# An AlN cantilever for a wake-up switch triggered by air pressure change

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**Abstract.** This research reports an AlN cantilever with an air chamber for a wake-up switch triggered by air pressure change. The proposed sensor is designed to fulfil both high sensitivity and low power consumption. By combining an air chamber to the one side of the AlN cantilever surface, the barometric pressure change generates a piezoelectric voltage. Thus, a wake-up switch triggered by air pressure change can be achieved using an AlN cantilever. The size of the fabricated AlN cantilever was 2000 μm × 1000 μm × 2 μm. The sensitivity to static differential pressure was 11.5 mV/Pa at the range of −20 Pa to 20 Pa. We evaluated the response of the sensor, which was composed of the AlN cantilever and the chamber of 60 ml in volume, when air pressure change was applied. The output voltage increased with increasing the applied air pressure change. It was observed that the maximum output voltage of 50 mV was generated when the air pressure change was 13 Pa.

## 1. Introduction

In the wireless sensor network (WSN) system, the monitoring objects, such as temperature, humidity, and the amount of particle, are related to air pressure change due to human moving. Thus, information of the change of air pressure around the sensor nodes will manage WSN system efficiently [1,2]. A barometric pressure sensor with low power consumption is suitable for the application as the trigger switch of WSN systems due to limited battery power. However, it was difficult to monitor air pressure change with high sensitivity and low power consumption by the conventional methods.

Previously, we presented a differential pressure sensor using a cantilever with piezoelectric element which can achieve both high sensitivity and low power consumption due to the deformable structure and sensing element characteristics [3,4]. By combining an unsealed air chamber to the one side of the piezoelectric cantilever surface, the air pressure change around the other side generates a piezoelectric voltage due to the cantilever deformation as shown in Figure 1(a) [5,6].

In this research, a piezoelectric cantilever with an air chamber was designed and fabricated for a wake-up switch triggered by air pressure change. Aluminum nitride (AlN) was used as a piezoelectric element due to its excellent chemical stability and a small dielectric constant [7,8]. The response of the fabricated sensor to static differential pressure was measured. We also evaluated the sensor response to instantaneous pressure change.

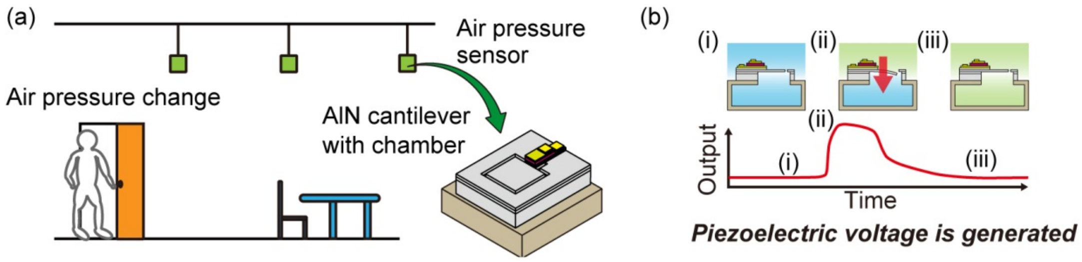


**Figure 1** Concept (a) and principle (b) of an air pressure change sensor using an AlN cantilever with an air chamber.

## 2. Design and Fabrication

### *2.1. The principal of pressure change detection*

The principle of pressure change detection using a piezoelectric cantilever is shown in Figure 1(b). The sensor consists of a AlN thin cantilever with small gaps around the cantilever fixed on an air chamber. When pressure difference is applied between the upper surface and the lower surface of the cantilever, the cantilever is bent. Then, the piezoelectric voltage is generated between the upper and the lower cantilever surfaces.

Pressure in the chambers is the normally same as atmospheric pressure as shown in Figure 1(b)(i). When the air pressure around the sensor changes, the pressure difference between upper and lower surfaces occurs because the pressure in the chamber is still atmospheric pressure as shown in Figure 1(b)(ii). Therefore, the cantilever can detect barometric pressure change. In a few moments both pressures in the upper and lower surfaces become same pressure because of the air leak through the gap around the cantilever as shown in Figure 1(b)(iii).

In cases where the sensor nodes were deployed in an industrial clean room, for example, pressure difference between inside and outside of the room is several tens of pascals. Thus, door opening and closing will generate air pressure difference of several tens of pascals. For this reason, the proposed sensor is required to be able to detect air pressure change of ten pascals.

The generated piezoelectric voltage becomes a trigger signal due to barometric pressure change. Because the sensing element needs no power consumption in principle, the proposed device can perform as a barometric pressure change trigger without power consumption.

### *2.2. Design and Fabrication process*

A design of the AlN cantilever is shown in detail in Figure 2(a). The cantilever is 2000 μm × 1000 μm × 2 μm in size. The front edge of the cantilever is wide to increase the area where pressure acts. The base of the cantilever is narrow to have stress concentration and low capacitance [3,4]. The base area consists of Pt/Ti/AlN/Pt/Ti/$SiO_2$/Si multi-layer. The cantilever gap is designed to be 5 μm in order to prevent air leaks through the gap [3-6]. The fabrication process was shown in Figure 2(b). The AlN cantilever was fabricated from the multi-layer of Pt/Ti/AlN/Pt/Ti/$SiO_2$ on a silicon on insulator (SOI) wafer as shown in Figure 2(b)(i). Firstly, the Pt/Ti/AlN/Pt/Ti/$SiO_2$ multi-layer was etched as shown in Figure 2(b)(i). An Au layer was deposited and patterned for pads. Secondly, the device Si/$SiO_2$ layers were etched to form the cantilever shape as shown in Figure 2(b)(iii). Finally, the handle Si and $SiO_2$ layers were etched as shown in Figure 2(b)(iv).

Figure 2 (c)(d) shows a photograph of the fabricated sensor chip and an SEM image of the cross-sectional surface of the cantilever. The sensor chip is 3.0 mm × 5.0 mm × 0.4 mm in size. It is observed that the Pt/Ti/AlN/Pt/Ti/$SiO_2$ multi-layer was formed on the Si layer. The capacitance of the fabricated AlN cantilever was 68 pF.

We measured the response of the fabricated AlN cantilever when static differential pressure was applied between upper and lower surfaces of the cantilever. The cantilever chip was mounted on a substrate that separated two chambers. The differential pressure was provided by applying air pressure

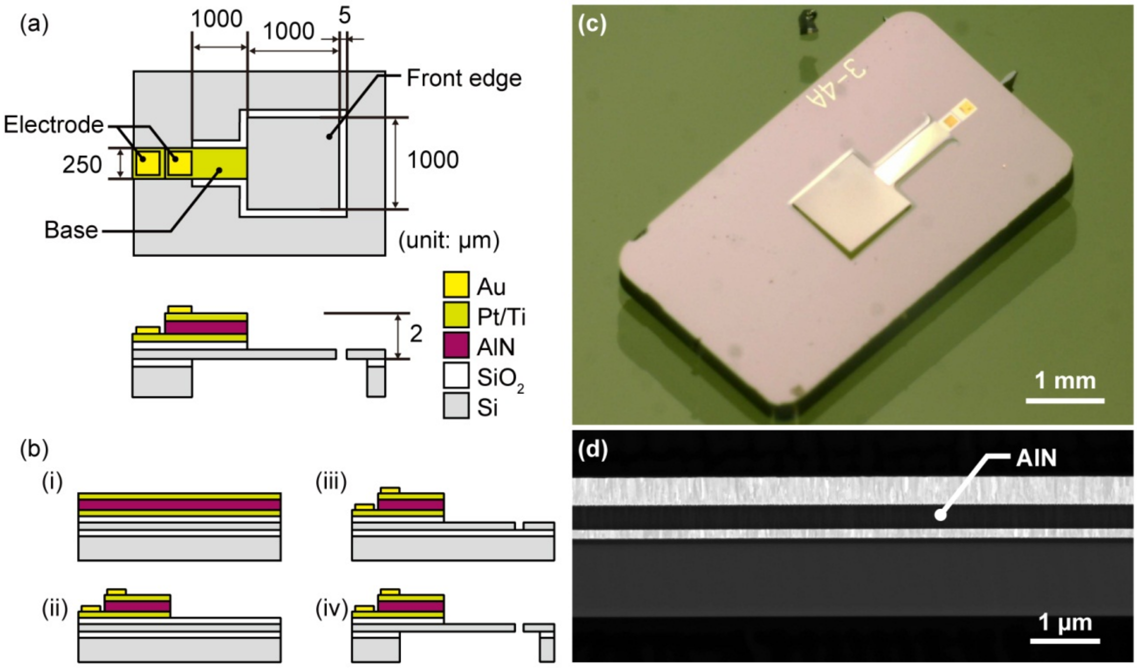


**Figure 2** (a) Design of the AlN cantilever. (b) Fabrication process of the AlN cantilever. (i) An AlN cantilever is fabricated from the multi-layer of Pt/Ti/AlN/Pt/Ti/$SiO_2$ on an SOI wafer. (ii) The Pt/Ti/AlN/Pt/Ti/$SiO_2$ layers are etched. Au layer is deposited and patterned. (iii) The device Si layer and buried oxide (BOX) are etched. (iv) The handle Si layer and BOX are etched. (c)(d) Photograph and SEM image of the fabricated device.

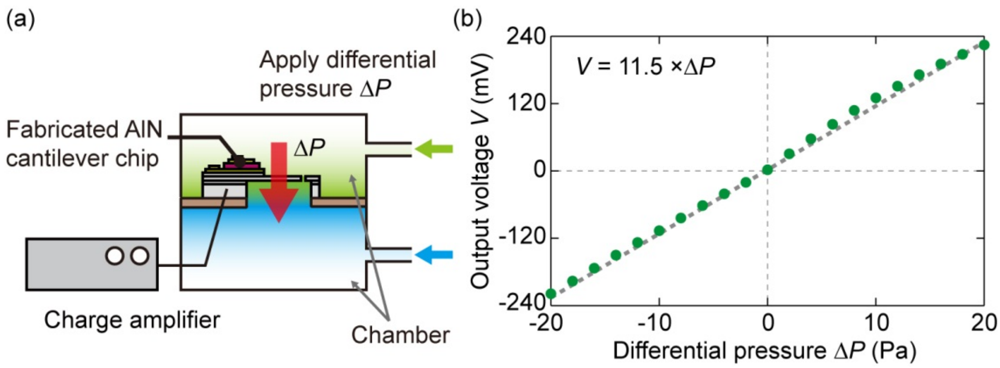


**Figure 3** (a) Schematic image of the experimental setup to measure the response to static differential pressure change. (b) Relationship between the differential pressure and the output voltage.

to two chambers through a pressure generator as shown in Figure 3(a). Then, the piezoelectric voltage was measured through a charge amplifier. Figure 3(b) shows the relationship between the output voltage and the static differential pressure. The output voltage was proportional to the applied differential pressure. The sensitivity to the differential pressure was calculated to be 11.5 mV/Pa at the range of −20 Pa to 20 Pa.

## 3. Experiment and result

We measured the response of the sensor, which was composed of the AlN cantilever and an air chamber, when air pressure change was applied as shown in Figure 4(a)(b). The volume of the sensor chamber is 60 ml. Chamber 1 and Chamber 2 were connected to the sensor though valves. The volume

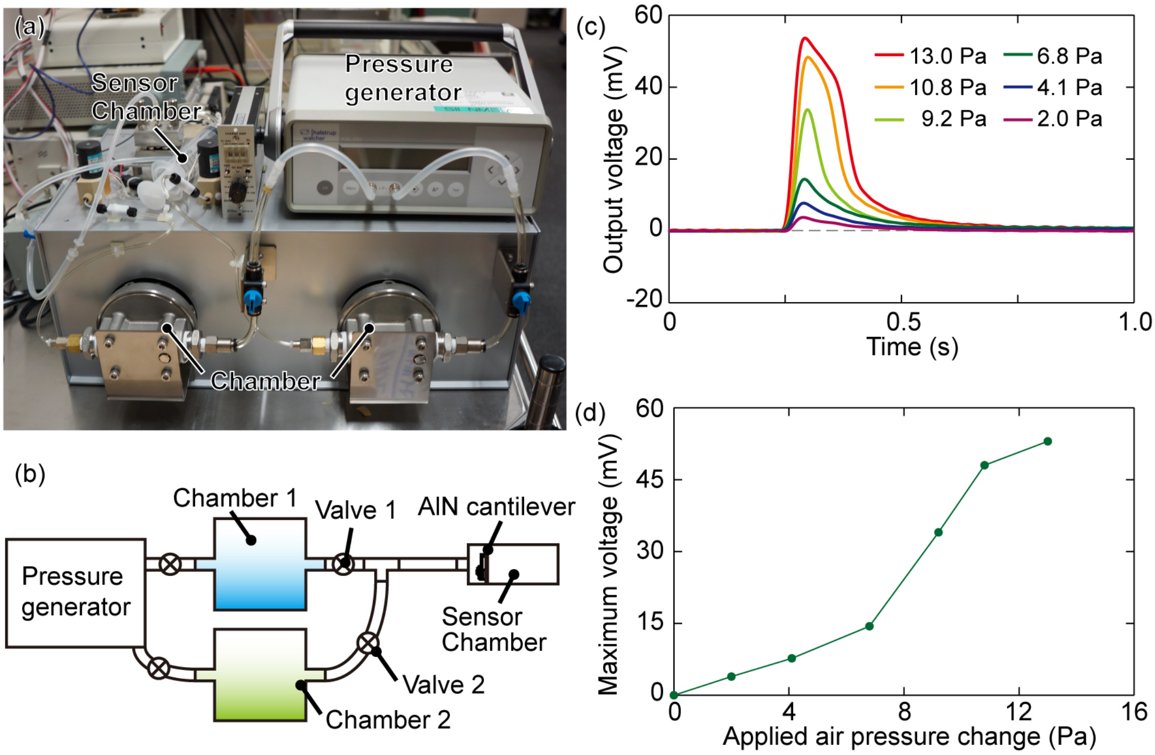


**Figure 4** (a)(b) Photograph and schematic image of the experimental setup to measure the response to barometric pressure change. (c) Real-time response to pressure change. (d) Relationship between the pressure change and the maximum output voltage.

of each chamber was 1000 ml. The chambers were also connected to a pressure generator, which applied differential pressure between the two chambers. At first, the valve 1 and valve 2 were opened and closed, respectively. Thus, the air pressures of the upper and lower surfaces of the cantilever were equal to that of the chamber 1. When the states of the valves were switched, the barometric pressure change was applied to the sensor. Then, the sensor generated piezoelectric voltage according to the pressure difference between the chamber 1 and chamber 2. We applied the barometric pressure change of 2.0, 4.1, 6.8, 9.2, 10.8 and 13.0 Pa.

Figure 4(c) shows the real-time response of the sensor to barometric pressure change. It was observed that there was the voltage peak shortly after changing the state of the valves in each pressure change. Then, we obtained the relationship between the maximum output voltage of the sensor and the magnitude of the applied air pressure change as shown in Figure 4(d). As shown in Figure 4(c) and (d), the output voltage increased when the applied air pressure change was increased. The maximum output voltage was approximately 50 mV when applied pressure was 13 Pa. The generated voltage was thought to be high enough to switching an electrical circuit. Thus, using the proposed sensor, a high sensitive switch with a low consumption triggered by air pressure change would be achieved.

The generated output voltage corresponded to differential pressure change of 4.3 Pa. It was thought that the differential pressure between the chamber 2 and the sensor chamber did not reach to 13.0 Pa because of the air leak through the gap. The waveform of the output voltage was different between over 10 Pa and under 10 Pa. It was also considered that there was the different behaviour of the cantilever bending due to the air leak in a boundary 10 Pa. This phenomenon would be related to the cantilever and the sensor chamber sizes. By improving the sensor design, the output voltage would become larger. We will research the relationship of the cantilever and the chamber sizes and the applied air pressure change in future work.

## 4. Conclusion

The AlN cantilever with the air chamber for a barometric pressure change trigger was designed and fabricated. The fabricated AlN cantilever was 2000 μm × 1000 μm × 2 μm in size. In the static differential pressure detection, the fabricated AlN cantilever had a good linearity between -20 Pa and 20 Pa. The measured sensitivity was 11.5 mV/Pa. As a performance of a barometric pressure sensor, the output voltage of 50 mV was generated when the air pressure change of 13.0 Pa was applied.

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