Resonance based MEMS cantilever beam sensor for atmospheric gas

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Abstract : Worldwide coating some radical modifications in the climatic conditions due to that warming effect had by various greenhouse gases. The most harmful gas among them is Carbon dioxide and is increasing at an uncontrolled rate. This research study aims at getting better out the sum of the major polluting gas carbon dioxide. The sensor mechanism by adsorbing the CO_2 molecules on ZnO sensing layer, which modifies the overall volume of the detector. The construction is a MEMS cantilever beam, holding its own resonant frequency. To selectively adsorb CO_2 molecules from the mixture of gaseous molecules, ZnO at a specific temperature is applied. Every bit the gas atoms are adsorbed the mass increases and hence there is a change in resonant frequency. This alteration in frequency gives the criterion of the amount of CO_2 molecules present in that environment. The major expected advantage of this technique would be the reputability of the sensor that is employed. This Quantitative analysis of CO_2 would be helpful to mankind by alerting them about the environment in which they operate, by proper conditioning and networking.

KEYWORDS: MEMS Cantilever, Resonant Frequency, Atmospheric gas sensing

I. INTRODUCTION

The word 'greenhouse gases' is used to mention to the gases existing in the atmosphere which absorb the emissions and release them within the thermal infrared. These gases affects the temperature of the atmosphere significantly, thus the "greenhouse effect" is the warming of the Globe atmosphere due to the occurrence of greenhouse gases. The most visible greenhouse gases in the Earth's atmosphere are water vapor, carbon dioxide, methane, nitric oxide, ozone etc., The greatest harmful gases among them is Carbon dioxide, as its content is increasing in the atmosphere day to day. Carbon dioxide is produced prominently by the combustion of fossil fuels and geothermal processes. Recent estimates reveal, that the concentration of carbon dioxide in the Earth's atmosphere has increased to 400 parts per million by volume. This gas features second in the greenhouse gases list, comprising 10 to 28 percent of greenhouse gases. Hence MEMS technologies are increasingly being used for diverse measurements. They are comparatively inexpensive, show faster response, have high sensitivity and are suitable for mass production using MEMS technology. Hence there is keen interest in MEMS cantilever based sensors.In this paper deals with an original methodology of measurement of the major polluting gas carbon dioxide. The gravimetric sensor works by adsorbing the CO_2 molecules in ZnO sensing layer, which modifies the overall volume of the sensing element and thereby altering the resonant frequency of the cantilever used. This frequency shift is used to identify the quantity of CO_2 molecules present in the atmosphere. Here a MEMS cantilever beam is fabricated using selective coatings on the surface to adsorb CO_2 molecules.

II. DESIGN OF MEMS CANTILEVER BEAM

The sensor arrangement is that an exact binding induced surface-stress causes bending of the MEMS cantilever beam. The Present research integrates the SiO_2 cantilever with sensing Layer for the measurement of CO_2. The appearance formed would be as shown below in Fig.1 and Prathish Raaja et al. Illustrated as

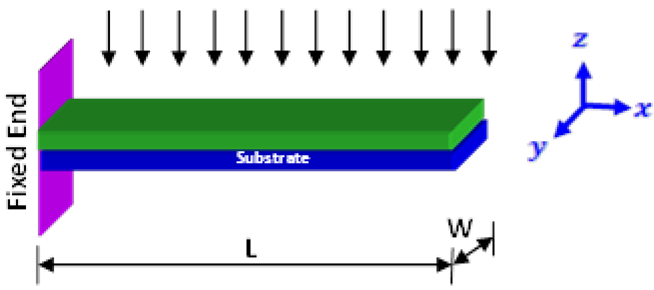

Fig. 1: Three dimensional view of MEMS Cantilever

2.1 Theory

The MEMS cantilever beam is a generally used module in microsystem devices. It exposures wide-ranging of applications in different fields such as biomedical, SHM applications [Prathish Raaja et al.], Consumer products due to its flexibility and versatility. A cantilever is the type of beam which is supported and constrained at only one end.

Fig. 2: Simple Cantilever Beam.

MEMS cantilevers can be as tinny as micrometers with lengths that range from a few microns to several hundred microns. Using the equations and proved to realize the behavior of the MEMS cantilever beam [Prathish Raaja et al]. The maximum displacement to the applied force is calculated as

$$D_{max} = -\frac{4L^2}{Wt^3}$$

Where D_{max} is maximum deflection (m), L is Beam Length (m), W is Cantilever Width (m) and t is Cantilever Thickness (m). Similarly, the cantilever beam spring constant K to the cantilever's dimensions and material constants is

$$K = \frac{EWL^3}{4L^3}$$

Where, F is applied or ambient Force (in N) and Harmonic oscillator is,

$$\omega_0 = \sqrt{\frac{K}{m}}$$

Where, K is Spring Constant, M is Mass (in Kg) and ω_0 is Cantilever beam resonance Frequency (in Hz). Change in force applied to a cantilever can shift the resonance frequency. The frequency shift can be measured with exquisite frequency accuracy using heterodyne techniques and is the basis of alternative current coupled cantilever sensor. The mass sensitivity (S_m) of a cantilever is defined as the change in frequency divided by the mass load. It can be experimentally calculated by the following equation.

$$s_m = \frac{\Delta_f}{\Delta_m}$$

Where, S_m is Mass sensitivity, Δ_f meant by Change in frequency and Δ_m meant by Mass load.

2.2. Cantilever beam resonance frequency measurement for MEMS gas Sensors

The principle used in this type of MEMS sensors is to exactly grasp gas molecules and to balance by measuring the shift in resonance frequency. The MEMS biosensor contains of two strategic mechanisms: a sensitive layer and the transducer. The sensing layer is the acute factor and responsible for selectively seizing the CO_2 gas molecules and the MEMS cantilever beam which acts as the transducer converts the mass into a vibrant shift in the resonant frequency. The Molecular weight of CO_2 is 100 g/mol. The mass change is sensed by measuring resonance frequency shifts while triggering the MEMS cantilever beam. The additional mass load on the MEMS cantilever beam results in a decrease of the resonance frequency and which is detected. The simulation was carried out using COMSOL Multiphysics software as shown in Fig. 3(a) and the results are graphically represented in Fig. 3(b).

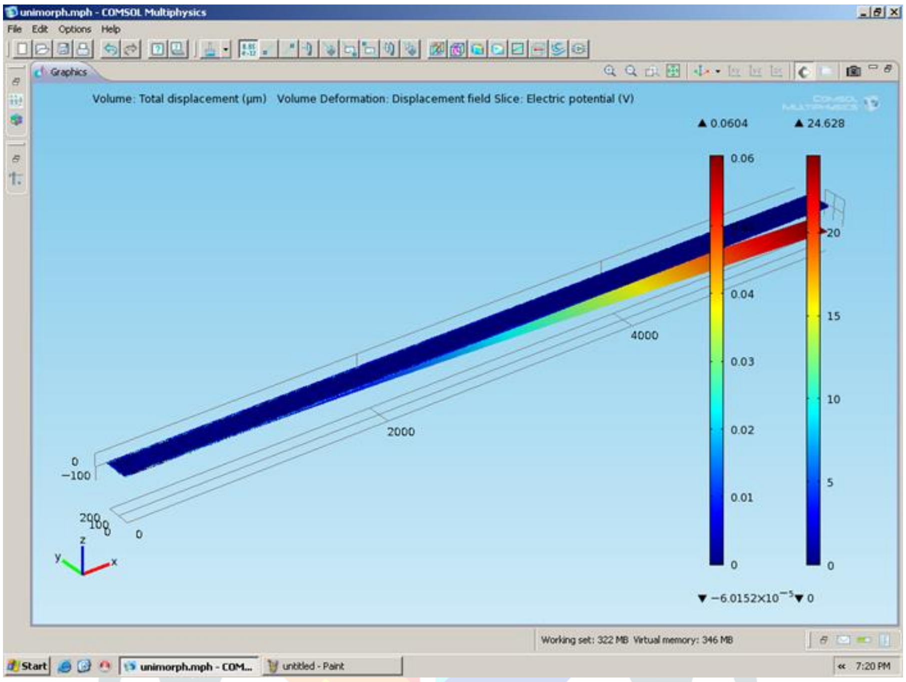

Fig.3 (a). Tip Displacement of MEMS cantilever bam using COMSOL Multiphysics 4.0

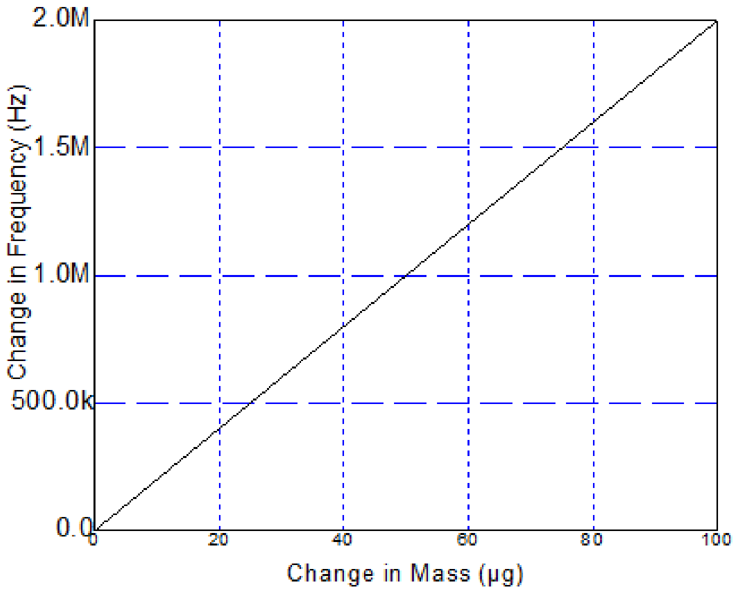

Fig. 3: Response of Δ_m versus Δ_f

It is observed that as the change in mass increases there is a matching increase in change of frequency. Similarly, hereby calculate the amount of atmospheric gas present in that environment from the resonant frequency. The resonant frequency is related to MEMS cantilever beam mass by

$$f = \frac{2}{4\pi}\sqrt{\frac{k}{m}}$$

2.3. MEMS Cantilever beam Array

Instead of having individual MEMS cantilever beams they can be combined as an array as shown in Fig. 4 to ensure a collective response.

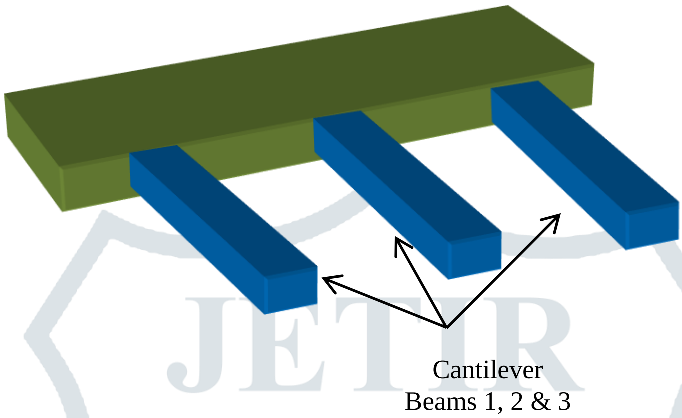

Fig.4 MEMS Cantilever beam Array

An array of MEMS sensors can usually give a better amplified signal which would be of importance and also the selective coating could be varied to give us the quantitative details of N number of gas molecule detection.

2.4. Sensitivity of MEMS Cantilever beam

The maximum frequency change from the change in mass due to the atmospheric gas being absorbed. In this work a MEMS cantilever beam size of length is 100µm, Width is 20µm and height 10µm was considered. The sensitive coatings of length 20µm and thickness of 0.1µm was integrated from the tip of the MEMS cantilever beam to the fixed end and the results were simulated using COMSOL Multiphysics software and the results are combined and graphical represented in Fig. 5

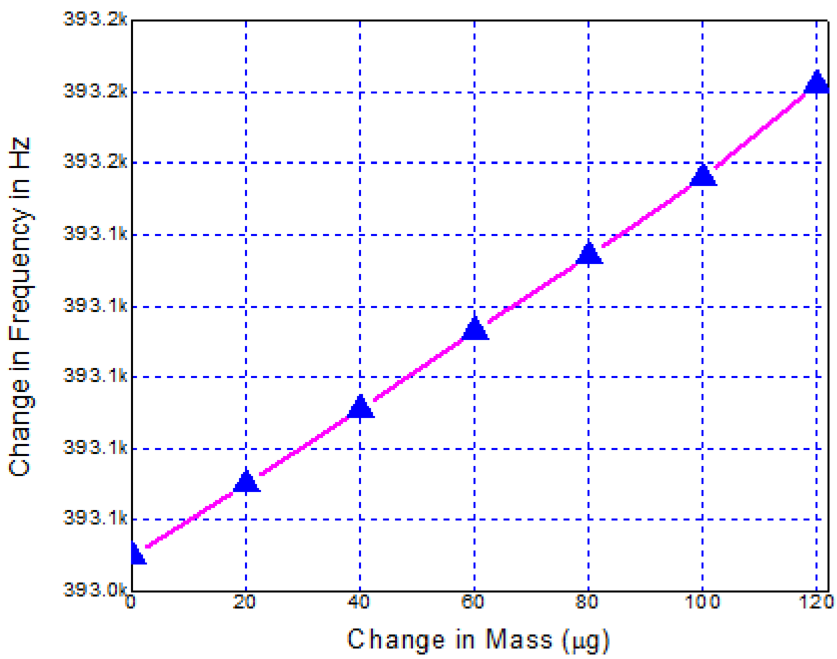

Fig. 5: Load Distribution across the cantilever beam

The total sensitivity was formulated as $\frac{4*10^{\wedge 3}}{20*10^{\wedge}-6}$ which is able one and hence this sensor supports to identify atmospheric gas molecules even when the measure is same as ppb.

III. CONCLUSIONS

This paper hence gets out the unique approach of quantity of the major polluting gas in atmosphere. The integration of the composite by a sensitive layer changes the thorough volume of the detecting element that varies the resonant frequency that means an increase in mass indications to a decrease in resonant frequency, this change in frequency gives the volume of CO_2 gas molecules existing in the atmosphere. Subsequently, when the change in mass is more than MEMS cantilever beam resonant frequency change is also more. Finally, MEMS cantilever beams sensitivity is proved. This work ensures the using the same method of identify various gas molecules. The output could be an electrical signal of MEMS cantilever beam could be a gated pulse. The sensitivity voltage could be compared and applied to an alert.

IV. REFERENCES

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