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Original Research Article

A proposal to design MEMS based IOT health care sensor

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ABSTRACT
In the Present time, healthcare and other medical services can be easily accessed with the help of a smart phone. It has become more convenient to track, regulate, and monitor several medical cycles such as medicine intake, therapy, and treatment. Telehealth holds the promise to significantly impact some of the most challenging problems of our current healthcare system: access to care, cost effective delivery, and distribution of limited providers. MEMS is the acronym for Micro-Electro-Mechanical systems, technology has the potential to revolutionized customer, industrial and commercial products by fabricating micro-range miniaturized devices which are conjunction of mechanical and electronic components on a single chip. MEMS based sensors integrated into a telemedical system holds the promise to become a key infrastructure element in remotely supervised, home-based patient rehabilitation. It has the potential to provide a better and less expensive alternative for rehabilitation healthcare and may provide benefit to patients, physicians, and society through continuous monitoring in the ambulatory setting, early detection of abnormal conditions, supervised rehabilitation, and potential knowledge discovery through data mining of all gathered information. In this paper an attempt has been made to design an MEMS based IOT health care sensor using gas sensor, strain sensor, pressure sensor, heartbeat sensor.

1. Introduction

MEMS is the acronym for Micro-Electro-Mechanical Systems. This technology has the potential to revolutionized consumer, industrial and commercial products by fabricating micro-range miniaturized devices which are conjunction of mechanical and electronic components on a single chip. Thus the main criterion of MEMS is that there are at least some elements having some sort of mechanical functionality under the control of integrated microelectronics. The critical physical dimensions of MEMS devices can vary from well below one micron on the lower end of the dimensional spectrum, all the way to several millimeters. The functional elements of MEMS are miniaturized structures like microsensors and microactuators which are appropriately categorized as “transducers”, and defined as devices that convert energy from one form to another. In the case of microsensors, the device typically converts a measured mechanical signal into an electrical signal. For the past few decades researchers and developers have came up with several possibility of sensing modality like thermal, chemical, electromagnetic, pressure, inertial forces, etc these physical variables are processed by Microelectronics and then Micro actuators acts according to the changes of the environment. Typical sensors consist of strain gauges, silicon cantilever-based accelerometers, optical fibers, piezoelectric films, and piezoceramics. Pressure sensors, strain gauges, vibration sensors, and gyroscopes have been made using these techniques. MEMS based sensors have demonstrated performances exceeding those of their macroscale counterparts, on top of that gross reduction of cost due to batch processing.

Current time need and future prospective advance the idea of integration of MEMS and other domain including photonics, nanotechnology, heterostructure material like MoS2, and Carbon composite nanomaterials like 1D CNT, 2D Graphene, reduced Graphene oxide. They attracted great research interests in recent years for various potential applications using the unique mechanical, electrical, optical and chemical properties. Specifically, the large surface area-to-volume ratio of these carbon-based material make them prime candidates for sensing applications in MEMS and NEMS devices. State-of-art synthesis processes for graphene and CNTs are vital for the commercialization of graphene- or CNT-based products. Before these materials can be successfully utilized in MEMS/NEMS systems, effective integration processes with high yield have to be established [1-3].

In our previous work attempts are made to design the sensors and sensor based system for different applications [4-7] like detecting food quality, early detection of birdflu disease, ethanol sensor, hydrogen gas sensing system. So in this current work a new attempt is made to integrate the IoT technology with MEMS based sensor in the application area of medical field.

2. Literature survey

Nowadays the monitoring and detection of different toxic gases/vapours like ethanol, methane, ammonia, hydrogen is very important with respect to energy savings and environment [8-9]. So different types of gas sensors are fabricated to achieve the goal. In literature many types of gas sensors are developed using different types sensing materials and methods. These gas sensors can be classified as electrochemical, catalytic combustion, solid electrolyte, infrared absorption, thermal conductive and SMO type sensors. On the basis of sensing methods gas sensors further classified into two groups (a) Sensors varies its electrical properties like resistance for SMO sensors and (b) Sensors varies its other properties (like magnetic, optic, and acoustic). Further the gas sensors may be classified according to the measurement methods as (1) Field Effect Transistors (FET) based gas sensors (2) Photo-luminescence based gas sensors (3) DC conductometric gas sensors. Among these gas sensors SMO sensors are smaller size, cheap, repeatable and low power-consuming. Generally the SMO sensors exhibit a surface depleted of electrons in the presence of adsorbed oxygen from the atmosphere at its operating temperature zone. The size of depletion region reduces by leaving the chemisorbed oxygen in existence of the reducing type gases like: methane, hydrogen, ethanol at the grain boundaries of the semiconductor surface. This change in the depletion region noticeably influences the sensing phenomenon of the sensor. In presence of oxidizing gas like carbon monoxide, oxides of nitrogen, carbon di oxide, oxygen the reverse phenomenon occurs at the surface of SMO sensors. The resistance of the SMO sensors changes due to adsorption of gas at the surface of the sensors. This sensing phenomenon is analysed to detect different flammable and toxic gases in the environment. This function can be modulated by the addition of an additive like basic or acidic oxide, noble metal [10-11]. The response magnitude of the sensing device is changed largely due to these additives. Transducer function concerns about the capability to transform the generated signal from the SMO surface into electrical signal.

MEMS based communication devices like as RF MEMS based antennas used in a large range of applications like different communication and IOT based systems. They offers high simplicity, low cost useful in design and analysis of different software. Today's system requires high speed fast data transmission with lighter compact designs area, higher frequency design solutions using high integration of microwave devices, circuits, and radiating elements that offer light weight, small size, and optimum performance. Compact circuit design is achieved by high-permittivity substrates which is in direct contrast to the low-permittivity substrates material and low loss which is ideal for an efficient antenna performance. The other motivation for the use of MEMS and micro sensor continues to increase in everyday life, from automotive manifolds, bio-medical analysis and aerospace structures. More than two-third of the overall micro-transducers and micro-sensor market share is accountable only for pressure sensor and ink-jet nozzles. In addition to the reduction of size there is added functionality and also the possibility of producing arrays of individual sensor element on the same chip and use of silicon as base element which has stable electrical properties and features studied for many years and are well understood and thoroughly documented [12-14]. Some of the main factors that results a high level of interest in MEMS technology are:

1. MEMs, NEMs or Sensors have brought together people from diverse discipline; this is the key to growth.
2. Due to the pure crystalline structure with a silicon content of 99.999 percent, MEMs devices gives excellent mechanical characteristics which are resulting in no mechanical hysteresis or material fatigue.
3. It is possible to produce low cost due to Integration with electronics on single chip (system or lab on chip) and high-volume MEMS devices with batch wafer processing technology. This high-volume production is very convenient with availability of cutting edge IC processing equipments.
4. MEMS (and sensors) offer the same scaling benefits that IC technology offers like speed, size/complexity, power consumption and lower cost, but they do so for domains beyond electronics.
5. A lateral dimension to sub micron level is greatly controlled.
6. Micro/Nano gas analyzer: develops and manufactures solutions enabled by micro chip technology (MEMS). Focus on gas analysis and diagnostics for high tech instruments and sensors Fast Process Gas Analyzer (micro Gas Chromatograph) product development.
7. Availability of sophisticated devices for test and diagnosis and also high end software systems are available for design and simulation.

3. Section II

Block diagram: Our proposed system's block diagram is shown in Figure 1. The MEMS sensors have been used for the application of IoT based heath sensor. The fabricated sensor schematics is shown Figure 2 and the detail steps for fabrication are described in the following sections.

Figure 1: Basic block diagram of proposed proposal.

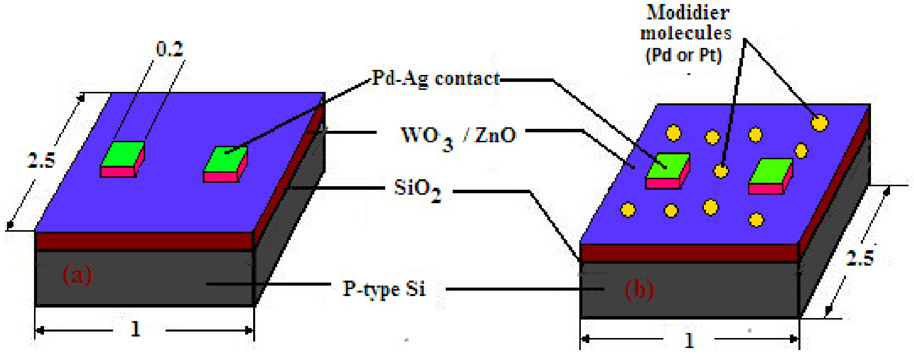

Figure 2: Basic block diagram of MEMS sensor.

3.1 Preparation of WO_3 thin film sensor

The thin film of WO_3 has been fabricated by sol-gel method using Tungsten hexa-choloride as a precursor. The thin film was prepared by the sol–gel process. The sol–gel method has emerged as one of the most promising processing route as it is particularly efficient in producing thin, transparent, homogeneous, multi component oxide films of many compositions on various substrates at low cost and it allows the tuning of the thickness of the film by varying synthesis parameters. As a starting material WCl_6 was used as a precursor to prepare WO_3 thin film. WCl_6 was dissolved in isopropanol at a ratio of 10g/150ml and stayed in dry air for 3 days. Then the sol was deposited on the substrate by spin coating method (3000rpm, 30s) and the substrate was dried in air at 150^0C for 30 minutes. Post deposition heat treatment (annealing) at 600^0C for 2 hours was carried out to improve microstructure and crystalline properties of the deposited thin film. Then Pd-Ag contact (0.2µm) was deposited for metallic contact formation by thermal evaporation technique.

3.2 Preparation of Pd-surface sensitized WO_3 thin film sensor

For Pd sensitization, an aqueous solution of 0.01 (M) $PdCl_2$ is prepared and the sol-gel grown WO_3 thin films are dipped in the solution for 10s and annealed at 125^0C for 15 minutes. The mechanism of formation of Pd nano-clustered from $PdCl_2$ is investigated with oxidation reduction reactions in solution. In such solution, $PdCl_2$ dissolved easily Pd^{++} and Cl^- ions. The Pd^{++} ion took two electrons from the surface of WO_3 thin film to form Pd. E-beam vacuum evaporation technique is used to deposit pd-Ag (70%) electrodes (2 mm × 2 mm) with a thickness of 0.2 µm on top surface and back surface of Pd-surface sensitized WO_3 thin film using Al mask.

3.3 Preparation of Pt-surface sensitized WO_3 thin film sensor

1 ml of 80 mM H_2PtCl_6 solution in ethylene glycol was rapidly added to 8 ml ethylene glycol at 160°C that contained 0.08 g Polyvinylpyrrolidone K-30 (PVP) under continuous stirring. The black colour Pt nanoparticles formation could be observed during the reaction. Then using acetone and ethanol the black solution was washed continuously two or three times. Then the Pt nanoparticles were obtained after centrifuging and drying at 60°C under vacuum for 8 hour. The solution of Pt nanoparticles (0.8 mg) and deionized water (10 ml) is prepared and were mixed with WO_3 solution. Finally using this solution the Pt modified WO_3 thin film sensor was fabricated by calcining at 600°C in air for 2 h. Table 3.1 describes the detailed description of the fabricated samples.

Our system consists of two parts:

1. Wearable system, which includes sensors, signal conditioning circuits, a microcontroller, and
2. a personal computer (PC) for collecting and elaborating data.

The wearable system mainly consists of strain sensor, temperature sensor, Bluetooth module, the custom electronics for conditioning and transmitting the sensor signals, and a battery. Here we use Bluetooth UART module based on HC-05 as it is easy to use and designed for transparent wireless serial connection setup. A temperature sensor which has following properties: calibrated directly in centrigrade, linear +10mv/degC scale factor, suitable for remote application ,low self-heating, and low cost. Multiple such kinds of sensors can be used simultaneously. Finally a CPU which plays the pivotal role of the whole process system. It is the heart of the whole processing system which is programmed. Circuit diagram of different parts are shown in next Figure 3-4.

Table 1.1: Description of the fabricated samples.

Sample Number	Description		
	Substrate	Sensing Layer	Top Contact and Bottom Contact
S1	p-Si <100>	un-sensitized WO_3	Pd-Ag (70%)
S2	p-Si <100>	Pd surface sensitized WO_3	Pd-Ag (70%)
S3	p-Si <100>	Pt surface sensitized WO_3	Pd-Ag (70%)

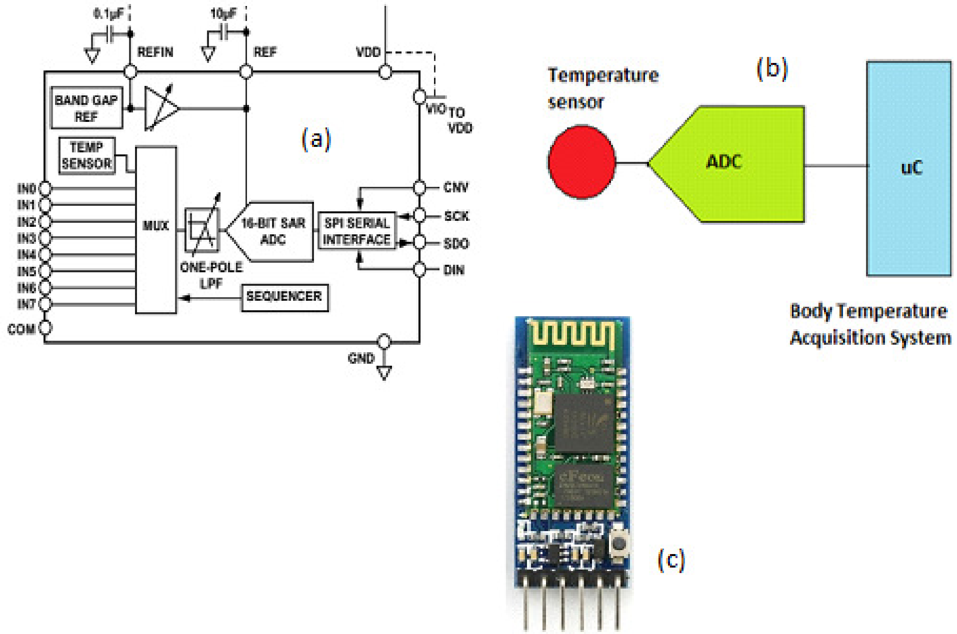

Figure 3: Proposed system components and connections.
(a) Circuit diagram of ADC, (b) temperature sensing system, (c) Bluetooth device.

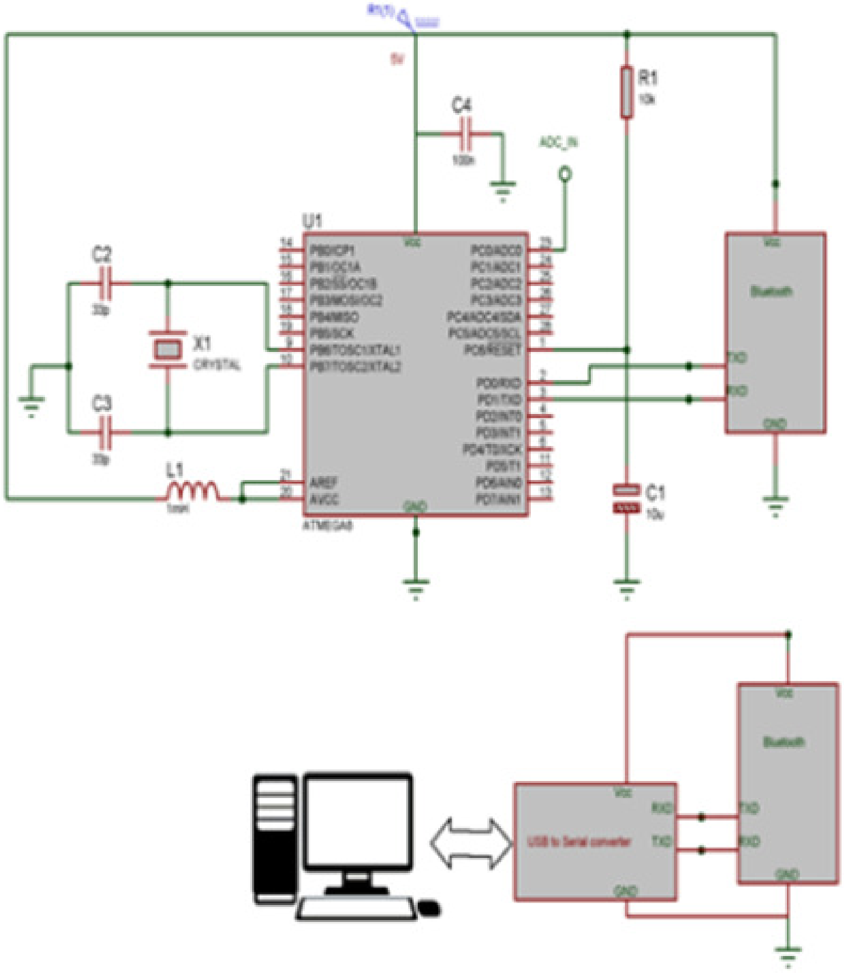

Figure 4: The measurement system including the microcontroller, the transmitting unit and the power supply. The PC collects the data via Bluetooth connection.

4. Section III

4.1 Measurement setup

Figure 5 shows the schematic of measurement set up for ethanol vapour sensor. The cylindrical sensor chamber is made of glass (length 25cm and diameter 3.5 cm).The thin film sensor is inserted into the chamber (by contact connection). The temperature controller (TC) was used to attain the operating temperature. Temperature controller was operated by resistive heating coil (≈ 8cm of constant heating zone, with temperature accuracy ±1˚C). The gas flow and mixing ratio were precisely monitored and controlled with the help of mass flow controller (MFC), Mass Flow Meter (MFM) (Alicat scientific, M-50SCCM-D) for air (reference gas). The homogeneous mixture carrying the desired percentage of the target vapour was fed into the chamber with a flexible PVC pipe. During the testing the gas pressure on the sensor was 1atm. Figure 3 shows that schematic diagram of experimental set up. The sensitivity (S) is defined as:

$$\text{Sensitivity (S\%)} = (R_A - R_V)/R_A \times 100 \qquad (1)$$

where R_A is the sample resistance in N_2 (i.e. at 0% ethanol vapour) and R_V is the sample resistance at a given concentration of ethanol vapour. The operating temperature of the sensors is the critical parameter as it directly determines the stability and longevity of the sensors. The experimental work has been carried out to find out accurate operating temperature for all the sensor samples. The response time and recovery time of the sensor is other very important parameters to observe. Response time is the time interval over which resistance of the sensor material attains a fixed percentage (using 90%) of the final value when sensor is exposed to full scale concentration of the target gas/vapour. On the other side recovery time is the time interval over which sensor resistance reduces to 10% of the saturation value when target gas/vapour is removed and sensor is placed in reference air. Small value in response time and recovery time is mostly desirable in real time application.

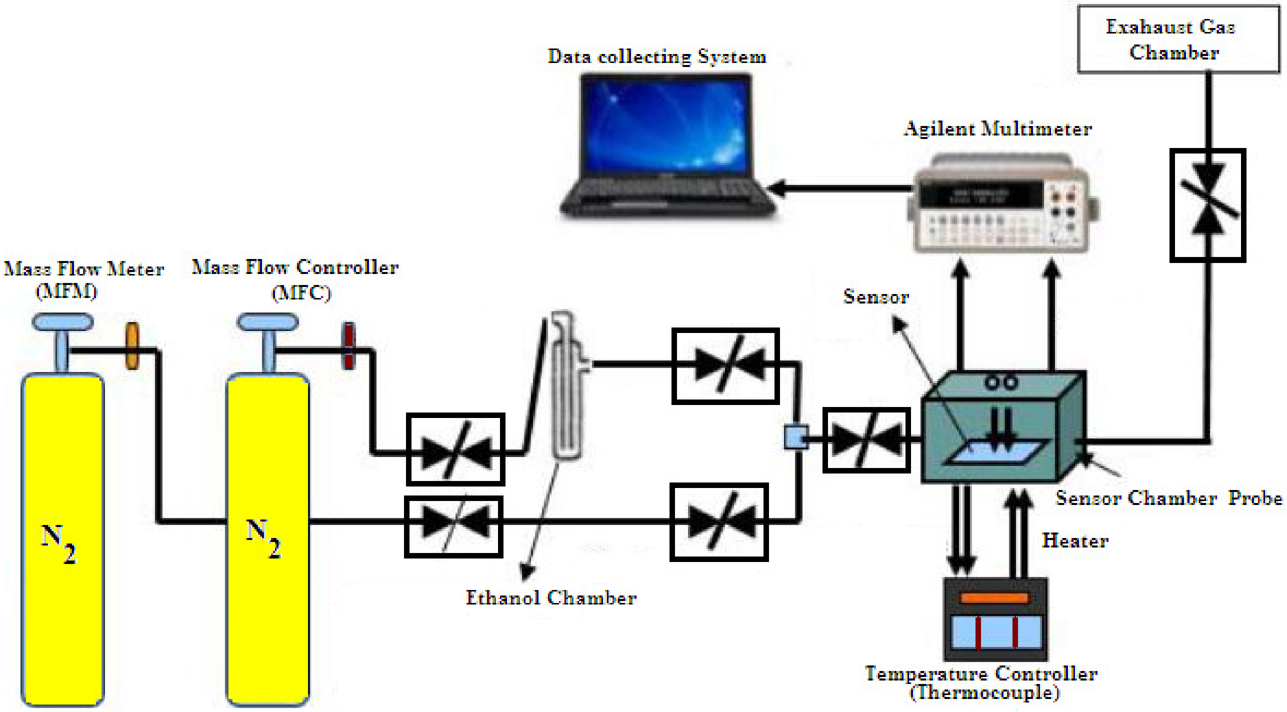

Figure 5: Experimental set up.

A four-layered IoT structure is proposed in which the MEMS sensors will be deployed. Initially the performance of the sensors is tested. Then these sensors will be associated with the Node MCU. This sensor will inspect the health conditions and feed information to the server. The hub MCU is going about as a WiFi module. This information thus is contrasted with the standard datasets for the individual in the web server as shown in Figure 6.

Figure 7 shows the sensitivity of the MEMS sensor as a function of temperature. The performance of three different sensors is shown and Table 2 shows operating temperature and sensitivity of those sensors.

The sensitivity of the sensors is enhanced with modification of Pd and Pt for both the materials WO_3 and ZnO. Figure 7 shows the change of sensitivity of different sensors according to Eq. (1) with respect to change of ethanol concentration at each sensor's respective operating temperature. The reason for enhancing the sensitivity lies in the fact that the addition of noble metals creates more space for interactions between ethanol vapour molecule and sensing layer. The noble metal additives with high effective oxidation catalytic enhance the spillover effect. Besides, the surface to volume ratio is further enhanced as the diameter of the nanoparticles reduces.

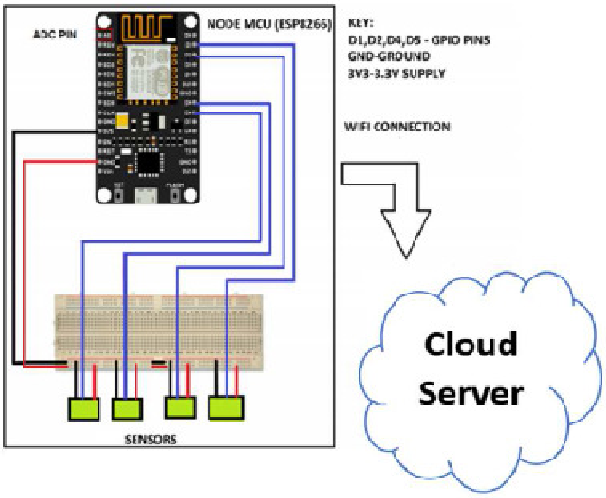

Figure 6: Block diagram of IoT System.

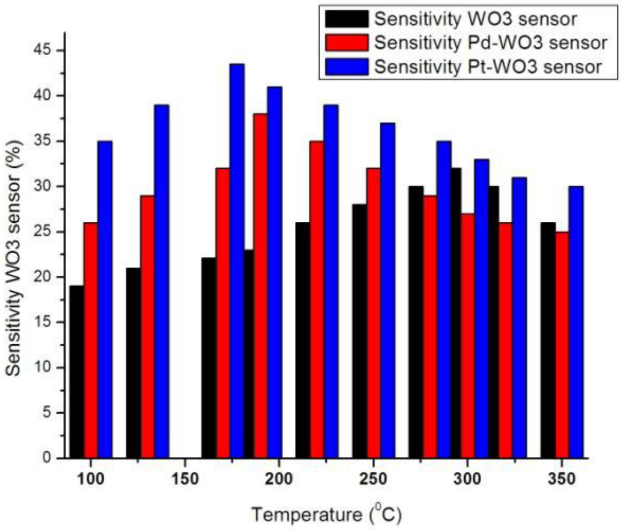

Figure 7: Sensitivity of MEMS sensor vs. temperature.

Table 2: Experimental result for calculating operating temperature (OT (^{0}C)) for different sensors using sensitivity (S%).

Ethanol Concentration	WO_3 sensor		WO_3-Pd sensor		WO_3-Pt sensor	
	OT (^{0}C)	S (%)	OT (^{0}C)	S (%)	OT (^{0}C)	S (%)
500 PPM	300	30.1	210	35.3	170	45.2

5 Conclusions and future work

Health monitoring assumes a significant part in the dependability and upkeep. Computerized monitoring strategies have been displayed to expand more accurate diagnosis where detecting gadgets are acquiring conspicuousness lately. The proposed IoT empowered detecting gadget precisely estimated the parametric essential qualities for better health monitoring system. The proposed work has two parts namely the design of MEMS sensors and deployment of MEMS sensor into the IoT architecture. In this attempt 1st part has been completed and in the next part will be our future work.

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