fabricated Thin-film Electrodes for Stimulation of the Central Auditory System”, IEEE Trans on Biomedical Engg. Vol. 36, No. 7, , pp. 693-704,July 1989.
[7] Tarn, J.-Q., et.al. end effects in multilayered piezoelectric laminates. Int. J. Solids Struct. , 39, 49794998.2002
[8] Tognola, G., et al. "Numerical Modeling and Experimental Measurements of the Electric Potential Generated by Cochlear Implants in Physiological Tissues. Instrumentation and Measurement", IEEE Transactions on, Volume: 56 Issue:1, 187-193,February 2007.

Figures used in the abstract

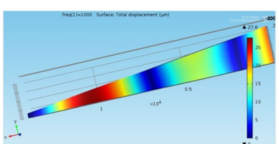

Figure 1: Surface displacement for 1KHz frequency.

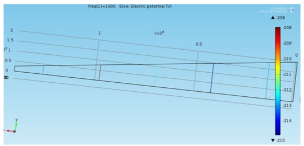

Figure 2: Electric potential for 1KHz.

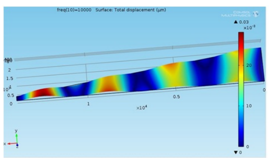

Figure 3: Surface displacement for 10KHz frequency.

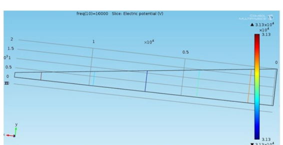

Figure 4: Electric potential for 10KHz.