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Wireless passive flexible accelerometer fabricated using micro-electro-mechanical system technology for bending structure surface

Key words: Bending structure surfaces; Flexible accelerometer; Micro-electro-mechanical system (MEMS) technology; Wireless non-contact measurement

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Motivation

- Common accelerometers are piezoelectric, piezoresistive, capacitive, and so on, with excellent performance. However, the vibration of these accelerometers is measured through the wire; however, the wire may break during severe vibration.

- Wireless passive sensors can achieve non-contact measurement, but most of the existing sensors are made of ceramic materials, which are difficult to adhere to the surface of a bending structure in the vibration process, leading to problems such as incomplete adhesion.

Main idea

- Adopt a wireless passive measurement method to avoid vibration drop off of the accelerometer during testing.

- Select flexible material polyimide (PI) as the base material for the accelerometer, and prepare the flexible silver electrode on the surface of polyimide by a micro-electro-mechanical system (MEMS) process. It can be better attached to the surfaces of special-shaped components and complex structures, and achieves acceleration with better performance measurement.

Method: wireless passive measurement

- Through the non-contact measurement method, using the principle of electromagnetic coupling, the change of the distance between the accelerometer and test antenna during the vibration process is converted into the change of voltage to realize the measurement of acceleration.

Fabrication of the non-contact flexible accelerometer

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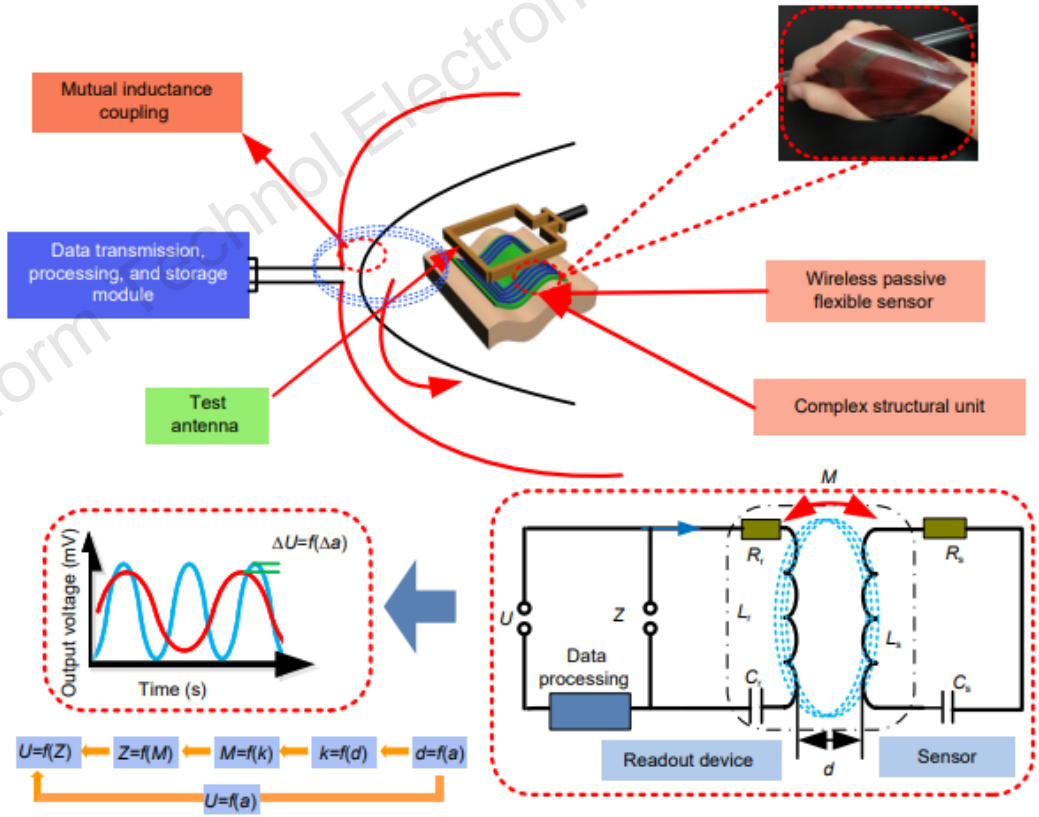
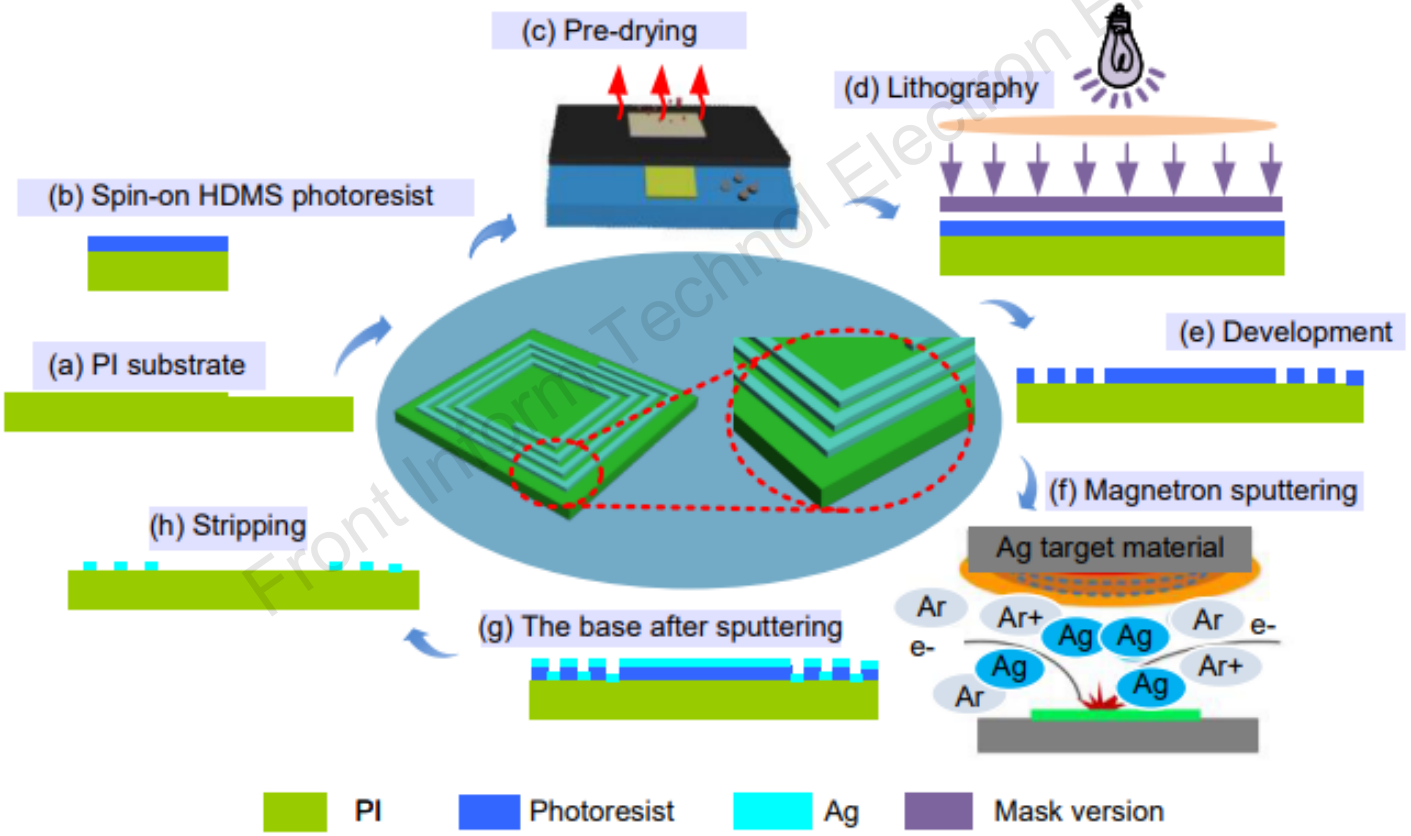
Wireless passive acceleration signal extraction



Wireless non-contact measurement method

Method: MEMS fabrication process

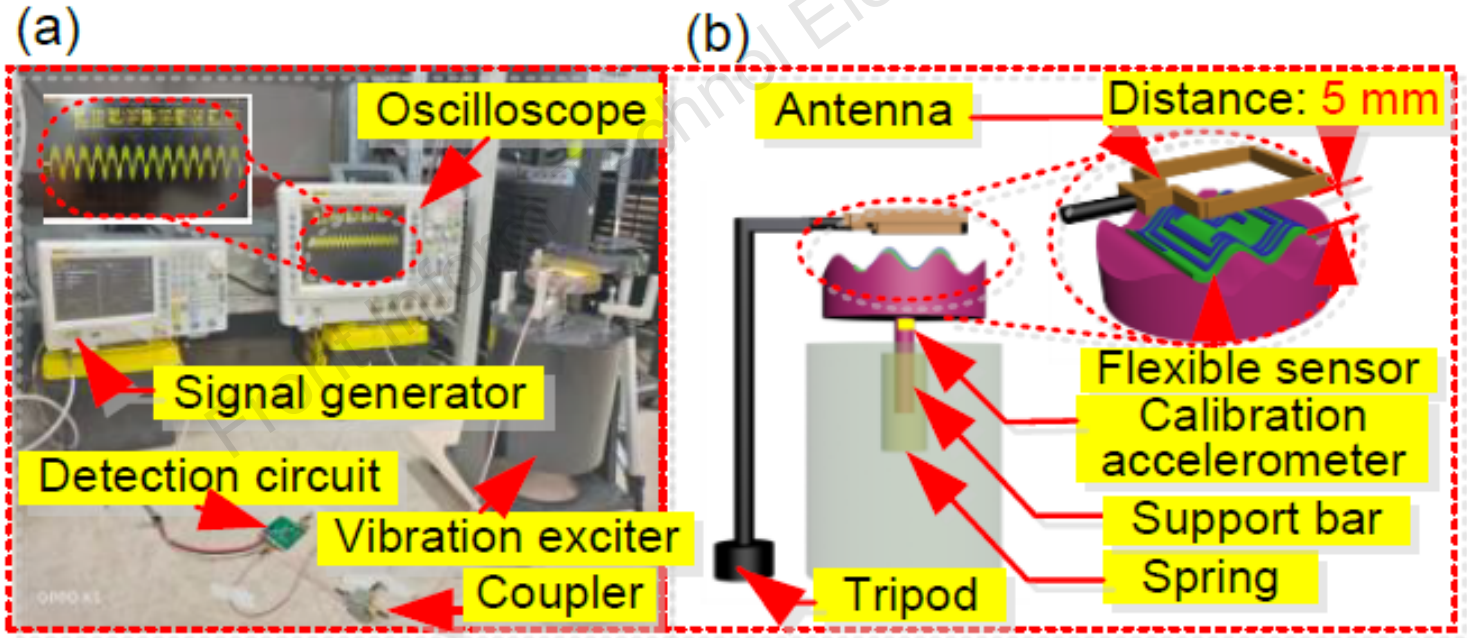
- The main processes of fabricating the wireless passive flexible accelerometer include cleaning, gluing, pre-drying, lithography, development, magnetron sputtering, and cleaning via sonication.



Fabrication of the accelerometer

Method: measurement of acceleration

- The antenna input the sensed sinusoidal vibration signal into the detector circuit in the form of an envelope. Then, the detector circuit converted the envelope signal, which contained the information of voltage amplitude, into sinusoidal voltage feed into the oscilloscope. Thus, the acceleration test of the accelerometer was carried out successfully.

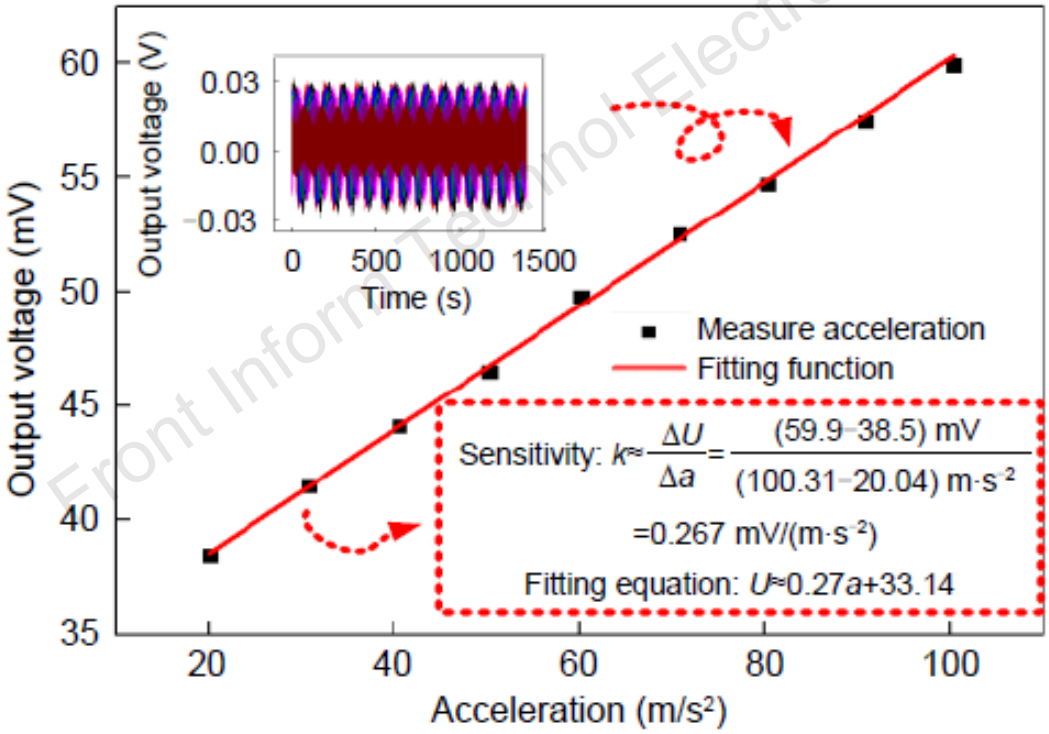


Experimental platform and measurement system (a) and the working principle of the test platform (b)

Major results

Relationship between the acceleration and output voltage:

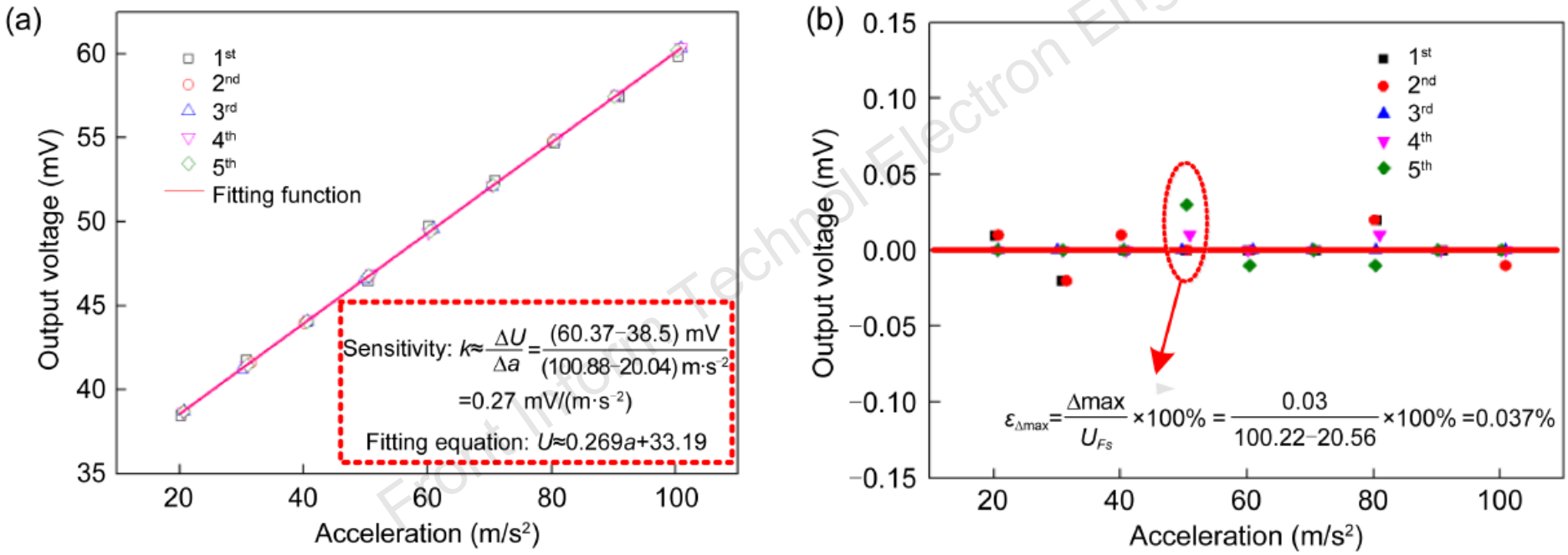
The peak voltage of 20–100 m/s^2 was recorded at 20 Hz, and the corresponding function of the acceleration and amplitude was plotted.



The corresponding function of acceleration and amplitude

Major results

Repeatability test:



Repeatability test of the accelerometer at 20–100 m/s² (a) and standard error of the repeatability test of the accelerometer (b)

Conclusions

We have proposed a type of LC wireless passive flexible accelerometer that can be used on the surface of a bending structure. The flexible accelerometer was fabricated using MEMS technology, the substrate was made of flexible PI material, and the thickness of the inductance coil was only 300 nm. Acceleration of 20–100 m/s^2 at 20 Hz can be measured by the accelerometer. The peak-to-peak output voltage was linear with the change of acceleration. In the acceleration range tested, the average sensitivity was 0.27 $mV/(m \cdot s^{-2})$, and the repeatability error was less than 0.037%.

Future outlook

☐Wearable field

Physiological information monitoring

☐Industrial field

Surface measurement of engine blade and bearing

Chen LI was born in 1987. He received the MS and PhD degrees in intelligent instruments and measurement technology and instrument from North University of China, Taiyuan, China, in 2014 and 2016, respectively. He is currently an associate professor with the Department of Instrumentation and Electronics of North University of China. His research focuses on dynamic testing technology and micro-nano sensor devices in extreme environments.