Synthesis of Ferrite based Sensor and Development of PIC 18F4550 based Sensor Module for Measurement of Ammonia Gas Concentration

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Abstract: The monitoring of hazards gas and controlling of the same is an important to avoid the dangerous accidents. Considering this fact it is proposed to develop an embedded system based on PIC microcontroller. Moreover, it is proposed to study and development of Ferrite Based Sensor gas sensor for ammonia gas monitoring. For proposed research work, the Ammonia Gas Sensor is designed by using COxZn1-xFe2O4 ferrites. The developed sensor is wired with the signal conditioning system around with PIC microcontroller to obtain the desired aim of proposed research work. The developed sensor is calibrated by using two point calibration method. The PIC microcontroller is programmed by using embedded C, which helps to work all peripheral devices as family members. The developed system is implemented successfully for the typical application.

Keywords: Ferrite Based Sensor, PIC 18F4550, Ammonia Gas, Display Device.

Introduction:

During recent days, the development of an embedded system, based on microcontroller is new area where in many students are undertaking the research work. On literature survey, it is found that PIC 18F4550 microcontrollers are having promising on-chip resources [1]. Deploying which one can develop smart embedded system. The field of embedded system design deserves significant place in many industrial as well as domestic applications. Moreover, one can design an embedded system for domestic application. As per definition it is known that embedded system comprises a sophisticated computing device such as microcontroller, wherein respective firmware is really embedded into it. Hence, the development of an embedded system based on microcontroller found rather easier and application oriented. Therefore, many researchers and students are showing interest in doing work based on microcontroller. Moreover, it is also found that the development of software for dedicated applications is becoming easier because of the availability of respective IDE. It is found that in addition to the other fields, the industrial field is open for the designers to design instrumentation for industrial application. For industrial application, it is essential to develop a highly sophisticated instrumentation. However, it can be attempted to do work of development of instrumentation for this purpose. In industrial fields embedded system can find applications for detection instrumentation such as temperature measurement, gas leak detection etc. and real time applications.

On literature survey, it is found that the detection and measurement of environmental parameters is prime important, particularly in industrial and agricultural sectors. Therefore, there is a need of sophisticated instrument. Considering this fact we design ferrite based sensor and develop the PIC 18F4550 based sensor module for measurement of ammonia gas concentration. However, for smart sensor module is essential. Therefore, for sensor sensing material is equally important. Hence, a study the suitability of sensor material and design own sensor for smart sensor module [2]. Electrical and magnetic properties of polycrystalline ferrites can be significantly improved by preparing homogeneous and high density compositions. This can be done by preparing the compositions, under investigation, by wet chemical method, wherein the reaction is at atomic level. The resulting Nano-ferrites would show significant modification in the electrical as well as magnetic properties. The proposed research work consists of two parts. First part is the investigation of structural, and electrical properties of substituted ferrites and to check the material`s suitability for various applications. The second part of the work consists of design of PIC 4550 based smart sensor module. Whereas the objectives of the research work are:

a) Preparation of the polycrystalline single phase spinel ferrites by co-precipitation method.
b) Characterization of prepared compositions by standard tools like X-ray diffraction.
c) Formation of thick films to develop the sensors and to study electrical properties.
d) To study the architectural details of PIC 4550.
e) Designing of PIC microcontroller based smart sensor module for detection of ammonia gas.
f) Interpretation of results.

1. **Development of Smart Sensor Module for Ammonia Gas Monitoring:**

As per the proposal, the smart sensor module for ammonia gas monitoring is develops in college lab. The work is done in two parts. In the beginning the compositions of polycrystalline, AxB1-xFe2-yCyO4 (where A & B are divalent metal ions and C is the trivalent caution), spinel ferrites will be prepared by standard ceramic method, employing AR grade starting materials in stoichiometric weight proportion. A single pan microbalance will be used for this purpose. The starting materials will be either oxides or carbonates of the respective constituents. These starting materials are mixed with acetone based and milled. It is then subjected to calcination process. The compositions are again milled and subjected to the process of final sintering. The sintering time and temperature will be optimized to achieve necessary properties. Formation of compositions will be confirmed after characterization by X-ray diffraction and IR absorption technology. After confirmation of satisfactory preparation, the material will be used for further investigations.

The ferrite compositions, NixZn1-xFe2O4 (x =0.40) were prepared, using AR grade starting materials. Formation of the compositions was confirmed on characterization by X-Ray diffraction. The electronic circuit is designed to sense the concentration of ammonia gas. The development of sensor module is based on:

a) The Ferrite
b) The Spinel Structure
c) Classification of the Spinel ferrites
d) Preparation and Characterization of Polycrystalline Spinel Ferrites
e) Preparation(i.e. Methods of Preparation)
f) Preparation of ferrite Compositions under Investigation
g) Characterization
h) Experimental
i) Result
j) Gas Sensing Mechanism in the Polycrystalline ferrite materials
k) Measurement of NH3

2. **Hardware:**

The hardware consist mainly two objects, sensor and other is processing system. The sensor array consists of two or more sensors, on other hand processing system enclosed of microcontroller with advanced features along with on-chip resources.

The ammonia sensor is developed to form Smart Transducer Interface Module (STIM). Figure 1 depicts the entire

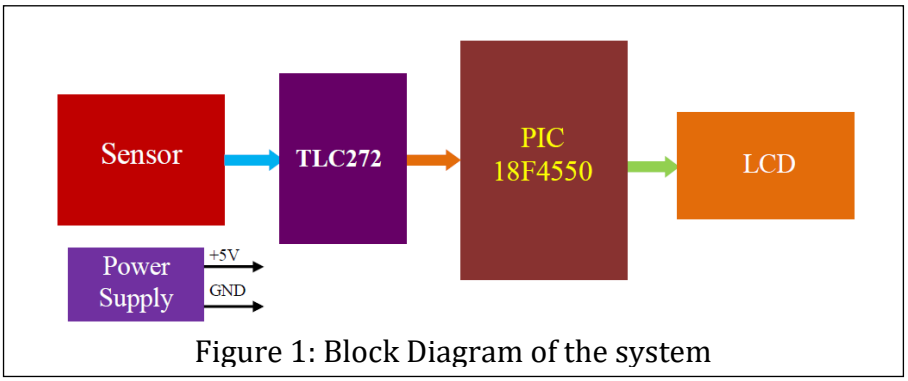

Figure 1: Block Diagram of the system

view of the system which is designed in terms of the block diagram. As in figure, the ammonia sensor is wired with microcontroller 18F4450. In addition to this, the smart LCD realizes the output unit [3]. Moreover, the figure 2 depicts circuit schematic of system.

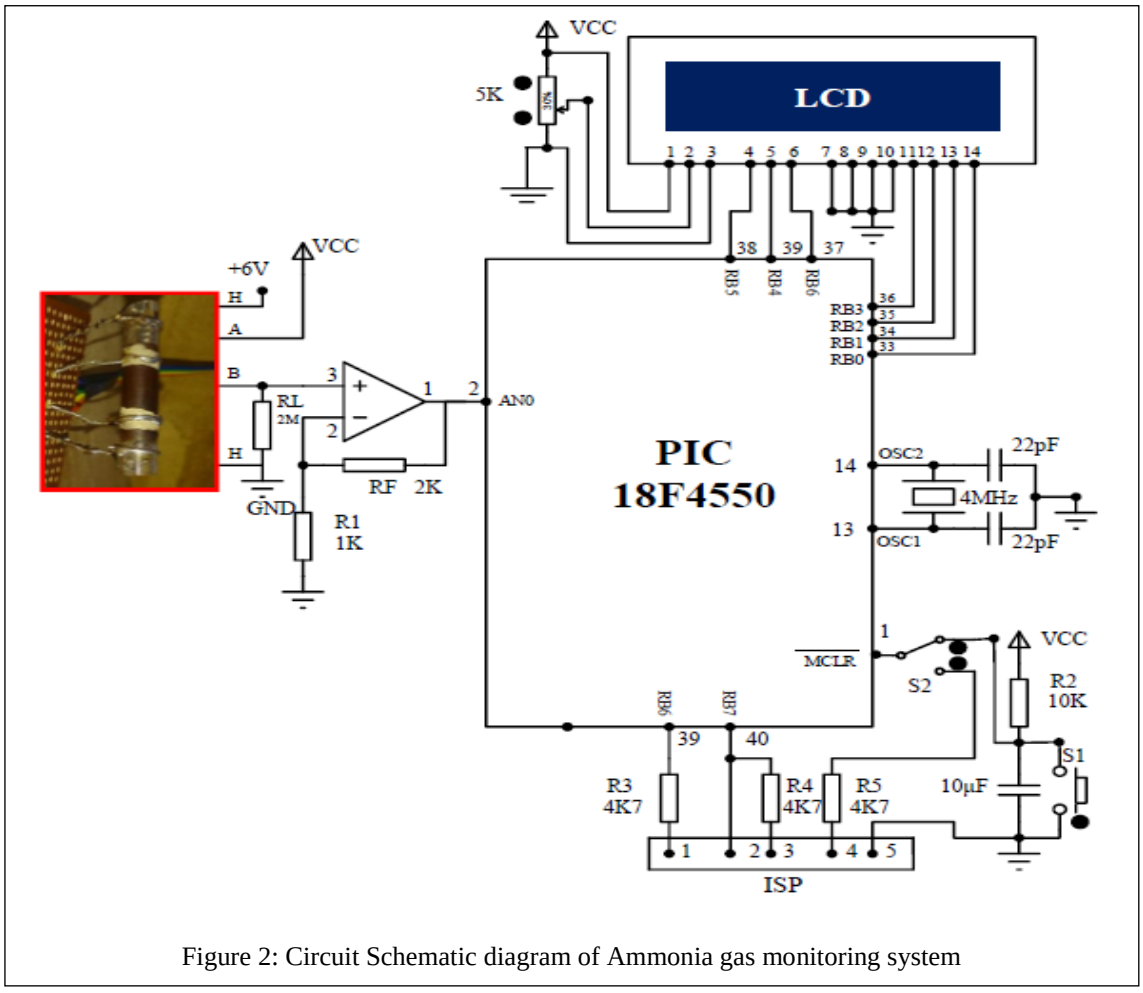

Figure 2: Circuit Schematic diagram of Ammonia gas monitoring system

Ammonia Gas Sensor:

Basically, the Ammonia Sensor designed by using COxZn1-xFe2O4 ferrites. The thick film is deposited, using screen printing technology, on the backlight substrate. The thick film is deposited in cylinder shape on glass tube as shown in figure 3. Where, the coil is deployed to provide typical temperature to the sensor material. In addition to this, figure depicts sensor terminals. 'H' indicates heater terminal and A is input terminal of sensor, whereas terminal B is used to interface sensor output. The silver paste is pasted at one end of each rectangle to achieve Ohmic contacts. The silver electrode is used to facilitate the connection of the same to electronic circuits. The present Ammonia sensor is passive. Here, the resistance of the material linearly decreases with increasing ammonia. This property is utilized in this design. Therefore, the present sensor is of resistive type. Since, the sensor is passive in nature, it is excited by +5V supply [4]. To achieve good stability in the output, it is recommended to employ highly stable and noise free power supply. While interfacing this sensor module to the further

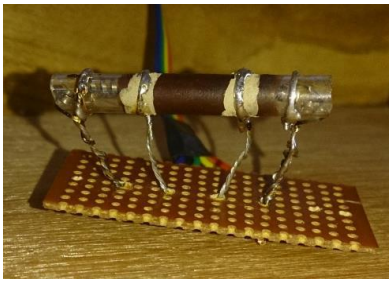

Figure 3: Ammonia Gas Sensor

electronic instrumentation, the designer must take care of the power supply of the instrument. The sensor is used in resistive divider combination as shown in figure 4.

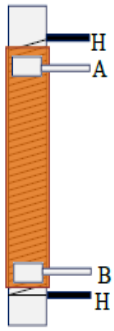

Figure 4: Ferrites based

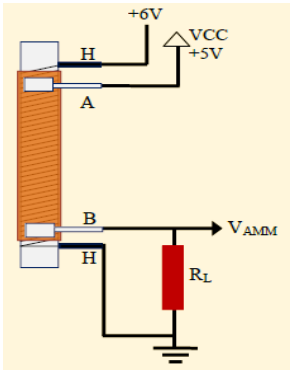

Figure 5: Interfacing of

The Ammonia sensor used in this system is highly precise and reliable. It provides DC voltage depending upon surrounding ammonia gas concentration in %. This works with +6 Volt power supply for heater. The Ammonia Gas dependent voltage VA is taken across resistor of 2MΩ and connected to the signal conditioning stage. The voltage observed is in millivolt range and as expected, it exhibit linear relation with applied ammonia gas concentration.

b. Signal Conditioning: Signal conditioning stage of sensor module plays vital role on the salient features of the measurement and control instrumentation [5]. As the gas sensors produces small change at the output, hence to detect such change in typical parameter, signal conditioning stage is essential. Here, ammonia gas sensor is deployed for gas monitoring. To amplify the typical sensor output the amplification of signal is carried out using TLC 272 amplifier. The TLC 272 precision dual operational amplifiers combine a wide range of input offset voltage with low offset voltage drift, high input impedance, low noise, and speeds approaching those of general-purpose BiFET devices, which provides offset voltage stability far exceeding the stability. The extremely high input impedance, low bias currents, and high slew

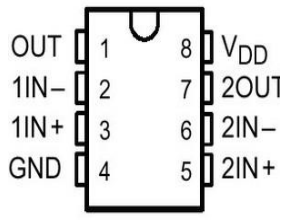

Figure 6: TLC 272

rates make these cost effective device. These advantages, in combination with good common-mode rejection and supply voltage rejection, make these devices a good choice for new state-of-the-art designs as well as for upgrading existing designs. The TLC272 has two pairs of input channels, hence one can interact two different signals at a time. For present system TLC 272 is wired as amplifier, with non-inverting configuration. Where, the gain of amplifier is calculated to scale the sensor output.

c. Microcontroller (PIC 18F4550): The system is wired about microcontroller. The fundamental characteristic of the Smart Sensor Module is the intelligence, which could be ensured by the deployment of microcontroller of promising features. In fact, present design is good example of an embedded system, wherein microcontroller plays commendable role in enhancement of features of sensors interface. In embedded control and monitoring system, microcontroller acts like core of the system. The microcontroller scans data from respective peripheral devices, process received data according to user software. After processing data is stored in on-chip memory of microcontroller, also sends at output for display purpose. Moreover, some microcontroller in built with on-chip analog to digital conversion, which is more suitable to interface peripherals having analog output. However, signal processors are widely used in several applications like, smart mobiles, microwave ovens, hi-fi equipment, home automation, bank security, industrial process control and several others. On intensive study on microcontroller series, it is found that, the microcontroller, PIC 18F4550 is suitable for present design. Which is from 18F series of Microchip, is selected for this research work. Whereas, there are some features of PIC 18F4550 [6] are:

1. 40 pin DIP package Operating frequency is DC-48Mhz.
2. Program memory is 32768 bytes and 16384 instructions.
3. Data memory is 2048 bytes.
4. Data EEPROM memory 256 bytes.
5. Twenty interrupt sources.
6. Five I/O ports.
7. Four timers.
8. 8.10bit Analog-to-Digital module of 13 input channel.
9. Programmable low voltage
10. There are 40 pin PDIP package.

d. Display unit: The present electronic system, designed for measurement of ammonia gas, always needs a suitable display device to represent the parameters in real engineering as it. For this purpose, the Hitachi makes intelligent LCD have been employed as shown is the figure 2.

3. Implementation of Sensor Module for Ammonia Measurement: Nano sized spinel ferrite have wide range of application from microwave to radio and audio frequency as well. Traditionally, the ferrites are used for various applications, wherein the electric as well as magnetic properties are significantly employed. However, on survey, it is found that, the polycrystalline ferrite materials are mostly suitable as sensor materials. During early days, its applications are constraints over sensing of typical gases. The spinel ferrites are highly sensitive to various parameters such as preparation condition, chemical compositions, use of caution, distribution of cautions, sintering temperature etc. Slight modification in such parameters, result into significant modification in the electrical properties of ferrite material. Moreover, such polycrystalline ferrite materials are also suitable for various environment gases like CO_2, H_2S, and LPG etc. To detect and measure various environmental parameters the ceramic sensor, either thin film, thick film or bulk form, are suggested. Mostly, polymers are also used for detection of the Ammonia. However, the polymer materials are hardly of thermal satiability, mechanically strength, fast response etc. On investigation electric properties, it is found that, the ceramic sensors are exhibiting promising response to Ammonia Gas concentration as well as other various environmental gases. They also show the improved parameter like response time, settling time etc. Actually, the ferrite materials are showing linearly characteristic to the ammonia gas as well as different gases. But the response for high concentration of gas is faster than that of less concentration. As discussed earlier, this phenomenon supports the absorption and adsorption. In short the ferrite materials are mostly suitable for ammonia as well as other gases. Therefore, it can be deployed for development of a smart sensor model for measurement of ammonia gas. The implementation of the system is shown in figure 7.

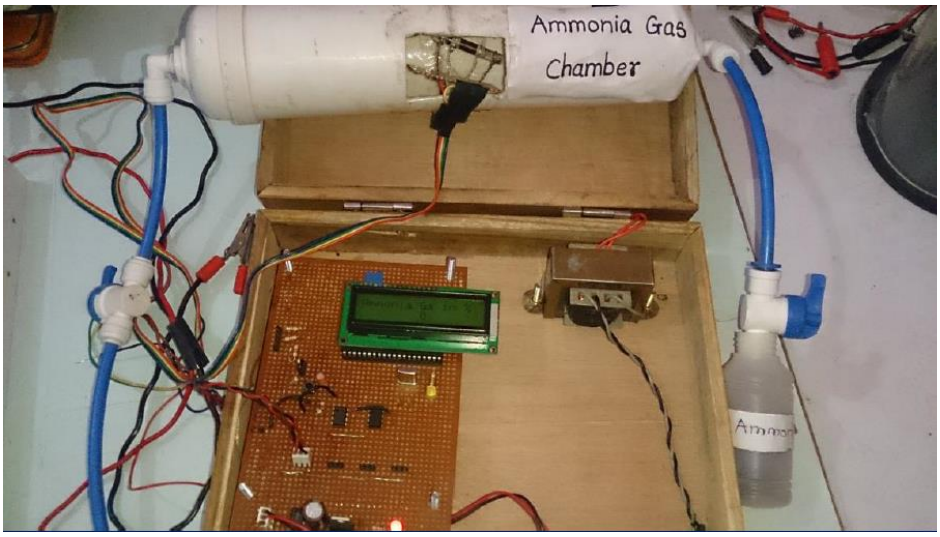

Figure 7: Implementation of Sensor Module for Ammonia Measurement

4. Calibration: The ammonia monitoring it is calibrated by two point calibration method. The gas sensor is calibrated setting Zero reading and the saturated environment level considered as 100%. The zero present gas concentration is obtained at clean air or at ambient air. The sensor sensitivity is adjusted through 2M load resister within the full scale range according to characteristics of developed sensor. The sensor produces proportional EMF response in mV (VAMM) is acquired through analog channel AN0. Initially, deploying system at ambient air the (SAMM) is recorded. Secondly, the exposing the sensor module to gas chamber with the saturated ammonia gas second point is recorded for 100%. The recorded EMF in mV (VA) is plotted against standard concentration (SA) [Figure 8], which gives empirical equation 2.

Standard VAMM = 5.8 SAMM + 174 1

Wherein, slope of graph xx represent the ammonia gas coefficient of system under investigation and the offset is compressed by rearranging this equation as equation 2.

SAM = VAM - 174 /5.8 2

Using this equation, the system is reprogrammed for conversation of EMF in mV to percentage.

The steps of Ammonia gas calibration as fallows;

1. Start system and record EMF generated in mV for clean air.
2. Apply 100 % ammonia gas concentration and record EMF in mV.
3. Plot the graph of recorded two point response in mV verses standard concentration.
4. Reprogram mote by empirical equation for conversion of EMF in mV to % unit that is standardization of system.

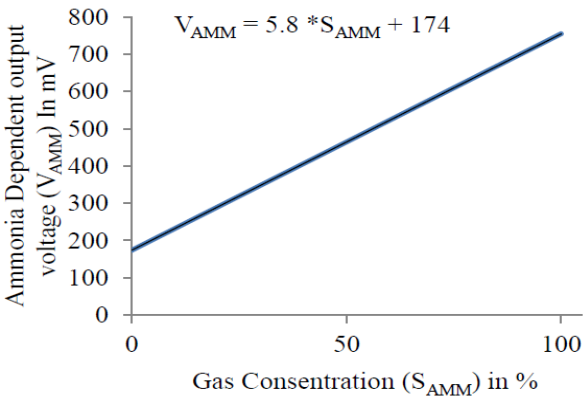

Figure 8: Calibration of Ammonia Gas Sensor

Figure 9: Recorded Response of Ammonia Gas Concentration in environment near industrial area

5. Result:

On survey, it is found that, industries concentrated in typical area are the major source of pollutant gas. Considering this fact into account, typical industrial different sites have been investigated for suitable deployment of present smart sensor Module. The figure 9 shows onsite implementation of typical smart sensor module. The smart sensor module is established for different periods of the day and on various days. Instantaneous values of the Ammonia in the air are recorded. The instantaneous data of the typical period is presented in figure 9. As shown in figure 9, the data regarding concentration of Ammonia gas (%) recorded for hours are presented.

On inspection of the figure 9, it is found that, the concentration of ammonia gas in chemical laboratory is about 0%. Thus for inspection of the system, the manual ammonia gas leakage is created. After the manual gas leak, the system shows Ammonia gas concentration is plotted against time as figure 9. The present smart sensor module is successfully designed and implemented for monitoring of environmental pollution due to gases and effluents.

6. Conclusion: Emphasizing the PIC 18F4550, the Smart Sensor Module is designed for monitoring of the ammonia gas. The smart sensor is designed, wherein the smart sensor module is calibrated to scientific units and standardized with standard instruments. The Smart Sensor Module is implemented to realize on-site application. The module is installed at various sites of the typical chemical industries. On inspection of the results, it is found that, the system is working with great preciseness and provides Site Specific data regarding concentration of the gases leaked by the industries into peripheral environment. The modules are most suitable for on-line implementation to collect the data in real-time.

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