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Plasma Enhanced Detection Of Methane On Pt/SnO_2 Sensors At Low Temperatures

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Abstract:
In this study, a non-thermal plasma (NTP) corona needle-shape reactor was applied before Pt/SnO_2 sensor to detect methane with high responses at low temperatures. 5000 ppm methane in air, by passing through NTP reactor at ambient temperature, have been converted to reactive intermediately including CO. After reaching to the sensor, the responses have been measured at 200-400ºC temperature range. The effects of plasma parameters including the distance between electrodes and electrical power, as well as sensor temperature have been varied. The synthesis of Pt/SnO_2 was carried out by precipitation method impregnated with H_2PtCl_6 to get 1.0 wt% Pt/SnO_2. The sample was characterized by XRD, BET and FTIR. Exposure of methane to NTP reactor with 2.5 mm electrode distance by an increase in electrical power to 0.9 W results in 20% conversion. The corresponding parameters at 5 mm interval are 1.4 W and 41%. Without using the plasma, maximum response to CH_4 occurs at the high temperature of 400ºC. At electrode distances of 2.5 mm with 0.9 W electrical power and 5mm with 1.4W, the maximum responses has increased 144 and 331 times respectively than the single sensor at 200ºC. This way, very high responses to CH_4 at 200ºC has been achieved by Pt/SnO_2 gas sensor in the presence of NTP corona needle system.

Key words: non-thermal plasma, corona, gas sensor, methane, CO

Introduction

For about thirty years, non-thermal plasma (NTP) technologies have been successfully implemented to combustion processes such as reforming of methane or natural gas to produce H_2 and CO [1]. Providing required energy to produce reactive species (electron, radical and ions) is the main role of such a plasma results in boosting fuel reforming reactions [2]. Detection of methane as one of the pollutant and the main component of natural gas for domestic and industrial uses is indispensable [3]. As reported in litteratures among most dopants and catalysts, the platinum group metal (Pt and Pd) are mainly utilized for enhancing the selectivity and sensing response especially to methane [4]. In this study, Because Pt/SnO_2 sensors have high response to detect CH_4 gas at high temperatures and contrary to it for CO at low temperatures, an NTP system is introduced to obtain a high response to methane at lower temperatures by converting methane into carbon monoxide.

Experimental

SnO_2 nanostructures were synthesized by a precipitaion method. Anhydrous stannic tetrachloride has been dissolved in de-ionized water and precipitated by ammonia solution.

The precipitate were centrifuged and washed with deionized water several times and dried at 80ºC for 12 h. The obtained powder has been calcined at 500ºC for 4 h. To obtain 1.0 wt. % Pt/SnO_2, H_2PtCl_6 has been impregnated onto the SnO_2 powder, followed by drying at 80ºC and calcining at 500ºC for 4 h (Pt/SnO_2). A corona reactor including two needle type electrodes (platinum wire of 100 µm ID) in a micro reactor connected to a high voltage DC power supply.

Results

The BET surface area of Pt/SnO_2 is 70 m^2/g. Figure 1 shows The XRD patterns of the tetragonal phase with cassiterite structure of SnO_2. Sensor response to CH_4 with a concentration of 5000 ppm and a flow of 50 ml / min without the presence of plasma has risen

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from 1.4 to 19 with an increase in temperature from 200 ˚C to 400 ˚C (see Fig. 2).

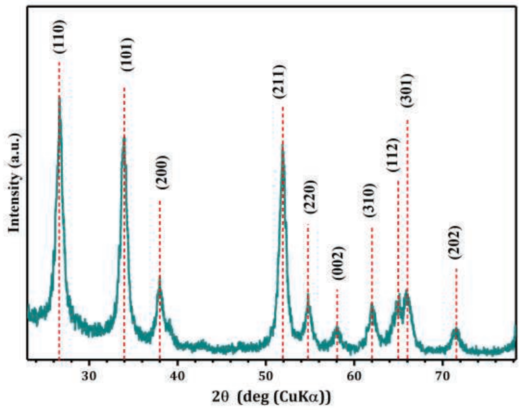

Fig. 1. The XRD patterns of Pt/SnO₂

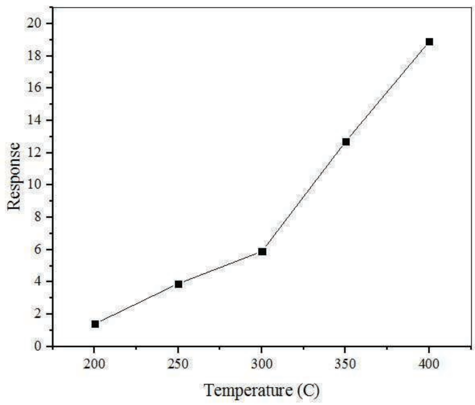

Fig. 2. Pt/SnO₂ sensor response to 5000 ppm CH₄ at different temperatures without using NTP system.

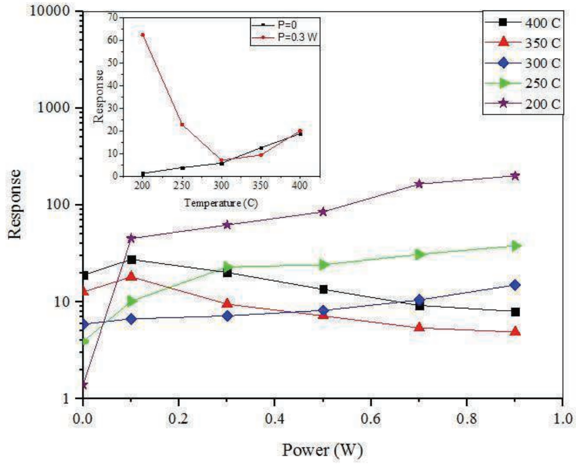

Fig. 3. Pt/SnO₂ sensor response to 5000 ppm CH₄ at different temperatures in the presence of NTP system with various electrical power at the electrode distance of 2.5 mm

Conclusion

CH_4 converts to reactive intermediates such as CO by the needle-shaped corona plasma. Sensor response to methane by changing the plasma electrical power at 5 mm and 2.5 mm electrode distances are shown in Fig. 4 and 5. With increasing corona power up to 0.9 W at 2.5 mm of electrodes distance, conversion reaches 20%. At an interval of 5 mm, the corresponding parameters are 1.4 W, 41%. At the electrode distance of 2.5 mm with 0.9 W power the maximum response is 201 at 200ºC that is 144 times higher than the sensor without applying NTP reactor. As the same way, for 5mm interval with 1.4 W, the maximum response is 463 at 200ºC that is 331 and 2.3 times higher than single sensor and sensor along with NTP system of 2.5 mm interval model respectively.

This way, very high responses to CH_4 at 200ºC has been achieved by Pt/SnO_2 gas sensor in the presence of NTP corona needle system.

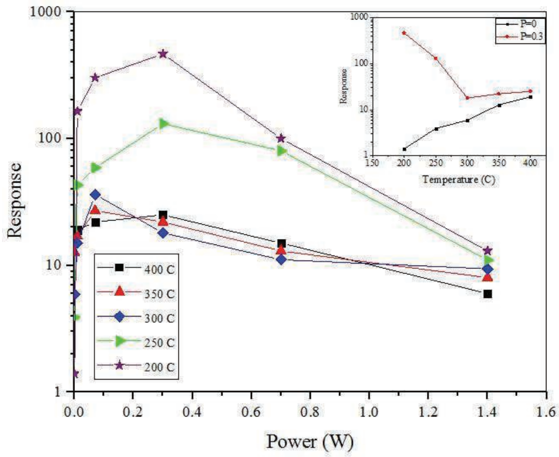

Fig. 4. Pt/SnO₂ sensor response to 5000 ppm CH₄ at different temperatures in the presence of NTP system with various electrical power at the electrode distance of 5 mm.

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