Study of Optimization Temperature of Tungsten Oxide (WO_x) Thin Films for NH_3 Gas Detection

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Abstract **- Metal oxide semiconductors have attracted a lot of attention due to several advantages such as high sensitivity, small size, low cost production, low power consumption and simplicity of fabrication technology and its high compatibility with micro-fabrication. The detection and measurement of flue gases are critical not only for achieving real time process control of new clean combustion systems, but also to minimize their emissions of dangerous air pollutants. Now-a-days ammonia (NH_3) gas detection has drawn lot of attention due to its wide industrial applications and also the harmful effect arising due to inhalation of humans even at ppm levels. Tungsten oxides is one of the widely studied materials for the development of solid-state gas sensing devices based on thin and thick films structures. However these oxides require higher temperature to operate them and creation of such high temperature is crucial for these sensors. Combining with MEMS features and WO_3 is very attractive to detect NH_3 even in the presence of other gases such as H_2, CO, CH_4. WO_3 thin films need a higher temperature range. In this study we found that the temperature in the range of 200 ^oC to 350 ^oC is a better option to use it as a good sensing material. By using MEMS technology and suspended platforms such temperature creation is possible. In this paper we report the best operating temperature of 280 ^oC for detecting the pollutant gases such as NH_3 using WO_3 thin films.**

Index Terms: **- MEMS, Gas Sensor, Micro Hotplate, Tungsten Oxides, NH_3 Gas Detection**

I. INTRODUCTION

Gas monitoring devices are in great demand for a rapidly growing range of applications. Metal oxide semiconductors have been used extensively for the detection of toxic, pollutant gases, combustible gases, organic vapors, and for the prevention of hazardous gas leaks. Different oxide semiconductors such as SnO_2, WO_3, ZnO, MoO_3, TiO_2, In_2O_3 and mixed oxides have been studied and showed promising applications for detecting target gases such as NO_x, O_3, NH_3, CO, CO_2, H_2S and SO_2 [1-4]. Tungsten oxide (WO_3) is an *n*-type semiconductor with interesting physical and chemical properties that make it suitable for various technological applications such as catalysts [5], electrochromic devices [6-7] or gas sensors [8-11]. In particular, WO_3 has remarkable gas sensing properties that account for the considerable attention given for the past few years. As it is known, metal oxide semiconductor gas sensors are suitable for the detection of oxidizing and reducing gases, since they react to their presence, on surface, with a measurable change of their electrical conductivity. The mechanism of gas detection with these materials is based in large part, on reactions that occur at the sensor surface, resulting in a change in the electron concentration. The sensing mechanism on consists chemisorptions of gaseous molecules on the surface. As a consequence, electrons flow from the surface states to adsorbed molecules and vice-versa depending on the gas, oxidizing gases like NO_2 extract electrons from the conduction band while reducing ones like CO and NH_3 inject electrons. The sensing properties of a material depend on its microstructure and also on the reactivity of its surface.

II. GAS-SOLID INTERACTION: RECEPTOR AND TRANSDUCER FUNCTION

Basically, a chemical sensor consists of three different parts: a receptor, a transducer, and a conditioning module defining the operation mode. The receptor part concerns the ability of the sensor surface to interact with the target gas and to transform this chemical information into a form of energy. The transducer part concerns the ability of the sensor to transform the energy into a useful electrical signal. These parts are presented in Fig.1 and explained in details by Simon *et al.* [12-13]. The receptor (the semiconductor surface) reacts under exposure to reducing or oxidizing gases with decrease, respectively, increase of the electron depleted region. The gas-induced changes at the semiconductor surface are transduced by the transducer (the microstructure of the sensing material), into an electrical signal. In the case of a polycrystalline material, the grain size and different grain intersections have, thereby, a strong influence on the final *output signal*. In most of the cases the sensor resistance is monitored as output signal, but thermo voltages or changes in sensor temperature (constant power operation), respectively, heating power changes (constant temperature operation) due to gas-specific heat of reactions at the surface can also be used.

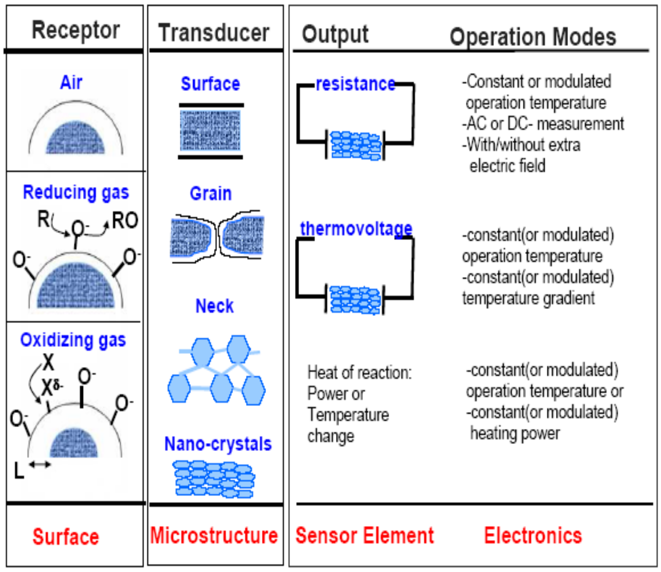

FIG 1: Schematic view of gas sensing. L is the thickness of the depletion layer) [12].

III. OPTIMIZATION TEMPERATURE OF TUNGSTEN OXIDE BASED GAS SENSOR FOR NH_3

In general the sensitivity of the sensors is affected by the operating temperature. The higher temperature enhances surface reaction of the thin films and gives higher sensitivity in a particular temperature range. A collection of literature survey was carried out for the optimization temperature of tungsten oxide based gas sensor for NH_3 gas. With the reference from the published research works it was found form that the thin films of tungsten oxide have good response in the range of 200 to 350°C for NH_3 detection, as shown in Fig.-2 [13-16]. The best operating temperature is 280 °C for detecting the NH_3 gas using WO_3 thin films.

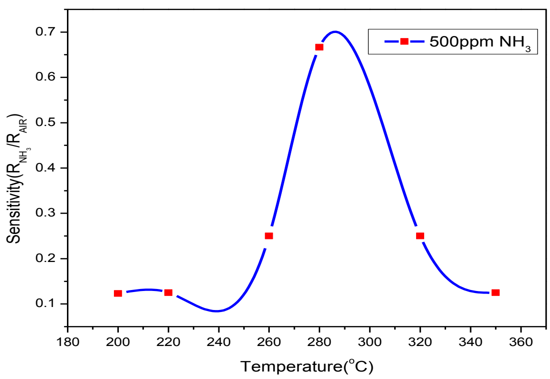

FIG-2. Sensor response of WO_3 to 500 ppm NH_3 at different working temperature.

IV. CONCLUSION

Tungsten oxide based gas sensor has been studied and it has been observed that sensitivity increases with increase the temperature and above optimum operating temperature the sensor response drops off as shown in the figure. The best operating temperature in this case is 280 °C.

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