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Ultra Low Power Thin Film MEMS Gas Sensor for Battery operated Gas Alarm

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Abstract:
Osaka Gas and Fuji Electric have developed a MEMS gas sensor obtained by laminating “nano-columnar structure SnO_2 thin film" and "selective oxidation catalyst layer" on the circular diaphragm support layer with a built-in thin film heater. Ultra-low power (0.06mW) required for 5 year battery operation was achieved by separating the functional elements of gas sensors, optimizing the materials and structures in charge of each function, microminiaturizing, and driving with low power ultra-short pulse. Furthermore, this sensor has realized higher sensitivity and higher selectivity than conventional methane sensors. In May 2015, Osaka Gas released the world's first battery operated city gas alarm equipped with this sensor. This work has achieved the innovation of gas sensor to thin film type / MEMS type device, and opened up a new era of gas sensor technology.

Key words: Semiconductor Gas Sensor; Tin Oxide; Thin Film; Noble Metal Oxide Catalysts; MEMS

Backgrounds

The importance of natural gas as an energy source with low environmental impact and chemical raw materials is further increasing. Semiconductor methane sensors play a very important role in securing safety at each stage of exploration, mining, transportation, supply and consumption of natural gas. In Japan, approximately 10 million gas alarms are installed. However, in order to proceed with the reaction of detecting the least reactive methane among the hydrocarbons, it is necessary to heat the sensor element to about 400 °C., and external power source is required to drive the gas alarms. Battery drive (cordless) has been strongly desired to solve installation restrictions and further promote widespread use of the alarm devices, but in order to drive the sensor with a Li battery for 5 years, it is necessary to reduce the heating power consumption of the sensor to several hundredths of the conventional heating power consumption. For these reasons, battery drive of gas alarm has been called "dream technology".

Development of ultra low power methane sensor

First, we clarified the sensor's performance control factor through elucidation of the sensing mechanism of semiconductor flammable gas sensors [1], and based on this finding, we separated each function of a sensor (detection, selectivity control, heating / thermal insulation, structural support), and optimized each functional element.

In order to achieve ultra low power gas sensing, it has been considered ideal to thin the gas sensing material. Conventionally, it has been considered difficult to stable gas sensing by the thin film material, however, by new thin film fabrication method, we have developed a novel "nano-columnar structured tin oxide thin film" (see Fig. 1 [2], [3]) which has high sensitivity to methane stably for a long time.

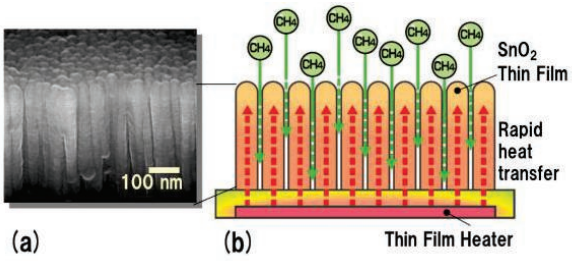

Fig. 1. Nano-columnar structure SnO_2 thin film.

In order to control the selectivity to methane, we have developed selective oxidation catalyst layer (see Fig. 2 [3]) consisting of newly created "noble metal solid solution type oxide catalyst" thin film etc. overturning the common sense of precious metal catalyst and laminated it, and realized highly selective methane sensing.

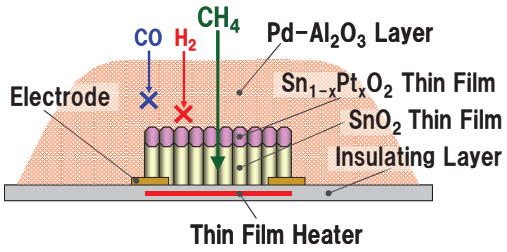

Fig. 2. Selectivity control by selective catalyst layer.

Furthermore, we have miniaturized the sensor by making use of MEMS technology. By improving the ultra-short pulse drive system which heats only at the moment of detection, we have developed the world's first "ultra low power methane sensor" with high sensitivity and high selectivity that can be driven with 0.06mW that is less than 1 / 600th of the conventional power. (see Fig. 3, 4). [3], [4]

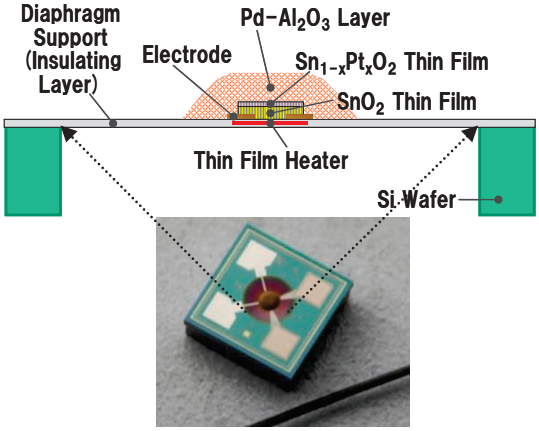

Fig. 3. Ultra low power methane sensor.

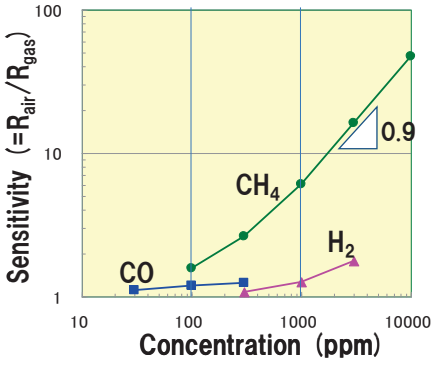

Fig. 4 Gas sensing characteristics of ultra low power methane sensor.

Establishment of long-term reliability

Since the gas alarms is security devices, extremely high reliability is required for a long time. For this reason, we analyzed the results of the realization environment environmental characteristic variation test at 660 different installation environments throughout Japan, elucidated the performance change mechanism, invented a reliability strengthening technology to suppress the performance change, established the acceleration evaluation method , we established extremely long long-term (5 years) reliability required for alarm device applications by verifying the effectiveness of reliability enhancement technology.

Practical development of battery operated sensor and its significance

In May 2015, Osaka Gas launched the world's first battery powered household city gas alarm equipped with this sensor (see Fig. 5). [5] This technology has rewritten the history that sintered body type sensors have been used in city gas alarms since 1980 and has achieved the innovation of gas sensor to thin film type / MEMS type device, and opened up a new era of gas sensor technology.

Fig. 5 Battery operated city gas alarm.

As the replacement of all gas alarm devices in Japan with battery-powered alarms progresses, it is estimated that the energy saving effect is equivalent to 61,000 MWh per year. In addition, due to the elimination of installation restrictions by cordlessness, it is expected that the alarm unit penetration rate will dramatically improve. Also, with the technological trends such as IoT, M2M and wearable sensors in recent years, development of a low power consumption sensor capable of driving a battery is required. Although this technology was first put to practical use as methane sensor at the first, since it is able to detect various combustible gases by tuning sensor drive, it is expected to be used as a sensor for detecting various gases with very low power consumption application for the wide field.

References

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