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FIXED POINT RH EQUILIBRIUM OF GAS SENSOR TEST CHAMBER USING SIMPLE AIR BUBBLER METHOD

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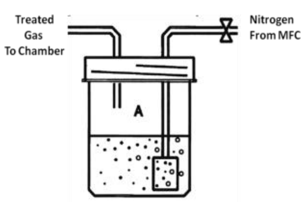
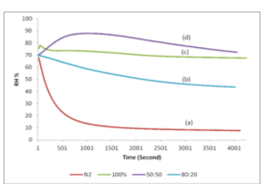
Graphical abstract





Abstract

Relative Humidity (RH) is considered as one of the important variable to be controlled during testing and characterizing of metal oxide gas sensor. This is because the metal oxide can easily react with the hydrogen and oxygen molecule of the water vapor which associated with RH level. In this paper, the effect of using nitrogen as carrier to feed the analyte to the sensor inside a 40 liter capacity container has been studied. When Nitrogen gas was supplied to the chamber, the RH value dropped significantly from initial ~67 % RH to ~7 % RH within one hour duration. As an alternative, a simple bubbler system was introduced to minimize the drop of RH. The bubbler which was filled with 100% distilled water or mixed with a certain percentage of glycerol are able to maintain the RH to a certain level for a certain period of time.

Keywords: Fix point RH, metal oxide, gas sensor, test chamber, air bubbler.

1.0 INTRODUCTION

Gas sensor systems are widely used in the development of 'electronic nose' system to monitor indoor and outdoor air quality, chemical industry, gas leak control food industry as well as precision agriculture applications. Different platform of gas sensors have been developed including metal oxide gas sensors. Development of metal oxide gas sensor has received much attention due to advantage it has to offer [2-5]. Material such as SnO_2, ZnO, Fe_2O_3, WO_3, Co_3O_4, and others was used as the sensing element to detect targeted gas or odors. Despite of offering many benefits such as high sensitivity, low cost and a short response time, their characteristic is influenced by various ambient parameters. Temperature and humidity are among parameters which act as disturbing factors in gas sensor detection system. Nevertheless, as part of characterization study, the sensor will have to go through thorough testing procedures to examine their gas sensor characteristic such as sensitivity, selectivity and drift effect over time. Particularly for metal oxide based sensor, RH was known to have a great effect on the performance of the sensor [6]. Hence, in conducting sensor performance testing, the RH and temperature should able to be controlled. However, depending on the gas type, pressure and flow rate of the gas carrier, this is very difficult to be achieved.

To mitigate this problem, there are various control chambers on the market available that have the capability to control precisely the temperature and RH. Different technologies used to control the internal condition of the chamber. This includes immersion water pump system, boiler or steam generator and atomizing system [7]. These instruments not only expensive but have a very limited space to set-up a controlled rig for gas sensor testing.

A simpler and less complex way to control the RH value inside a confine area is through an air bubbler system. Vasu et al. implement continous bubble humidification to increase the performance of proton echange membrane fuel cell (PEMFC) by control the humidity of the hydrogen gas [8]. In his work, H2 gas was finely bubbled through the water coloumn acting as humidifier system to facikitates a good control over the RH of the gas. Similarly, the initial resistance of the WO3/Nafion polymer gas sensor experimented by Rashid et. al. [9] was able to be maintained at certain value with help of air bubler which directly humidified the nitrogen gas carrier used in the test set-up. The air or mixed gas was simply bubbled through pure water or mix of water with other chemicals to create a level of humidity based on ambient or measured condition. Among the chemical systems can be used for this purpose are aqueous sulphuric acid solutions, glycerine, water solutions and single or binary salt solutions. Each such solution offers a degree of humidity adjustment that can be achieved by changing its concentration [10]. Nevertheless, to achieve a very accurate value of RH, the concentrations of the solution itself required precise control and measurement [d]. Such system as shown in Figure 1 was successfully implemented in typical laboratory set-up for controlling RH. It also has been used as part of controlled atmosphere system to store various fruits and vegetables as well as to control the insect attack [11].

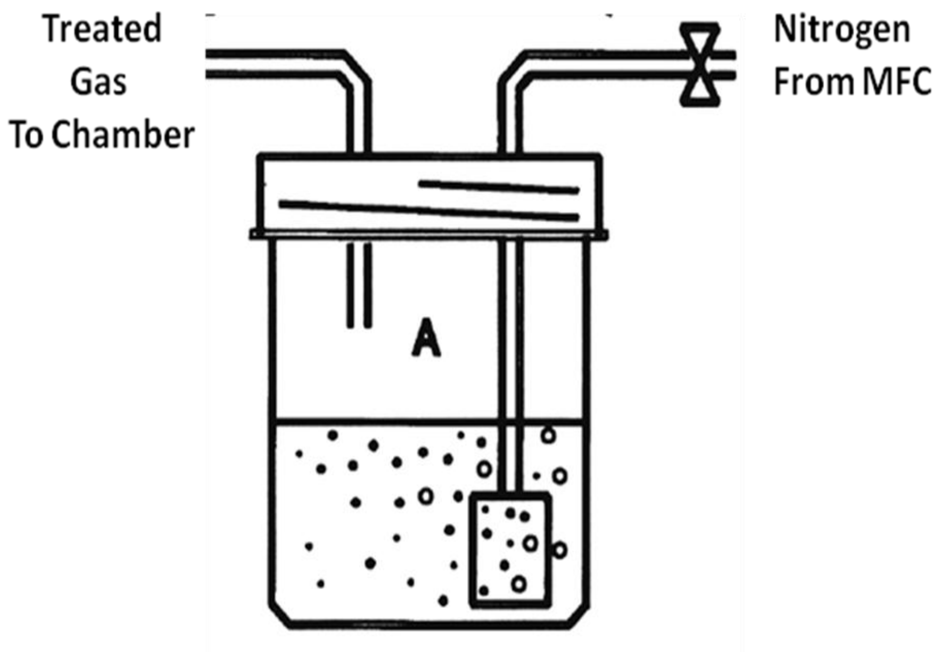


Figure 1 A typical simple bubbler system used for fix point RH control modified after Forney et al [1].

2.0 METHODOLOGY

In this study, a 40 liter capacity test chamber was used to investigate the effect of nitrogen carrier gas towards RH value when it supplied to the chamber. Initially, 10 sl/m of nitrogen gas was flown continuously to the chamber via mass flow controller (MFC). A commercial RH tester (Vernier Technology, USA) was placed inside the chamber to record the RH level. To examine the effect of bubbler system, the same procedure was repeated with a bubbler system containing different ratio of water to glycerol (100%, 50:50, and 20:80) connected to the incoming nitrogen gas inlet. The rate changes of RH and temperature over time was recorded accordingly for comparison. Schematic for the overall gas chamber set-up used in this study shown in Figure 2. The carrier gas (N_2) was directed to flow the humidifier system before entering the test chamber. The temperature inside the chamber was also been measured using thermocouple probe connected to the same sensor interface with RH sensor to ensure the steady state condition was achieved during the experiment.

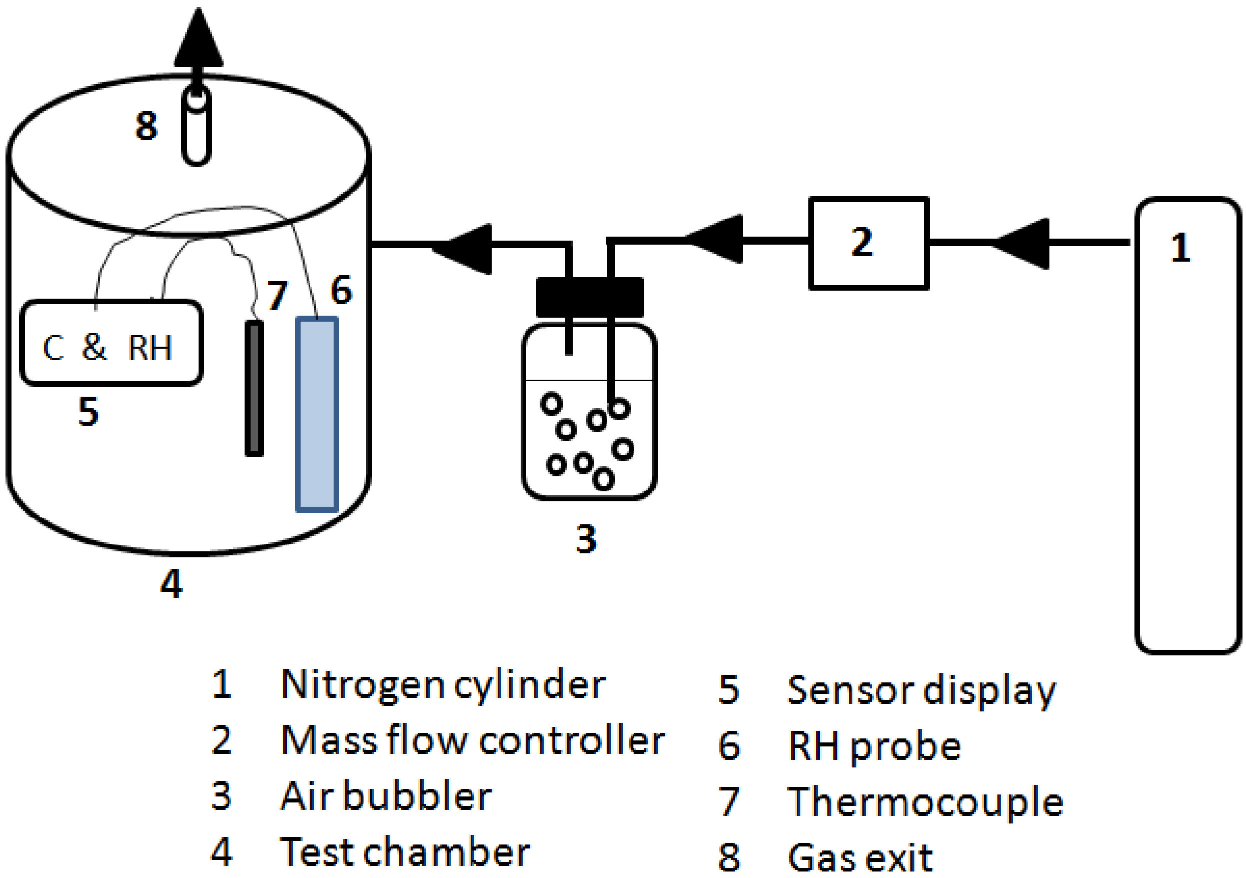


Figure 2 Block Diagram of the test chamber utilizing air bubbler unit

3.0 RESULTS AND DISCUSSION

The behaviour of temperature and RH changes inside the chamber upon pure nitrogen gas supply as well as treated with air bubbler as shown in Figure 3 and Figure 4 respectively. The temperature inside the testing chamber didn't changes with the changes of nitrogen supply condition at value ranging from 23° C – 25° C. However, without the bubbler unit, the flow of nitrogen will caused the RH inside the chamber dropped significantly from 68% to 10% at the rate of 4.2% per minute for the first 13 minutes before it stabilize between 8-9 % (Figure 4-a). This confirms the effect of the N2 gas which absorbing the majority of moisture molecule inside the chamber after some period of time. This is a very significant condition and can give a huge impact to the accuracy of the gas sensor especially which used metal oxide material for their sensing element. The responds of the sensor may actually due to the respond of the sensing element to the change in RH rather than the concentration of the target gas.

In contrast, when 100% DI water bubbler used (Figure 3-c), there were small spike of RH in the beginning before steadily maintained at slightly below 70%. The RH for 50:50 water to glycerol (Figure 3-b) shows more drastic increase at initial stage before it slowly reduced to 75% level while for 20:80 ratio (Figure 3-d), the RH was steadily at down trend before saturated at ~ 45% after 60 minutes. From this result, it was confirmed that without any treatment, the nitrogen gas which is dry in nature will drastically reduced the moisture level inside the test chamber. This was reflected by the significant drop of RH value in short amount of time. When nitrogen gas flown via the bubbler, it makes the gas become more humid .Therefore, as the gas enters the chamber, the amount of moisture inside the chamber was increased before it stabilizes over time.

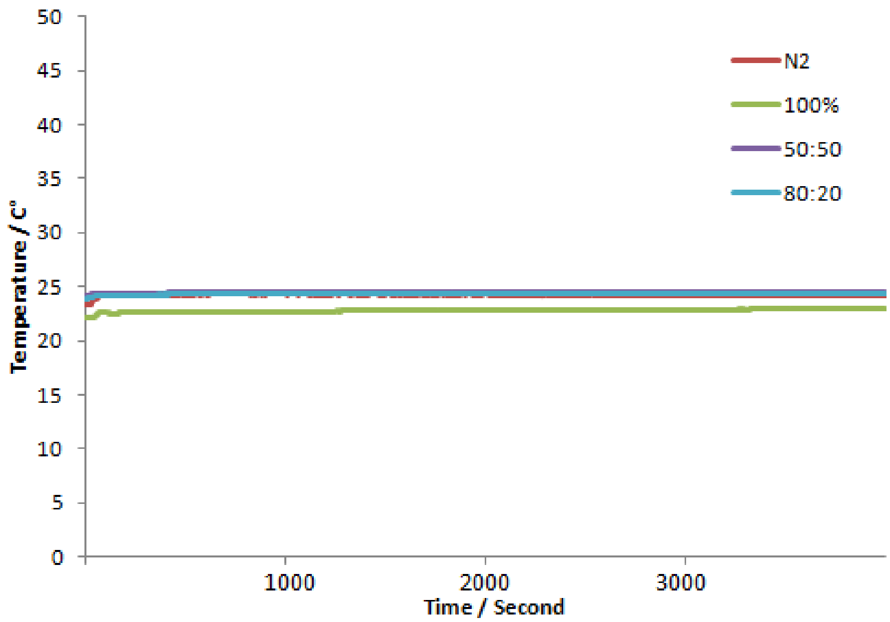


Figure 3 Temperature over time inside testing chamber at different Nitrogen flow concentration.

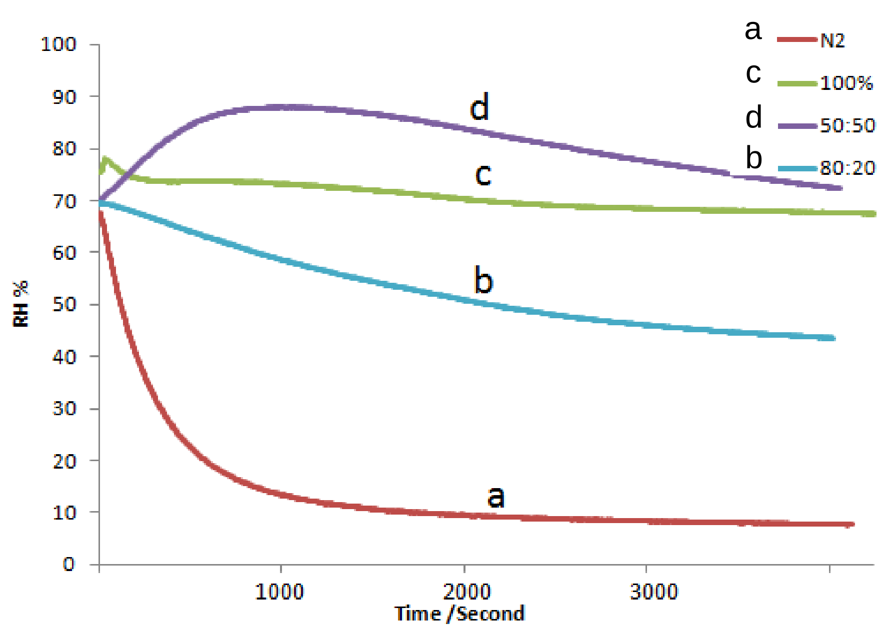


Figure 4 RH value inside testing chamber at different Nitrogen flow concentration.

4.0 CONCLUSION

From the result, it can be concluded that the usage of nitrogen as carrier gas will significantly influence the RH level inside the test chamber while the temperature can be remain consistence. To minimize the RH changes upon nitrogen gas flow, a simple bubbler method can be used as an alternative to expensive and complex control chamber system. Nevertheless, more comprehensive study and experiments need to be conducted in order to tabulate a precise correlation between the water - glycerol mix ratio to the RH level inside the chamber.

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