Ultrasound-induced piezoelectric energy harvesting for electrical stimulation of retina

USC Roski Eye Institute
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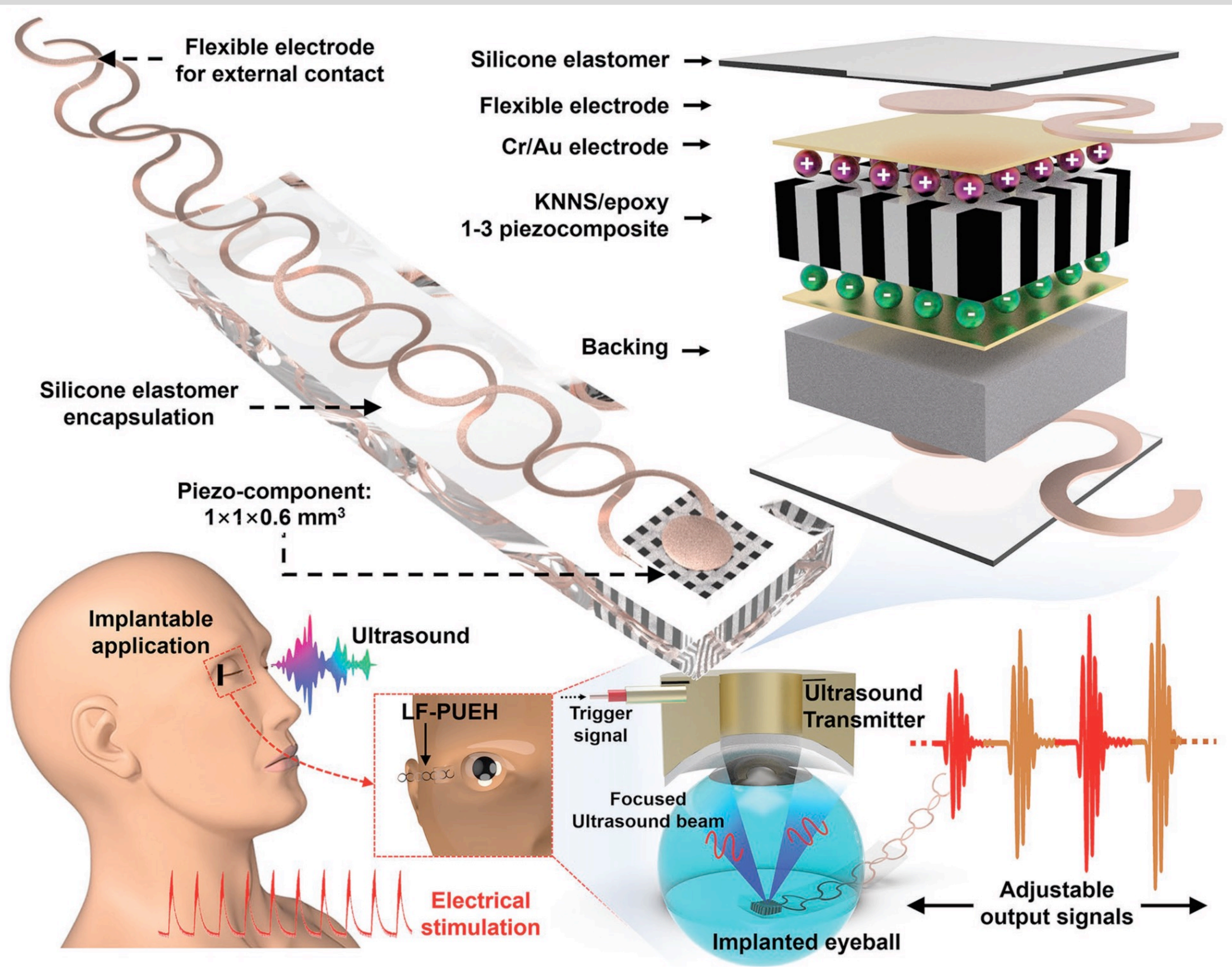
USC Ginsburg Institute for Biomedical Therapeutics

I. Purpose

To achieve ultrasound-induced wireless electrical retinal stimulation to help blind people rebuild their vision

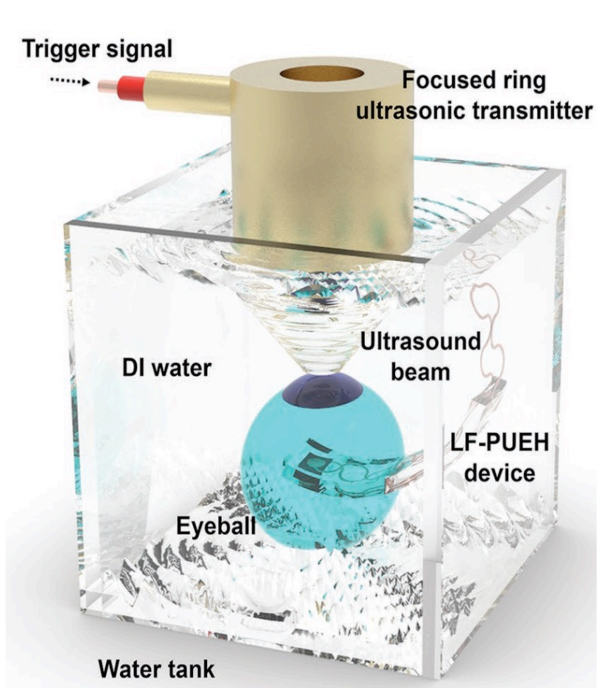


Retinal electrical stimulation for people with neurodegenerative diseases has shown to be feasible for direct excitation of neurons as a means of restoring vision. New approaches are required for the further miniaturization of wireless electronic platforms that are capable of effectively interfacing with small nerve bundles.

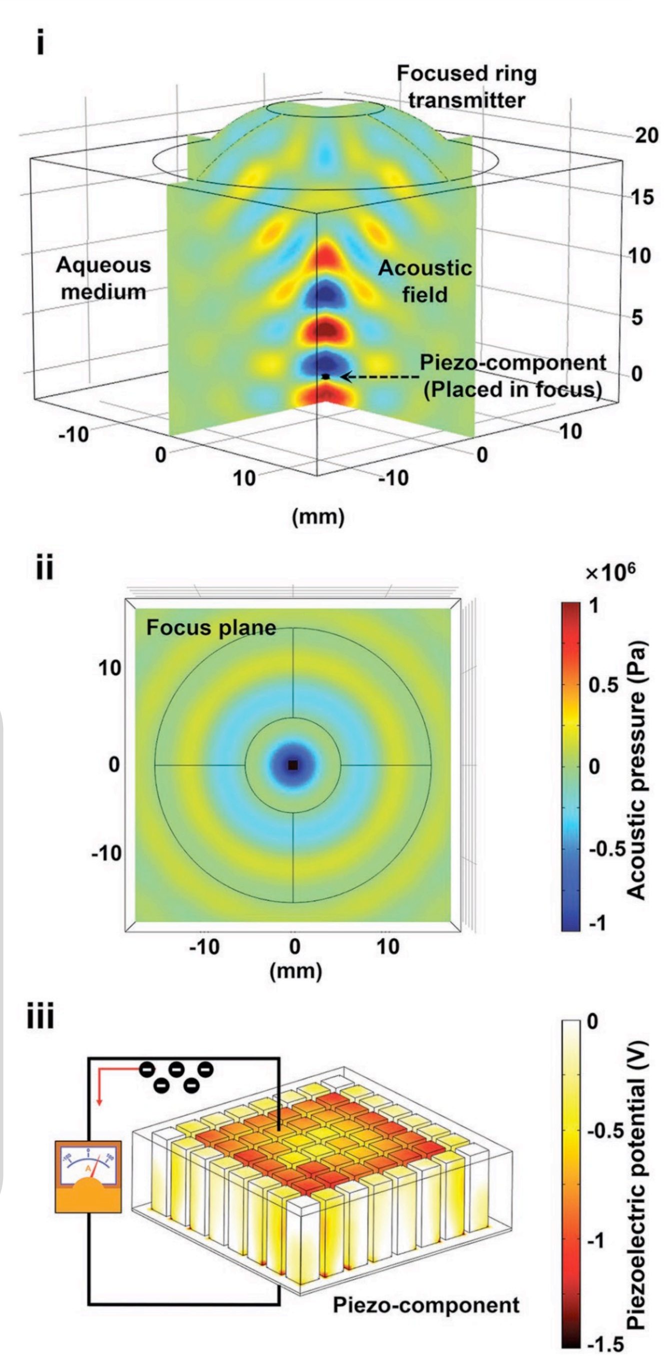
Our goal: Ultrasound-induced wireless electrical retinal stimulation

II. Methods

We prepare an anisotropic 1-3 type lead-free piezocomposite that is integrated into an mm-scale flexible format with a flexible electrode for external contact and a silicone elastomer for encapsulation. The developed lead-free piezoelectric ultrasonic energy harvester (LF-PUEH) is capable of being implanted into eyeballs to sense the transmitted ultrasonic signals from a few centimeters away and to convert them into usable electrical signals.



Focused transmitter
↓
LF-PUEH
↓
Electricity
↓
Stimulation



III. Results

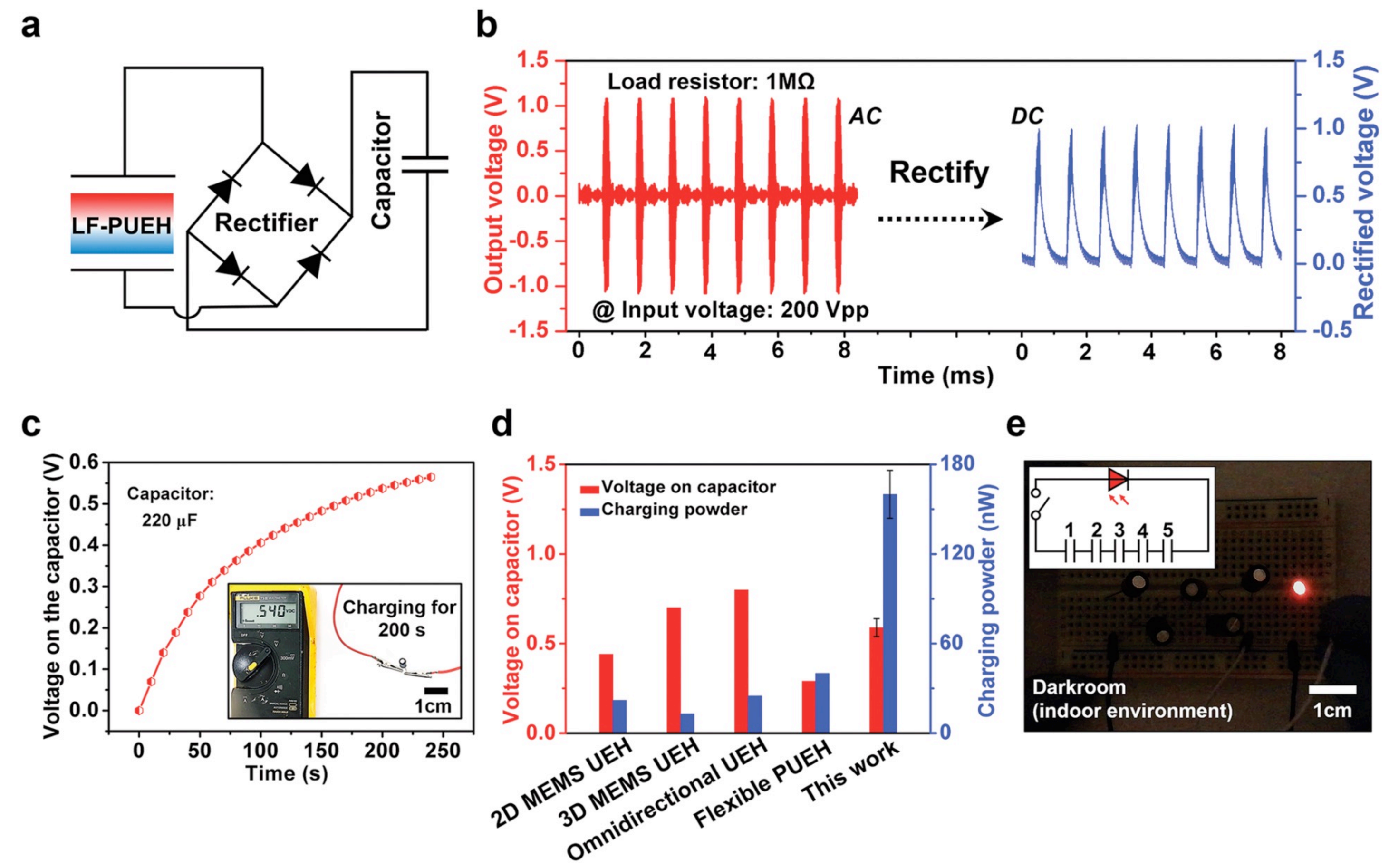


Figure 1. Applications of the LF-PUEH device on microelectronic devices. Optical image showing a commercial LED lit up by the electricity stored in capacitors. The inset shows a schematic circuit diagram of five capacitors in serial.

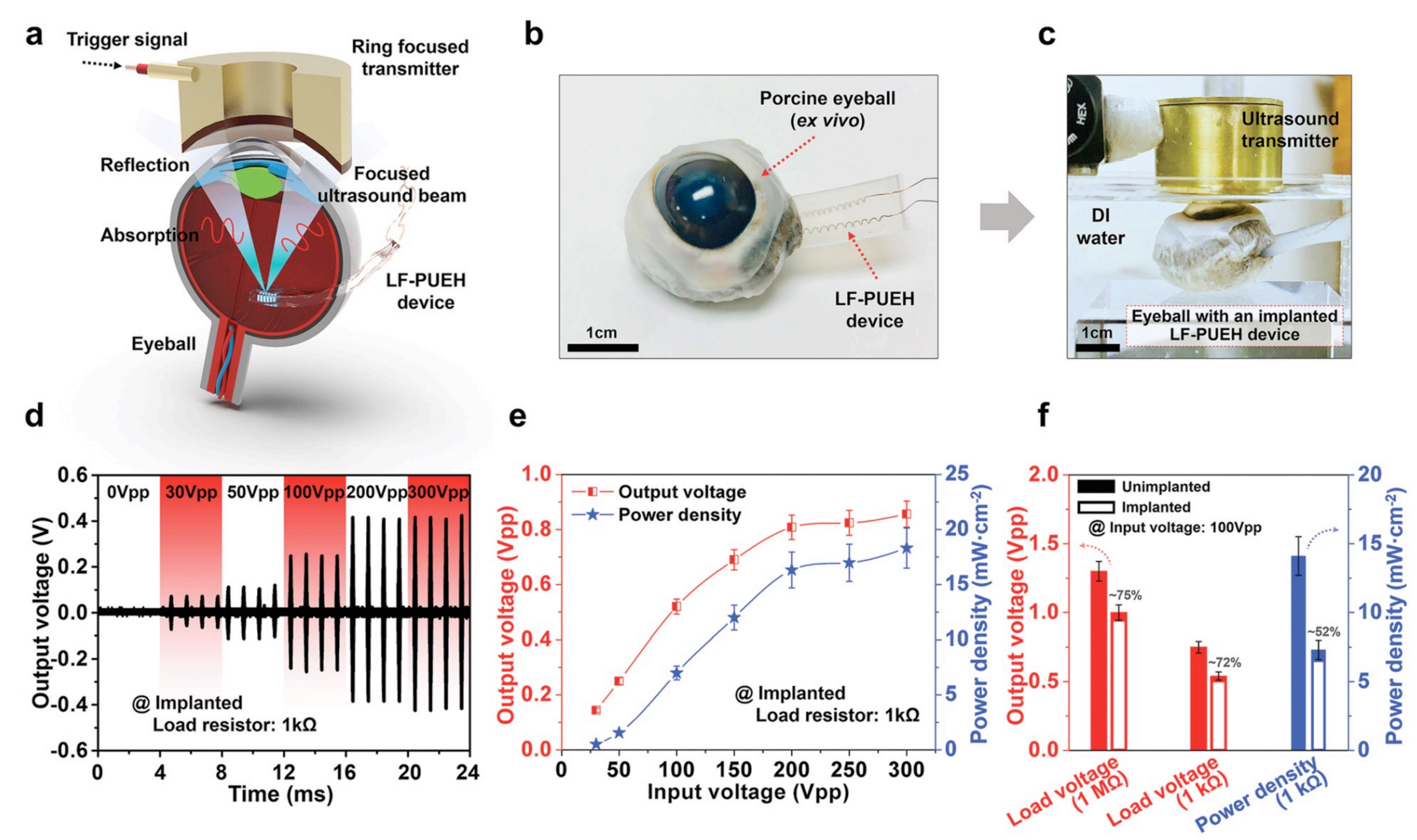


Figure 2. Evaluation of the LF-PUEH device in the ex vivo experiment of an implanted environment.

Systematic studies including frequency characteristics, input conditions, load optimization, and implant mimic are implemented to evaluate its output characteristics and to demonstrate its use in potential applications.

The developed device can be driven by ultrasound to produce adjustable electrical outputs, reaching a maximum output power of 45 mW·cm^{-2}.

The rectified energy generated from the device is stored in capacitors, that is demonstrated to be subsequently used to operate a commercial LED device.

Ex vivo experiment of the implant device was performed.

$$\frac{P_{\text{reflected}}}{P_{\text{tissue face}}} = \left(\frac{Z_a' - Z_a}{Z_a' + Z_a}\right)^2$$

$$\frac{P_{\text{absorbed}}}{P_{\text{source}}} = 1 - e^{-2\alpha_0 f^n d}$$

The considerable current signals (e. g., > 72 μA and > 9.2 nA·μm^{-2}), which are higher than the average thresholds of retinal electrical stimulation, are also obtained in the ex vivo experiment of an implanted environment.

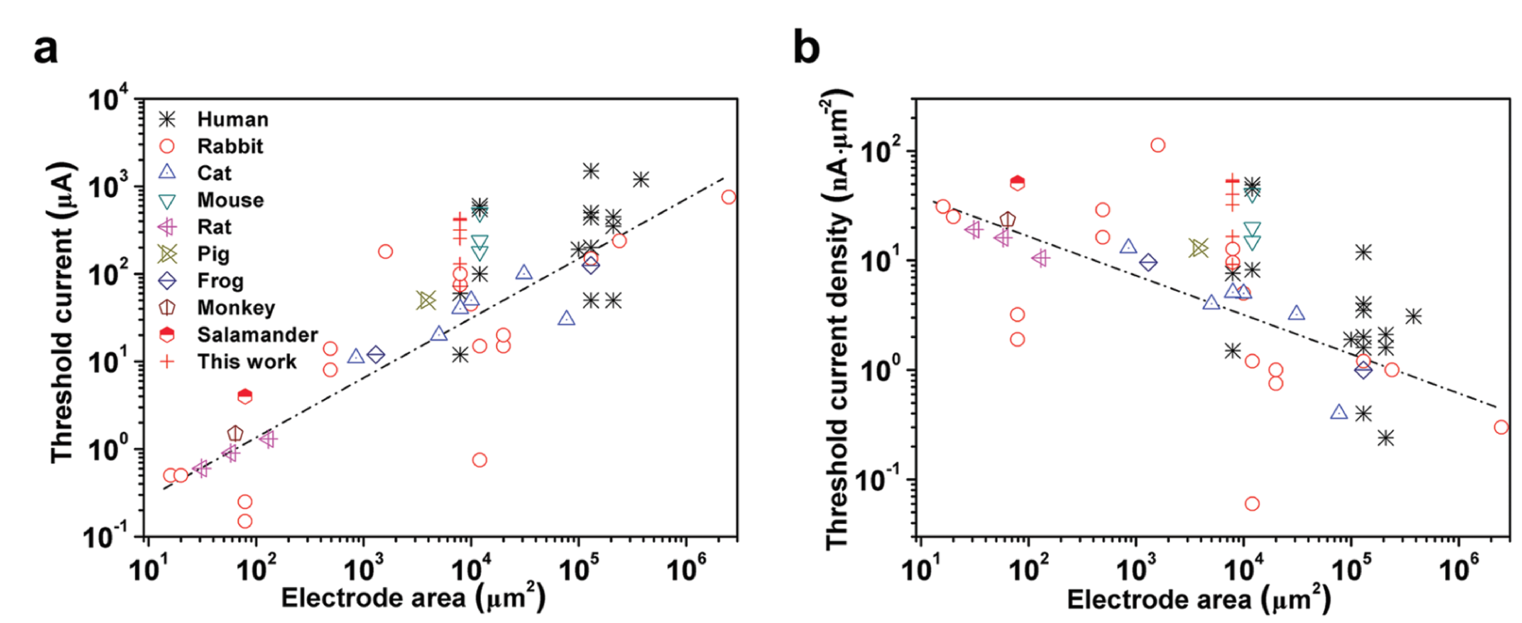


Figure 3. Analysis of thresholds for retinal electrical stimulation. a) Threshold current plotted against electrode area. b) Threshold current density plotted against electrode area. The data are from previously published literature, and dashed lines are best fits to the data.

IV. Discussion and Conclusion

1. A potential electrical stimulation strategy using ultrasound-driven wireless energy transfer technology was presented to convert acoustic energy into electricity through an mm-scale ultrasonic energy harvesting device that is flexible and lead-free.

2. The principle of power generation and the role of piezocomposite in LF-PUEH device have been theoretically analyzed.

3. The ultrasound-driven wireless energy transfer system innovatively expands the feasibility of using medical electrical stimulation in more general applications.

Design upgraded two-dimensional array
↓
Selective 2D image stimulation

V. Acknowledge and Support

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