**SSN COLLEGE OF ENGINEERING**

**KALAVAKKAM-603110**

**INTERNALLY FUNDED STUDENT PROJECT - 2023**

**Project Title**

**Analytical approach of the effect of surfactant on Mixed metal Oxide Materials(ZnO/NiO) to enhance the sensitivity of a humidity sensor**

Project Student

Biancaa. R, First Year ECE

Project Guide (s)

Dr.S.Kirubaveni , Associate Professor, Department of ECE

Dr.M.Gulam Nabi Alsath , Associate Professor, Department of ECE

**Budget**

**(25000 INR**)

**Project Duration**

**(12months)**

Signature of the Project Student Signature of the Project Guide(s)

Signature of the HOD

**Project Title: Analytical approach of the effect of surfactant on Mixed metal Oxide Materials(ZnO/NiO) to enhance the sensitivity of a humidity sensor**

**Broad Subject:** The main focus of the project is to fabricate a humidity sensor to detect the humidity with better sensitivity.

**Project Duration** (in months)**: 12 Months**

**Budget (in thousands):** 25,000/- (Twenty-five thousand only)

# Project Summary

Generally, humidity sensors can sense and measure substantial changes in water content in the air and convert them into an operational and functional signal per a specific rule of law. The single structure of pure ZnO has several disadvantages that severely limit the development of zinc oxide as humidity sensors, resulting in poor sensor performance. However, composites demonstrate a prominent effect on the surface of ZnO. The surface modification affects the nanostructures with active surface sensing sites and enhances surface-related properties. Integration of ZnO with other metal oxides further increases ZnO's sensitivity and moisture-sensing properties. In this paper, five different morphologies and composite structures have been presented. Each structure produces a considerable change in resistance with respect to the changes in RH. In addition to that, the working principle and sensing mechanism of the resistive-type humidity sensor are also discussed and presented. This paper proposes that other metal oxides contribute to the enhancement and improvement of the performance of the humidity sensor for humidity sensing. A facile one-step low-temperature method was adapted for the formation of NiO/ZnO heterojunction. The XRD graph exposed the presence of ZnO and NiO with their respective characteristic peaks. The nanoparticle structure of MMO is revealed by field passion and Scathing running electron microscopy. The chemical composition of Mixed metal oxides was analyzed by X-Ray photoelectron microscopy. A comparative study of the humidity-sensing properties of MMOs with surfactants was carried out. MMOs results show that cationic surfactants added to MMOs have a higher sensitivity than MMOs and the surfactant-free composite of ZnO and NiO. The humidity sensor was made with various molar concentrations of hexadecyltrimethylammonium bromide and Sodium Dodecyl Sulphate (CTAB: SDS) in 0:0.5, 1:1, and 1:1.5. Among the available p-type materials and invest-type materials, poly (3,4-ethylene dioxythiophene) polystyrene sulfonate (PEDOT: PSS) has an efficient effect on positively charged hole transportation and water molecule absorption (20%-80% RH), among others. The performance-improving humidity sensor was proposed for use in the medical field for detecting heart-related diseases in humans using heart-related rates. The Arduino nano microcontroller handles data management via cloud computing.

**Key words**: Surfactants (CTAB, SDS), MMO’s, Hydrothermal, XRD, FESEM, BET, Humidity sensor, PEDOT: PSS, Arduino Nano, Cloud computing

# Objective:

* To fabricate a surfactant based humidity sensor to improve the sensitivity.
* To increase the sensitivity of a humidity sensor, Hexadecyltrimethylammonium bromide and Sodium Dodecyl Sulphate (CTAB: SDS) in 0:0.5, 1:1, are preferred as surfactant.
* To verify the performance of a humidity sensor, resistive change in accordance with the instantaneous change in relative humidity is measured.

# Introduction:

The Concentration of water particles present in the air is normally mentioned as Humidity. It may be in the form of dew, fog, or other forms of precipitation. Humidity is a unique property of water. The humidity level is better sensed by choosing Zinc oxide and Nickel oxide composite-based humidity sensors. Humidity sensors can sense and measure substantial changes in water content in the air and convert them into an operational and functional signal per a specific rule of law. The single structure of pure ZnO has several disadvantages that severely limit the development of zinc oxide as humidity sensors, resulting in poor sensor performance. However, composites demonstrate a prominent effect on the surface of ZnO. The surface modification affects the nanostructures with active surface sensing sites and enhances surface-related properties. Integration of ZnO with other metal oxides further increases ZnO's sensitivity and moisture-sensing properties. Zinc oxide (ZnO) is a II–VI transparent, wide band gap (3.3 eV) semiconducting material. It is crystallized in three different structures: (wurtzite, zinc blende, and rock salt) . ZnO is an intrinsic n-type conducting material. However, its electrical properties are purely dependent on the surface conditions. The attributes of high specific surface area and more oxygen vacancies on the surface of ZnO provide more sensitivity to humidity and lend excellent performance. In order to enhance sensitivity to humidity sensors, surfactants like SDS, and CTAB can be added to the hydrothermal process. They control the size and morphology of nanoparticles effectively. The sensing performance of a humidity sensor is mainly affected by the operating temperature, humidity level, structure of a crystal, and morphology. Traditional humidity sensors are large in size, less response and are high cost. These limitations are overcome and have shown a challenging response by introducing surfactants with Metal Oxide - Metal Oxide composites (ZnO-NiO). Eventually, factors like low cost, small size, thermal stability, high surface area, and high response make mixed metal oxide composites with surfactant suitable for humidity sensors.

# Nickel oxide (NiO) is a p-type semiconductor and has excellent electrical, and optical properties, and chemical stability. It has a wide band gap in the range of 3.6-3.8 eV and a weak absorption band in the visible region.

# Definition of the Problems:

\* **Problem:** The respiratory rate should be measured and documented accurately in all hospital. And hence the humidity sensors have received much attention for disease diagnosis and human respiration rate monitoring.

\***Materials:** In recent years, many studies have been carried out to discover the materials of humidity sensors, such as SnO2, TiO2, ZnO, and BaTiO3. As one of the candidate materials of sensor, zinc oxide (ZnO) is finest due to its astonishing properties like, non-toxicity, wide and direct band gap (~3.37 eV) with a large exciton binding energy (60 meV), high surface area, synergistic effect between different components.

NiO has gained considerable interest due to its unique physio chemical properties, such as P-type semiconducting material. It has a wide band gap energy of approximately 3.6 to 4.0 eV. Surfactant (SDS:CTAB) are also added to achieve remarkable increase in their surface area.

\* **Method:** Hydrothermal method of synthesis of ZnO/NiO hollow spheres is said to be better than that of the other methods due to its easy procedure, great ease of controlling the particle size, simple equipment, catalyst free growth, low- temperature synthesizability(<100ᵒ), less cost, environmental friendliness, good dispersion in solution, large scale production and less hazardous nature.

This Problem is overcome by increasing oxygen vacancies and surface area of the mixed metal oxide material eventually.

# Review of status of Research and Development in the subject

A number of review studies about nano materials, relative humidity sensors, particular hybrid humidity sensing materials, and specific humidity sensors have been described. Respiratory rate monitoring sensors have been developed rapidly in recent years. The role of oxygen vacancies, surface reactive agents, molecular structure and charge transfer at the junction of P-N type material have also been studied briefly. Moreover, a number of additional factors, such as pressure, crystalline size, operating temperature, particle density, etc., have an impact on the sensor's performance. Lastly, the formation of physical adsorption and chemical adsorption contribute heavily to acquire larger conduction which may be more suitable for sensing applications.

# National Status

Relative humidity sensor are under research in the following institutions in India.

A nanomaterial sensor capable of sensing minute variations in relative humidity levels in the exhaled breath has been fabricated by the Department of Chemistry at the Indian Institute of Technology (IIT) Madras.

\* Improvement of humidity sensing performance and dielectric response through pH variation in ceramics, Indian Institute of Technology (ISM) India.[1]

\* Printable flexible sensors for hydration monitoring and moisture measurement in concrete structure, IIT (Madras).[2]

\* Highly sensitive and selective liquefed petroleum gas sensor based on novel ZnO–NiO heterostructures [3]

\* Superior humidity sensor and photodetector of mesoporous ZnO nanosheets at room temperature [4]

**\*** NO2 gas sensing performance of zinc oxide nanostructures synthesized by surfactant assisted Low temperature hydrothermal technique [5]

\* Hydrothermal synthesis and characterization of Zinc Oxide nanoparticles of various shapes under different reaction conditions [6]

\* Highly sensitive and selective liquefed petroleum gas sensor based on novel ZnO–NiO heterostructures [7]

**\* F**uture of Wireless Mobile Communication with Nanotechnology and Application of CNT in MOSFETs (Nano Transistors) [8]

**\*** Applications of nanotechnology in electronics and communication engineering [9]

\* Effective Heart Disease Prediction Using Hybrid Machine Learning Techniques [10]

**References:**

1. Anamitra Chattopadhyay“Improvement of humidity sensing performance ad dielectric response through pH variatios in ceramics” 2022
2. Tarikul Islam“Printable flexible sensors for hydration monitoring and moisture measurement in concrete structures” 2022
3. Gurpreet Singh “Highly sensitive and selective liquefed petroleum gas sensor based on novel ZnO–NiO heterostructures” 2019
4. Shobhnath P. Gupta “Superior humidity sensor and photodetector of mesoporous ZnO nano sheets at room temperature” 2019
5. T.V. Arsha Kusumam “NO2 gas sensing performance of zinc oxide nanostructures synthesized by surfactant assisted Low temperature hydrothermal technique”2021
6. Sonima Mohan “Hydrothermal synthesis and characterization of Zinc Oxide nanoparticles of various shapes under different reaction conditions”2021
7. Gurpreet Singh “Highly sensitive and selective liquefed petroleum gas sensor based on novel ZnO–NiO heterostructures” 2019
8. Rouman Firdous “Future of Wireless Mobile Communication with Nanotechnology and Application of CNT in MOSFETs (Nano Transistors)” 2018
9. A. Gayathri “Applications of nanotechnology in electronics and communication engineering” 2018
10. Senthilkumar mohan “Effective Heart Disease Prediction Using Hybrid Machine Learning Techniques” 2019

# International Status

Humidity sensor are under research in the following Research Institution across the world.

\* Electrical, Photocatalytic, and Humidity Sensing Applications of Mixed Metal Oxide Nano composites [1]

\* A nanoforest-based humidity sensor for respiration monitoring [2]

\* High-sensitivity wearable and ﬂexible humidity sensor based on graphene oxide/non-woven fabric for respiration monitoring [3]

\* An ultrafast QCM humidity sensor for respiratory monitoring outside a mask [4]

\* Chemiresistive humidity sensor based on chitosan/zinc oxide/single-walled carbon nanotube composite film [5]

\* Novel application on humidity sensor with wide detection range, low detection limit and high detection resolution [6]

\* Effects of pH on High-Performance ZnO Resistive Humidity Sensors Using One-Step Synthesis [7]

\* Heterogeneous SnO2/ZnO nanoparticulate film: Facile synthesis and humidity sensing capability [8]

\* Preparation and Research of a High-Performance ZnO/SnO2 Humidity Sensor [9]

\* Effect of surfactant on performance of ZnO humidity sensor [10]

# References:

1. Kausar Shaheen “Electrical, Photocatalytic, and Humidity Sensing Applications of Mixed Metal Oxide Nanocomposites” 2020

1. Guidong Chen “A nanoforest-based humidity sensor for respiration monitoring” 2022
2. Wang, Y. “High-sensitivity wearable and ﬂexible humidity sensor based on graphene oxide/non-woven fabric for respiration monitoring” 2020
3. Xuan Zhao“An ultrafast QCM humidity sensor for respiratory monitoring outside a mask” 2022
4. Haipo Dai“Chemiresistive humidity sensor based on chitosan/zinc oxide/single-walled carbon nanotube composite film”2019
5. Zaihua Duan “ Novel application on humidity sensor with wide detection range, low detection limit and high detection resolution”2021
6. Shuguo Yu “Effects of pH on High-Performance ZnO Resistive Humidity Sensors Using One-Step Synthesis” 2019
7. A.S. Ismail “Heterogeneous SnO2/ZnO nanoparticulate film: Facile synthesis and humidity sensing capability”2018
8. Fan Li “Preparation and Research of a High-Performance ZnO/SnO2 Humidity Sensor” 2022
9. Yang Chen “Effect of surfactant on performance of ZnO humidity sensor”2021

# Novelty Importance of the proposed project in the context of current status

\* The fabricated Surfactant based humidity sensor offers more oxygen vacancies and increased surface area.

\* Improved Sensitivity and repeatability when exposed to relative humidity between 10% to 95% (R.H).

\* Monitoring inhale and exhale rate at room temperature

# Patent details

|  |  |  |  |
| --- | --- | --- | --- |
| **Patent** | **Publication date** | **Applicant** | **Title** |
| US-9746438-B2 | 29-08-2017 | Albert PION | Humidity sensor with temperature compensation.  https://patentimages.storage.googleapis.com/a8/f1/57/2750b2eaab7256/US09746438-20170829-D00000.png |
| US-2011005313-A1 | 13-01-2011 | Matthew Vernon | Humidity sensor,  https://patentimages.storage.googleapis.com/47/ae/58/9cbd52735a7e1e/US20110005313A1-20110113-D00000.png |
| US-5844138-A | 01-12-1998 | Roger Cota | Humidity sensor  https://patentimages.storage.googleapis.com/2f/a5/17/84acd8702421b1/US5844138-drawings-page-2.png |

1. **Work plan and Detailed technical information**

|  |  |  |
| --- | --- | --- |
| **Sl.No.** | **Activity** | **Duration (Months)** |
| **PHASE I** | | |
| 1 | Literature Survey | 1-7 |
| 2 | Fabrication - Sensor | 3-6 |
| 3 | Experimental Analysis | 4-7 |
| **PHASE II** | | |
| 4 | Testing | 7-9 |
| 5 | Result | 9-10 |
| 6 | Documentation | 10-12 |

# Methodology

* + - Fabrication Methodology – Design of Humidity sensor with different molar concentration with surface reactive agents.
    - Material Characterization (XRD)
    - Structural and Morphological Analysis(FESEM, XPS,and BET)
    - Optical (UV) Analysis
    - Performance analysis and experimental evaluation of the proposed and fabricated sensor

# Explanation of method used

The substrate pre-cleansing treatment involves placing FTO in an ultra sonicator dipped in DI water for 30 min and drying for moist-free surface. The ZnO/NiO powder is obtained from one step hydrothermal treatment. PVDF is dissolved in 50 ml ehanol and are mixed using magnetic stirring.Here FTO acts as a first and base layer. Then the prepared ZnO/NiO PVDF paste is coated using famous doctor blade method. Then the coated FTO substrate is undergone with 350℃temperature treatment.The combination of FTO and ZnO/NiO layer acts as an n-type layer to sense the humidity . The p-type material PEDOT: PSS is coated above the active layer and this forms a P-N junction. To make an inter connection between p-type material PEDOT: PSS and N-Type ZnO/FTO material, silver is used eventually.

# Time schedule of activities giving milestones

* 1. **Time Schedule of Activities through BAR Diagram**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Months** | | | | | | | | | | | | |
| Activity | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** |
| Literature Survey |  |  |  |  |  |  |  |  |  |  |  |  |
| Fabrication of Sensor |  |  |  |  |  |  |  |  |  |  |  |  |
| Experimental Analysis |  |  |  |  |  |  |  |  |  |  |  |  |
| Testing |  |  |  |  |  |  |  |  |  |  |  |  |
| Result |  |  |  |  |  |  |  |  |  |  |  |  |
| Documentation |  |  |  |  |  |  |  |  |  |  |  |  |

# Deliverables

ZnO/NiO is coated with different concentrations to form pn-junction and the parameters like sensitivity, Response time, Recovery time and linearity are estimated. This ZnO/NiO pn-junction improves the performance of the sensor compared to DHT-11 humidity sensor.

# Target beneficiaries of the proposed work

* Bio-Medical
* Industries (Food )

# Suggested plan of action for utilization of research outcome expected from the project

As journal publication Patent filing

# References

1. Soumalya Kundu”Superior positive relative humidity sensing properties of porous nanostructured Al:ZnO thin films deposited by jet-atomizer spray pyrolysis technique” 2019
2. Amar Kapic”Humidity Sensors for High Energy Physics Applications” 2020
3. Jesus M. Corres”Optical Fiber Humidity Sensors Using PVdF Electrospun Nanowebs” 2021
4. Xiu-Juan Xie “Synthesis of ZnO/NiO hollow spheres and their humidity sensing performance” 2021
5. Mohammad Musarraf Hussain “Ultrasensitive and selective 4-aminophenol chemical sensor development based on nickel oxide nanoparticles decorated carbon nanotube nanocomposites for green environment” 2016
6. Hulugirgesh Degefu Weldekirstos “Surfactant-Assisted Synthesis of NiO-ZnO and NiO-CuO Nanocomposites for Enhanced Photocatalytic Degradation of Methylene Blue Under UV Light Irradiation”2022
7. Jiaqi Zhang “The Oxygen Vacancy Defect of ZnO/NiO Nanomaterials Improves Photocatalytic Performance and Ammonia Sensing Performance” 2022
8. Meng Ding “Fabrication of Hierarchical ZnO@NiO Core–Shell Heterostructures for Improved Photocatalytic Performance” 2018
9. Jingyu Wang “Research Progress on Humidity-Sensing Properties of Cu-Based Humidity Sensors” 2022
10. Christopher B. Jacobs “ UV-activated ZnO flms on a fexible substrate for room temperature O2

and H2O sensing”2017

# List of facilities and Equipments available with in the Department for the project

\* Humidity Sensing set up

\* XRD

\* UV

# Budget Estimation

|  |  |  |
| --- | --- | --- |
| **S.No** | **Item** | **Budget (In Rupees)** |
| 1 | BET Studies | 2000 |
| 2 | FESEM and XPS Studies (5 samples) | 18000 |
| 3 | Chemicals {Zinc Acetate,Urea,SDS,CTAB,Nickel Acetate} | 5000 |
| **Total** | | **25000** |

1. **Budget Justification**

**FTO (Fluorine doped Tin Oxide) –** The proposed humidity sensor ZnO/NiO is to be done on rigid substrate. It is chosen due to its temperature stability.

**FESEM** – Field Emission Scanning Electron Microscope analysis is used to analyze the morphological growth of the BaTiO3 and ZnO nanostructure.

**Zinc Acetate /Nickel Acetate**– It is used to synthesize ZnO using the hydrothermal method and also used as the coating powder and. it has same crystal structure as that of ZnO with high luminance properties.

**Urea** - The reason to choose this material instead of other available materials is that, it is non- toxic, biocompatible, and low cost.

**SDS/CTAB –** Both are used as a surfactant.