Flexible ultrasound-induced retinal stimulating piezo-arrays for biomimetic visual prostheses

Qifa Zhou

Department of Biomedical Engineering, Viterbi School of Engineering, University of Southern California, Los Angeles, California 90089, USA

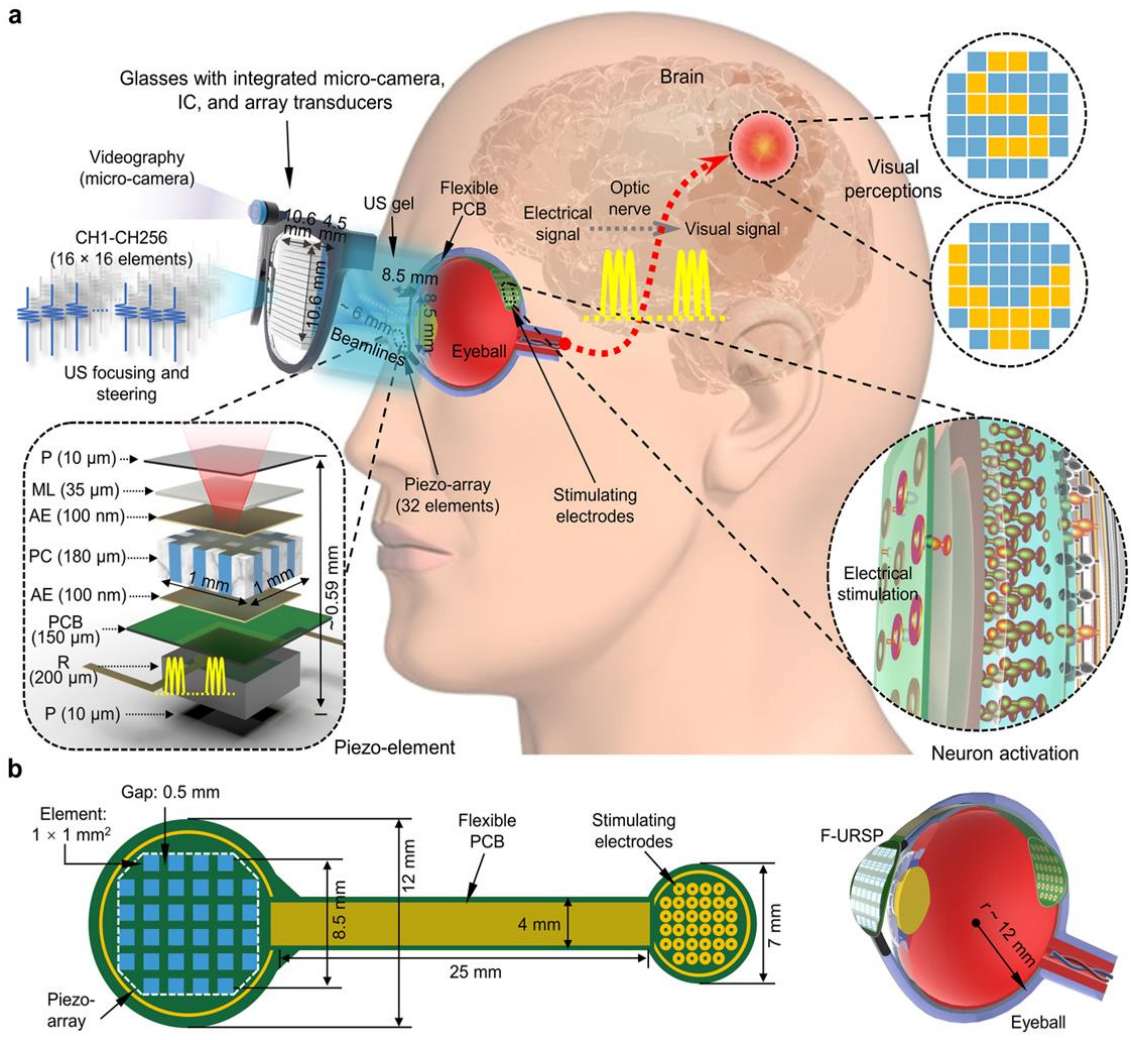
Roski Eye Institute, Department of Ophthalmology, Keck School of Medicine, University of Southern California, Los Angeles, California 90033, USA

Presenting Author' Biography

Dr. Qifa Zhou received his Ph.D. degree from the Department of Electronic Materials and Engineering at Xi'an Jiaotong University. He is currently a professor of Biomedical Engineering and Ophthalmology at the University of Southern California (USC). Dr. Zhou is a fellow of the Institute of Electrical and Electronics Engineers (IEEE), the International Society for Optics and Photonics (SPIE), and the American Institute for Medical and Biological Engineering (AIMBE). He has published more than 320 peer-reviewed papers including Science, Nature Medicine. Nature Biomedical Engineering, Nature Communication and Materials in Progress. His research focuses on the development of piezoelectric materials for high-frequency ultrasonic transducers/array and photoacoustic imaging as well as multimodality imaging.

Graphical Abstract

Electronic visual prostheses, or biomimetic eyes, have shown the feasibility of restoring functional vision in the blind through electrical pulses to initiate neural responses artificially. However, existing visual prostheses predominantly use wired connections or electromagnetic waves for powering and data telemetry, which raises safety concerns or couples inefficiently to miniaturized implant units. Here, we present a flexible ultrasound-induced retinal stimulating piezo-array that can offer an alternative wireless artificial retinal prosthesis approach for evoking visual percepts in blind individuals. The device integrates a two-dimensional piezo-array with 32-pixel stimulating electrodes in a flexible printed circuit board. Each piezo-element can be ultrasonically and individually activated, thus, spatially reconfigurable electronic patterns can be dynamically applied via programmable ultrasound beamlines. As a proof of concept, we demonstrate the ultrasound-induced pattern reconstruction in ex vivo murine retinal tissue, showing the potential of this approach to restore functional, life-enhancing vision in people living with blindness.


a
Glasses with integrated micro-camera, IC, and array transducers
Videography (micro-camera)
CH1-CH256 (16 × 16 elements)
US focusing and steering
10.6 mm
4.5 mm
10.6 mm
US gel
Flexible PCB
8.5 mm
~ 6 mm
Beamlines
Eyeball
Brain
Optic nerve
Electrical signal
Visual signal
Visual perceptions
Piezo-array (32 elements)
Stimulating electrodes
P (10 μm)
ML (35 μm)
AE (100 nm)
PC (180 μm)
1 mm
1 mm
AE (100 nm)
PCB (150 μm)
R (200 μm)
P (10 μm)
~ 0.59 mm
Piezo-element
Electrical stimulation
Neuron activation
b
Gap: 0.5 mm
Element: 1 × 1 mm²
Flexible PCB
Stimulating electrodes
12 mm
8.5 mm
4 mm
7 mm
25 mm
Piezo-array
F-URSP
r ~ 12 mm
Eyeball