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Acoustic Biosensor for Cochlear Device

The tympanic and basilar membranes are essential for sound reception and frequency selectivity. The tympanic membrane captures acoustic waves and transmits vibrations, while the basilar membrane enables mechanical frequency discrimination in the cochlea, where hair cells convert vibrations into neural signals. Inspired by these mechanisms, this study presents a bionic acoustic sensor integrating both functions into a compact, piezoelectric-based biosensor that directly converts sound waves into electrical signals.The sensor is made from electrospun polyvinylidene fluoride (PVDF)/thermoplastic polyurethane (TPU) nanofibrous membrane, utilizing PVDF's piezoelectricity for efficient signal conversion and TPU's flexibility for mechanical adaptability. By mimicking tympanic sound reception and basilar frequency selectivity, the device simplifies the auditory process into a miniaturized, high-sensitivity biosensor.Performance was tested using a custom-built LabVIEW module, synchronizing input and output signals from a microphone, Laser Doppler Vibrometer (LDV), and sensor.
Frequency sweep experiments confirmed a strong vibrational response, while COMSOL Multiphysics simulations accurately predicted resonance frequencies, later validated experimentally. Acoustic-structure interaction models ensured real-world auditory replication.Results highlight how membrane geometry and material properties enhance frequency tuning and sensitivity. Simulated vibrational modes between 100 Hz and 3000 Hz matched experimental data. The sensor's response to controlled acoustic stimuli from a speaker was captured in real time.By merging tympanic and basilar membrane functions, this bionic acoustic sensor offers a breakthrough in hearing restoration. Its compact piezoelectric-based design has applications in cochlear implants, auditory prosthetics, and bio-inspired sensors, with strong experimental validation supporting biomedical acoustics and AI-driven hearing technologies.