A self-powered signal rope based on triboelectric nanogenerator towards diving safety

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Abstract

In this work, a novel mechanical device is designed for diver's signal rope. By combining the mechanical structure with a triboelectric based sensor. The mechanical movement of the rope pulling can be converted into the electrical signal through the Triboelectric Nanogenerator(TENG). The mechanical structure is composed of a lever and a compressing spring. One end of the lever moves down as pulling the signal rope. The other end of the lever is raised at the same time resulting in the contact with the TENG. The copper and PTFE film contact with each other under the hit of lever. The positive and negative charge are induced respectively due to the electro-negativity difference between the PTFE and copper. As releasing the diver rope, triboelectric electrons flow from the upper copper electrode to the lower one through the external circuit, and a electrical signal is generated. Then as the two layers contacted again, the electrons flow back to the upper electrode again. The effect of some main structure parameters on the electrical performance of TENG are studied including the constant stiffness of compression spring, the position of pivot. Through the theoretical analysis and experiment, we find the voltage output of the device increases linearly with the pulling force. Finally, the electrical signal is processing by the machine learning. We believe our work provides a new way to ensure the safety of diver and improve the intelligence of diving equipment.

Results & discussion

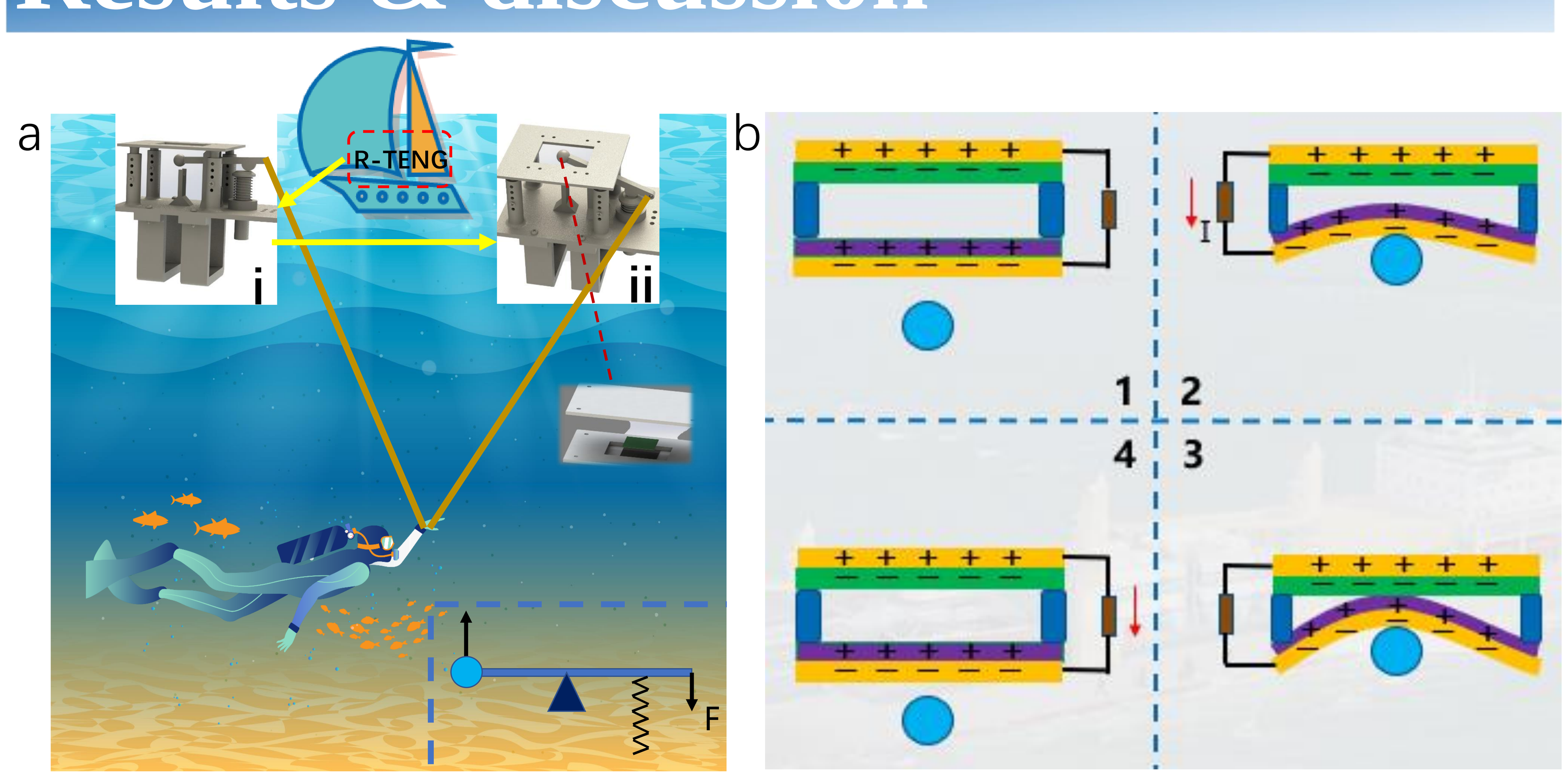

Figure 1. Structural features and working principle of the R-TENG and mechanical model. (a) Working scenario of experimental device. (b) The working mechanism of R-TENG.

As shown in Figure 1, the R-TENG is on the top of this device and consists of two parts, nylon and silicone rubber. Since the silicone rubber has excellent elasticity and long service life, it is chosen as the outer box. Silicone rubber is also chosen as the triboelectric material for the inner box, nylon is attached on the top of the silicone rubber box. Figure 1 also illustrates the operation mechanism of the R-TENG. The single-electrode mode triboelectric nanogenerator is based on the coupling effect of triboelectrification and electrostatic induction. Firstly, the clearance of the silicone rubber box decreases when the linkage is rising, which causes the inner surface of the bottom of the silicone rubber box to contact the nylon. Positive and negative charges would be generated on the surfaces of silicone rubber and nylon, respectively. Then, when the silicone rubber starts to recover, the silicone rubber will separate from the nylon, When the nylon and silicone rubber surface are completely separated, the charges transferred to the ground will reach the maximum value.

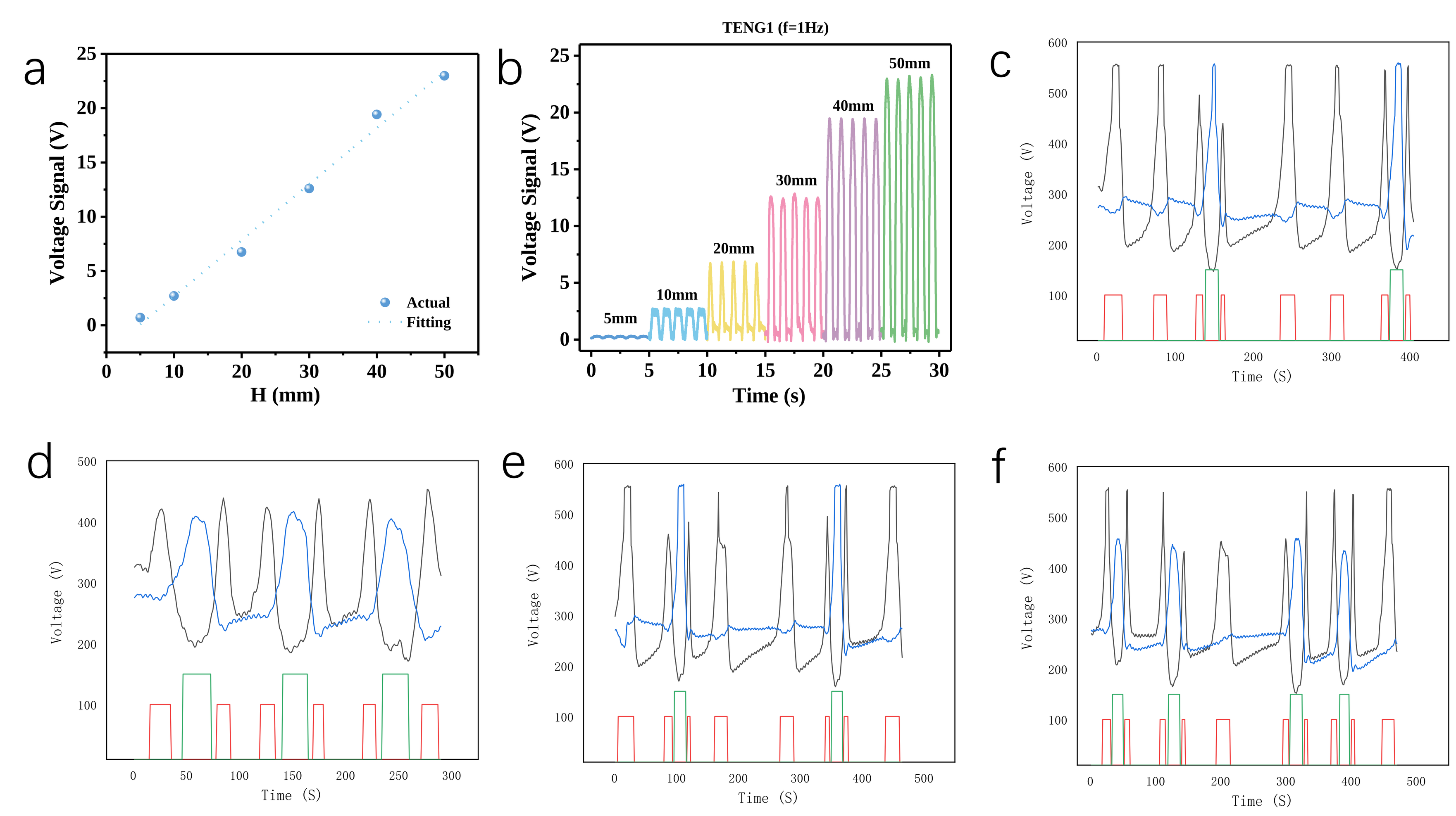

Figure 2. The electrical output performance of R-TENG. (a) Voltage output at the same frequency and different amplitudes. (b) Same amplitude, different frequency current output (c - f) Voltage output of signal rope according to certain coding protocol

Figure 2(a) shows the experiment data of the voltage output at the same frequency and different amplitudes. As the amplitude increase every 10 millimeter, the voltage shows the positive correlation growth. (b) shows under the same amplitude, different frequency, the current output also shows the same regulation with the voltage. (c - f) shows that the voltage output of signal rope according to certain coding protocol. Wo treat the single red signal as 0, the signal code consists of three signals as 1(three signals consists of two single red signals and a single green signal in the center), we arrange and combine these 0 and 1 in different groups, which group represents a message, such as needing oxygen, poor visibility, pull me up or continue to dive. We can specify these communication passwords according to our own needs, everyone in the team is extremely familiar with this. So these communication protocols can serve divers' underwater communication well, realize information interaction between over and under water.

Conclusion

In conclusion, a highly robust, compressible, and moisture-resistant rope-like multifunctional triboelectric nanogenerator has been designed, which exhibits excellent performance in sensing multi-mechanical deformation. The R-TENG exhibits its good working performance in sensing compressing with different loads were exerted by combining a highly flexible silicone rubber box and a nylon inner core. And the spring plays the role of reset, when the diver was end of sending message, the silicone rubber box will restore to the initial state. R-TENG shows great performance in voltage output. While it generates an AC signal, we set a threshold. If the value is exceeded, the part beyond the threshold will not change, so we can get a square wave signal. The square wave signal is divided into 0 and 1 according to the coding rules we specified earlier. At last, we combine 0 and 1 in different order to form a variety of corresponding information, just like a codebook. This work provides a possible way to realize real-time underwater communication of underwater operators through highly robust and low-cost self-powered sensors.