CHAPTER - 6

APPLICATION OF Co DOPED ZnO THIN FILM IN METHANE SENSING

6.1 Introduction

This chapter deals with the application of 8 % Co doped ZnO ($Zn_{0.92}Co_{0.08}O$) thin film in the methane sensing. The testing of methane detection concentration as 100 - 500 ppm range range between 75 ^{o}C - 200 ^{o}C operating temperatures and selectivity in presence of hydrogen, a brief description of all is presented in this section. It methane exposed on $Zn_{0.92}Co_{0.08}O$ based thin film sensor; we observed that resistance of film decreased and reached to a stable value. When gas flow was closed and gas was removed from testing chamber, then resistance increased and recovered to original resistance.

6.2 Results and Discussion

Fig.6.1, show the $Zn_{0.92}Co_{0.08}O$ thin film based sensor response for 500 ppm methane at 200 ^{o}C. In the graph, point A show to the gas inlet and point C show the outlet conditions. The resistance of the sensor decreased in the presence of methane from point A to B and was stable form point B to C and between point C to D, the sensor recovered to its original status in the absence of methane. Point A to B indicates the sensor response of the film for methane. The approximate response and recovery time are 110 sec, 160 sec respectively for 500 ppm methane at 200 ^{o}C.

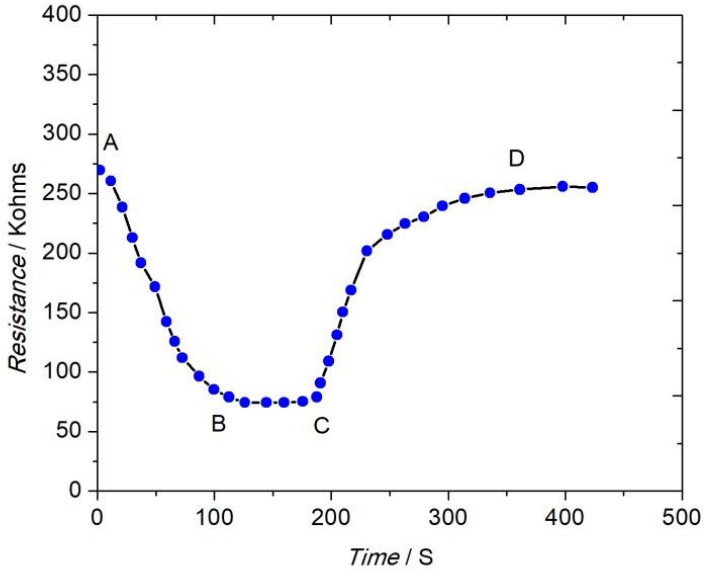

Fig.6.1. Sensor response of $Zn_{0.92}Co_{0.08}O$ thin film with methane as target gas at 200 °C.

Response in percentage at different operating temperatures, ranging from 75 °C to 200 °C with various concentrations of methane such as 100 ppm, 200 ppm, 300 ppm, 400 ppm and 500 ppm is shown in the Fig.6.2. In this graph it was shown that the response increases with increase in temperature and gas concentrations. Fig.6.3**,** show the resultant value of response for 100 ppm, 200 ppm, 300 ppm, 400 ppm and 500 ppm methane at 75 °C, 100 °C, 125 °C, 150 °C, 175 °C, 200 °C operating temperatures. The lowest value was 3.79 % for 100 ppm at 75 °C and highest value was 74.07 % for 500 ppm at 200 °C. The response was higher than undoped ZnO flat thin film, while lower than nano-wrinkled $Zn_{0.92}Fe_{0.08}O$ and $Zn_{0.92}Cu_{0.08}O$ thin film sensors.

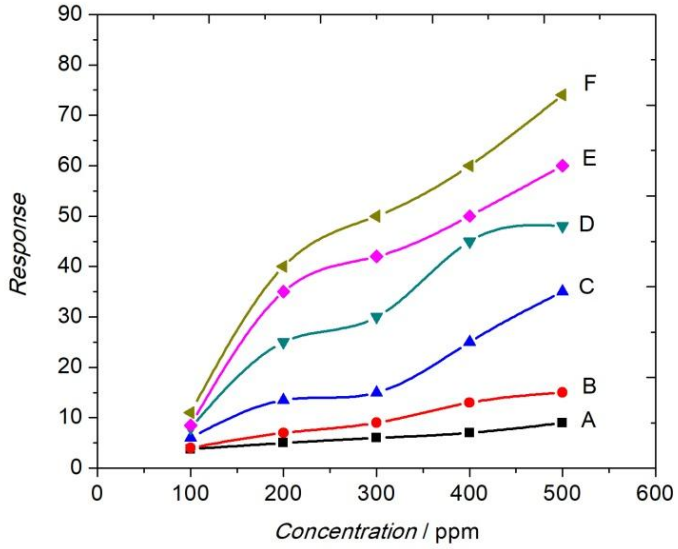

Fig.6.2. Response of the sensor on various concentrations and curve A, B, C, D, E, F as 75 °C, 100 °C, 125 °C, 150 °C, 175 °C, 200 °C respectively (Response versus Concentration).

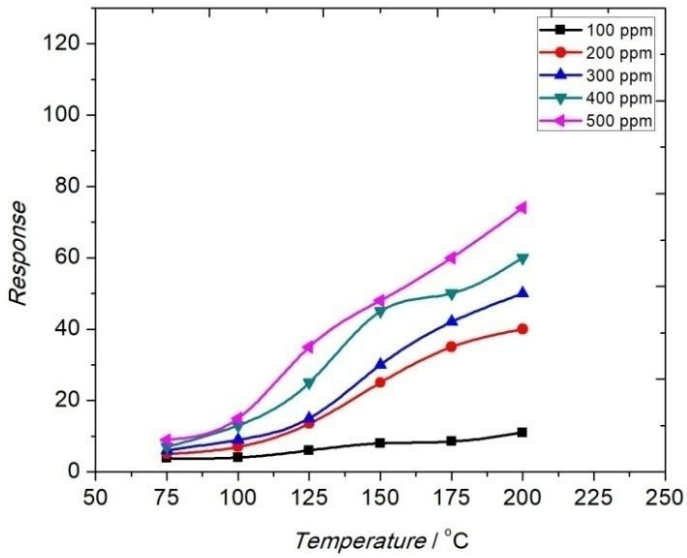

Fig.6.3. Response for 100 ppm, 200 ppm, 300 ppm, 400 ppm concentrations at 75 °C, 100 °C, 125 °C, 150 °C, 175 °C, 200 °C temperatures (Response versus Temperature).

In Fig.6.4 and Fig.6.5, show the obtained the response time of ZnO thin film for 100 ppm, 200 ppm, 300 ppm, 400 ppm, 500 ppm concentrations of methane at different operating temperatures ranging from 75 °C to 200 °C. The response time decreases with increasing concentrations at constant operating temperature. The response time decreased with increasing operating temperatures for same concentration. Resultantly, response time decreased with the combine effect of increasing of concentration and temperatures. Response time was 240 sec for 100 ppm at 75°C and 110 sec for 500 ppm at 200°C. Sensor response was quickest for 500 ppm methane at 200°C. The responses time was faster than undoped ZnO flat thin film, while slower than nano-wrinkled $Zn_{0.92}Fe_{0.08}O$ thin film and $Zn_{0.92}Cu_{0.08}O$ thin film for 100 - 500 ppm at ranges of 75 °C - 200 °C. In Fig.6.4, graph A, B, C, D, E, F denoted as operating temperature at 75°C, 100°C, 125°C, 150°C, 175°C, 200°C respectively.

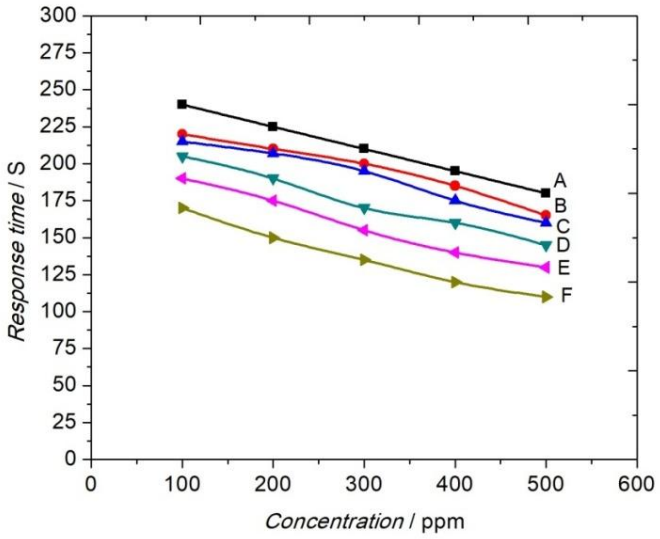

Fig.6.4. Show response time of $Zn_{0.92}Co_{0.08}O$ thin film methane sensor for 100 to 500 ppm at operating temperatures 75 °C to 200 °C (Response time versus Concentration).

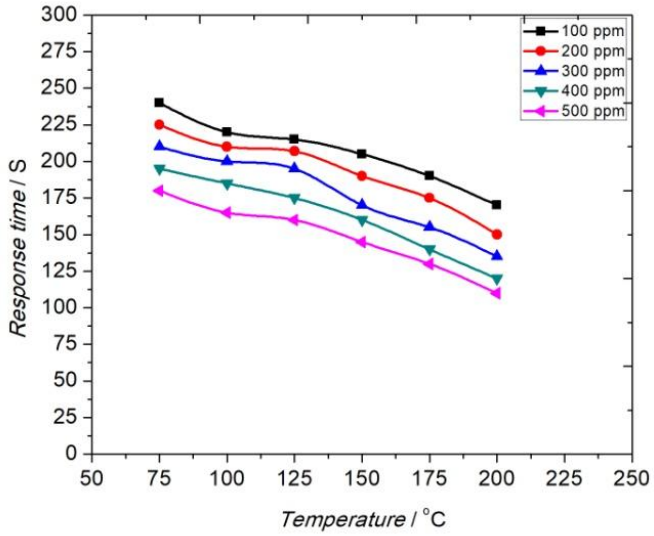

Fig.6.5. Show response time of $Zn_{0.92}Co_{0.08}O$ thin film methane sensor for 100 to 500 ppm at operating temperatures 75 °C to 200 °C (Response time versus Temperatures).

Recovery time increased with increasing concentration at constant operating temperature, while decreased with increase in operating temperature for same concentration. Resultantly, recovery time decreases with the combine effect of increasing of concentration and temperatures. Fig.6.6 and Fig.6.7 show the recovery time for 100 ppm, 200 ppm, 300 ppm, 400 ppm, 500 ppm methane at operating temperatures 75 °C, 100 °C, 125 °C, 150 °C, 175 °C and 200 °C and graph A, B, C, D, E, F denoted as operating temperature at 75°C, 100°C, 125°C, 150°C, 175°C, 200°C respectively. Recovery time was 190 sec for 100 ppm at 75°C and 160 sec for 500 ppm at 200 °C. This thin film based sensor is suitable up to 200 °C, however response was lower than the Cu doped and Fe doped ZnO wrinkled based thin film sensor and higher than undoped zinc oxide thin film. Desorption of gas molecules start from 200 °C. The recovery time was poor/ very slow compared to nano-wrinkled $Zn_{0.92}Fe_{0.08}O$ thin film sensor for 100 - 500 ppm concentration at operating temperature range of 75 °C - 200 °C and recovery time was faster compared to $Zn_{0.92}Cu_{0.08}O$ thin film for 300 -

500 ppm concentration at operating temperature between 75 °C - 200 °C. Similarly recovery time was faster compared to undoped ZnO thin film sensor for 100 - 500 ppm concentration at operating temperature of 75 °C.

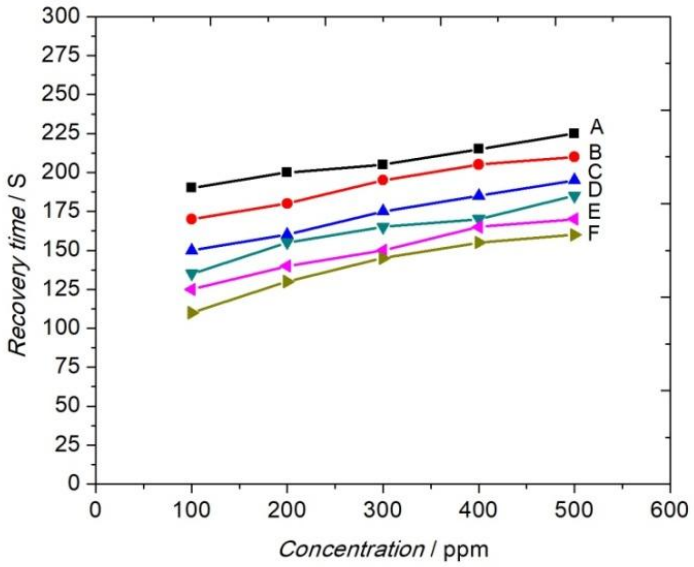

Fig.6.6. Show recovery time of $Zn_{0.92}Co_{0.08}O$ thin film methane sensor for 100 to 500 ppm at operating temperatures 75 °C to 200 °C (Recovery time versus Concentration).

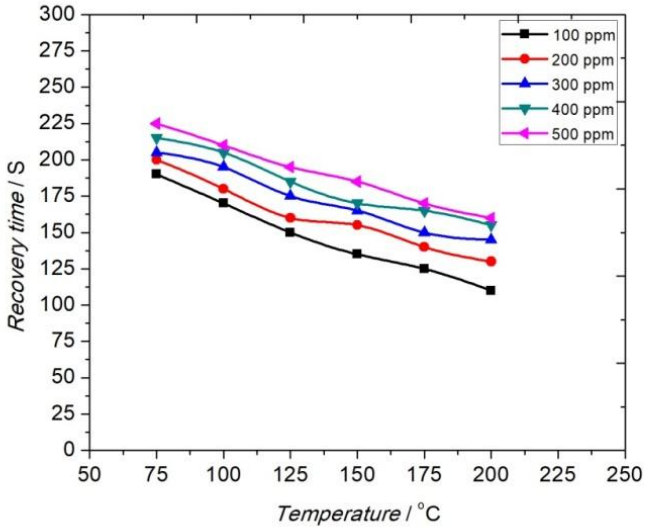

Fig.6.7. Show recovery time of $Zn_{0.92}Co_{0.08}O$ thin film methane sensor for 100 to 500 ppm at operating temperatures 75 °C to 200 °C (Recovery time versus Temperature).

6.3 Selectivity

Selectivity in presence of hydrogen for $Zn_{0.92}Co_{0.08}O$ thin film methane sensor, the high selectivity for 500 ppm of methane in presence of hydrogen was obtained at the operating temperature range of 150 °C to 200 °C. In this study, for H_2, high response was observed in the range of 75 °C to 150 ^{o}C for 500 ppm of H_2. The selectivity response was slower than Cu doped nano-crystalline and Fe doped nano-wrinkled based thin film sensors.

6.4 Conclusion

The sensing study confirm that film is sensitive for 100 – 500 ppm concentration of methane at operating temperature range of 75 °C - 200 °C was studied. The response was highest (74.07 %) for 500 ppm concentration of methane at operating temperature 200 °C. Selectivity was high in the presence of hydrogen for 500 ppm concentrations at operating temperature 200 °C. The developed film was better than undoped zinc oxide flat thin film for methane sensing.